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RE-EMPOWERED

Renewable Energy EMPOWERing European & InDian Communities

Deliverable 8.2: Report on the business models and financing tools (V2)

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DEM Demonstrator, pilot, prototype	CO Confidential, only for members of the consortium (including the Commission Services)
DEC Websites, patent fillings, videos, etc.	EU-RES Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)
OTHER ETHICS Ethics requirement	EU-CON Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)
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Executive Summary

Within the Work Package (WP) 8 of the RE-EMPOWERED project, and specifically in Tasks 8.1 and 8.2, the main objective is the analysis of the economic and financial feasibility of each ecoTool and Demo Site, proposing business models and analysing their economic profitability. The selected business models have been designed to maximize the penetration of renewable energies in the Demo Sites, considering that these areas have limited or no connection to continental power systems. At the same time, these business models should convey net benefits for the society and ensure the citizen engagement. This deliverable also explores different financial alternatives for each Demo Site and the advantages and disadvantages are discussed.

A cost-benefit analysis is performed for each RE-EMPOWERED ecoTool, which has resulted in an estimation of the number of potential customers which have to be reached, and an appropriate price at which the ecoTools can be sold, while the net present value (NPV), internal rate of return (IRR) and payback period are also calculated. According to the cost-benefit analysis carried out, the business model of all ecoTools is positive for both the ecoTool developer and the potential client.

Moreover, the economic feasibility of the Demo Sites is also evaluated. In some cases, the Demo Sites need some public support to become sustainable. Besides, an appropriate business model has been designed for each Demo Site, based on the actual business model which is applied.

Keywords:

Smart Grids, Energy Communities, Business Models, Economic and Financial Models, Economic Sustainability Analysis, Renewable Energies, Demand Response, Dynamic Pricing, District Heating System, Business Canvas, Cash Flow Model, Cash Flow Diagram, Cost-Benefit Analysis, Financing Tools.

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Acronyms

Acronym	Description
€	Euro
₹	Rupee
°C	Degree centigrade
1G	First Generation
2G	Second Generation
3G	Third Generation
AC	Alternating current
ACC	Advanced chemistry cell
ACER	European Agency for the Cooperation of Energy Regulators
AgDSM	Agricultural Demand Side Management
Ah	Ampere hour
AMI	Advanced Metering Infrastructure
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
API	Application Programming Interface
B2B	Business to Business
B2C	Business to Consumers
BDO	Block Development Offices
BEE	Bureau of Energy Efficiency
BEOF	Bornholms Energi & Forsyning Holding A/S
BEPC	Board for Energy Planning and Control
BESS	Battery Energy Storage System
BMS	Battery Monitoring System
BOOT	Build-own-operate-transfer
BRP	Balance Responsible Party
CAMS	Coal Allocation Monitoring System
CCUS	Carbon capture, use and storage
CEA	Central Electricity Authority
CEC	Citizen Energy Community
CERC	Central Electricity Regulatory Commission
CFA	Central Financial Assistance
CFD	Computational fluid dynamics
CfD	Contract for Difference
CHP	Combined heat and power
CO	Carbon monoxide
CO2	Carbon dioxide
COP	Conference of the Parties
CPP	Critical peak pricing
CRES	Centre for Renewable Energy Sources and Saving
CSA	Computational Structural Analysis
CSF	Community Support Framework
CST	Concentrated Solar Thermal
DAS	Day Ahead Scheduling

Acronym	Description
DC	Direct current
DDUGJY	DeenDayal Upadhyaya Gram Jyoti Yojana
DER	Distributed Energy Resources
DHN	District heating network
DISCOM	Distribution Company
DK2	East Denmark grid
DKK	Danish Krone
DoD	Depth of discharge
DR	Demand response
DSO	Distribution System Operator
DSM	Demand side management
DST	Department of Science and Technology
DTU	Denmarks Tekniske Universitet
EC	European Commission
EEFP	Energy Efficiency Financing Platform
EESL	Energy Efficiency Services Limited
EFKA	National Social Security Fund
EIA	Environmental Impact Assessment
EIC	Engineer-in-Chief
EMS	Energy Management System
ESCO	Energy Services Company
ESO	Energy Storage Obligation
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
FCR-D	Frequency containment reserve for disturbances
FIP	Feed-in premium
FIT	Feed-in tariff
FLCTD	Facility for Low Carbon Technology Deployment
FPGA	Field Programmable Gate Array
FPO	Farmer producer organization
GCF	Green Climate Fund
GDP	Gross domestic product
GEDCOL	Green Energy Development Corporation of Orissa Ltd.
GEF	Global Environment Facility
GIS	Geographical Information System
GRIDCO	Grid Corporation of Odisha Limited
GRPV	Grid-connected rooftop solar PV
GW	Gigawatt
GWEC	Global Wind Energy Council
GWh	Gigawatt-hour
GWhe	Gigawatt-hour electricity
GWhth	Gigawatt-hour thermal
h	Hour
HEDNO	Hellenic Electricity Distribution Network Operator

Acronym	Description
HETS	Hellenic Transmission System
HLS	House Lighting System
HP	Horse power
HTSO	Hellenic Transmission System Operator
Hz	Hertz
ICAP	India Cooling Action Plan
ICT	Information and Communication Technology
IDCO	Odisha Industrial Infrastructure Development Corporation
IEP	Integrated Energy Policy
IESA	Indian Energy Storage Alliance
iFOREST	International Forum on Environment, Sustainability and Technology
IGCC	Integrated Gasification Combined Cycle
ILC	Intelligent Load Controller
INDC	Intended Nationally Determined Contribution
IoT	Internet of Things
IPM	Intelligent Power Module
IPP	Independent Power Producer
IPTO	Independent Power Transmission Operator
IREDA	Indian Renewable Energy Development Agency
IRR	Internal rate of return
ISGF	India Smart Grid Forum
ISTS	Inter-state transmission system
JNNSM	Jawaharlal Nehru National Solar Mission
kg	Kilogram
km	Kilometre
km^2	Square kilometre
ktoe	Kilotonnes of oil equivalent
kV	Kilovolt
kVA	Kilovolt ampere
kW	Kilowatt
kWh	Kilowatt-hour
kWp	Kilowatt peak
LED	Light-Emitting-Diode
LNG	Liquified natural gas
m/s	Meters per second
m3	Cubic meter
M&V	Measurement and verification
MAT	Minimum Alternate Tax
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
MEEC	Ministry for the Environment, Energy and Climate Change
MEEP	Municipal Energy Efficient Programme
MEPS	Minimum Energy Performance Standards
MEZ	Micro enterprise zone
MGCC	Microgrid central controller

Acronym	Description
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MoU	Memorandum of Understanding
MSME	Micro, Small and Medium Enterprises
MSW	Municipal Solid Waste
MW	Megawatt
MWh	Megawatt-hour
MWhe	Megawatt-hour electricity
MWp	Megawatt peak
NAPCC	National Action Plan on Climate Change
NATO	North Atlantic Treaty Organization
NECP	National Energy and Climate Plan
NEP	National Electricity Plan
NGO	Non-Governmental Organization
NII	Non-Interconnected Island
NIPS	Non-Interconnected Power System
NMEEE	National Mission for Enhanced Energy Efficiency
NO2	Nitrogen dioxide
Nº	Number
NPV	Net present value
NREAP	National Renewable Energy Action Plan
NREL	National Renewable Energy Laboratory
O3	Ozone
O&M	Operation and maintenance
OERC	Odisha Electricity Regulatory Commission
OPE	Operational Programme for Energy
OREDA	Odisha Renewable Energy Development Agency
P2X	Power-to-X
PaaS	Platform-as-a-Service
PCB	Printed circuit board
PERC	Procurement of Energy from Renewable Sources and its Compliance
PJ	Peta joule
PLI	Production-Linked Incentives
PM	Person-month
PM-KUSUM	Pradhan Mantri Kisan Urka Suraksha evam Utthaan Majabhiyan
PM2.5	Particulate matter with a diameter lower than 2.5 micrometres (Fine particles)
PM10	Particulate matter with a diameter lower than 10 micrometres (Inhalable particles)
PPA	Power purchase agreement
PPC	Partial power converter
PPC	Public Power Corporation
PRSF	Partial Risk Sharing Facility for Energy Efficiency
PSO	Public Service Obligation
PTR	Peak Time Rebate
PU	Public
PV	Photovoltaics

Acronym	Description
R	Report
R&D	Research and Development
RAE	Regulatory Authority of Energy
RE	Renewable Energy
REC	Renewable Energy Community
RES	Renewable Energies / Renewable Energy Sources
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
ROI	Return on Investment
ROSHANEE	Roadmap of Sustainable and Holistic Approach to National Energy Efficiency
RPO	Renewable Purchase Obligation
RPS	Renewable Portfolio Standard
RTP	Real Time Pricing
RVEP	Remote Village Electrification Programme
S&L	Standards and Labelling
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SC	Scheduled caste
SCADA	Supervisory control and data acquisition
SCGJ	Skill Council for Green Jobs
SCoE	State Centre of Excellence
SECI	Solar Energy Corporation of India Limited
SEEP	Super Efficient Equipment Programme
SERC	State Electricity Regulatory Commission
SiC	Silicon carbide
SIDBI	Small Industries Development Bank of India
SIGHT	Strategic Interventions for Green Hydrogen Transition
SME	Small and medium-sized enterprise
SMS	Short Message Service
SO2	Sulphur dioxide
SUV	Sport utility vehicle
toe	Tonnes of oil equivalent
TOU	Time of Use Program
TSO	Transmission System Operator
TTRC	Tradable Tax Rebate Certificate
TWh	Tera watt-hour
UC	Use case
UI	User interface
UJALA	Unnat Jyoti by Affordable LEDs for All
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
US$	United States dollar
V	Version
VAT	Value added tax
VCFEE	Venture Capital Fund for Energy Efficiency
VRLA	Valve regulated lead acid

Acronym	Description
W	Watt
WBERC	West Bengal Electricity Regulatory Commission
WBSEDCL	West Bengal State Electricity Distribution Company Limited
WTP	Willingness-to-pay
WP	Work Package
Wp	Watt peak
WUA	Water user association

Exchange rates

The Deliverable has been prepared using, mainly, the Euro (€) as reference currency. However, since some Demo Sites are based on countries which do not use the Euro as currency, it has been necessary to also use the Danish Krone (DKK) and the Indian Rupee (₹).

To transform Danish Krones and Indian Rupees into Euros, the following exchange rates have been used:

- 1 € = 7.463 DKK, or 1 DKK = 0.134 €.
- 1 € = 90.09 INR, or 1 ₹ = 0.0111 €.

These exchange rates are the average values for the last years.

1. Introduction

1.1 Purpose and scope of the document

The RE-EMPOWERED project aims to develop and demonstrate new tools to maximize the integration of renewable energies in microgrids, energy islands, and multi-microgrids applications, with a particular focus on energy communities. These tools are expected to increase the use of renewable energies in these areas, which typically display moderate renewable energy penetration due to lack of, or weak connection to the grid. During the project, a set of tools has been developed, known as “ecoToolset”, which introduced new functionalities, such as demand response and dynamic pricing, supporting the decarbonization of multi-energy local energy systems. Citizen engagement is also important in RE-EMPOWERED, as it is necessary to involve all the stakeholders in the decarbonization of the end electricity use. To demonstrate the ecoToolset applicability, it has been tested across the four European and Indian Demo Sites of the RE-EMPOWERED project: Bornholm Island (Denmark), Kythnos Island (Greece), Ghoramara Island (West Bengal, India) and Keonjhar (Odisha, India).

Although the ecoTools have been developed and their operation has been fully tested and demonstrated, to ensure their sustainability it is necessary to design new business models which encompass that (i) the ownership of the assets is the most appropriate, (ii) project objectives are achieved, and (iii) benefits from the use of the tools are obtained, making the investment attractive. In some cases, benefits are not only monetary and quantifiable, but they may reflect qualitative impact such as environmental or social benefits.

The objective of the Work Package (WP) 8 in the RE-EMPOWERED project is the development, benchmark and testing of the new business models which are to be applied to the energy systems of the pilot sites. Furthermore, the financial viability of the development of the ecoToolset and its use in the Demo Sites is analysed. This allows to assess the technical, economic, and financial viability of the renewable energy, demand response, energy storage, clean mobility, and citizen engagement technologies applied in the demo sites and the ecoToolset, to maximize project replicability.

The economic profitability of the application of the ecoToolset, both for the developer of the ecoTool and for the final user, is necessary to ensure that the renewable energy, demand response and citizen engagement technologies and the ecoToolset can be used by the different stakeholders (e.g., citizenship, public administration, private organizations).

First of all, the ecoTools are described, and a cost-benefit analysis for each one is included, to evaluate their economic feasibility both from the point of view of the ecoTool developer, and the final user. Then, and based on the energy systems which are used in each Demo Site, and the ecoTools which are installed, a business model is proposed for the use of the ecoToolset and the different technologies in each Demo Site. According to this business model, an economic sustainability analysis is carried out, evaluating the use of alternative financing mechanisms, focusing specially on new models specially designed for renewable energy and energy efficiency projects.

This Deliverable is the **update of Deliverable 8.1** "Report on the business models and financing tools (V1)", which was delivered in December 2022. The work carried out for Deliverable 8.2 has been focused on refining of the hypotheses taken in Deliverable 8.1, about investment costs, operation and maintenance costs, incomes etc. As the ecoTools were developed in 2023 and 2024, the economic information about ecoTools is much more detailed and accurate. Besides, DelAdv has actively participated in the BRIDGE Business Model Working Group. As a result of this collaboration, new business model methodologies, like the cash flow diagram, have been applied to the ecoTools and Demo Sites. Moreover, the cash flow models already applied to ecoTools have been defined, when possible, to both the ecoTool developer, and to the final client. Besides, although the business models for each Demo Site were described in Deliverable 8.1, in Deliverable 8.2 they are much more detailed. Some business models which in 2022 seemed to be economically not sustainable, have been made profitable by defining new income sources.

The results from Deliverable 8.2, and from WP8, have fed other WPs and Tasks, especially, WP6 "Energy community development and stakeholder engagement" (in particular, Deliverable 6.1: "Engagement Status Report") and WP9 "Dissemination and exploitation", namely, Task 9.3. "Exploitation and commercialization analysis". In particular, the use of business canvases has helped in the identification of stakeholders for Deliverable 6.1, and the exploitation and commercialization analyses use some results from the cost-benefit analyses of the ecoTools.

1.2 Structure of the document

This document is structured as follows. The first section includes the objective of the document, as well as its structure and content.

Next, section 2 includes a cost benefit analysis of the ecoToolset, focusing on the estimated investment and deployment cost of each ecoTool, and the expected cash flows along its lifetime: revenues (or energy savings), and operation and maintenance costs. Additionally, in the cases when, according to the available information, it is possible, an analysis of the economic profitability is carried out for both the ecoTool developer, and a typical final user.

Section 3 includes the description of the Demo Sites in the European Union: Bornholm Island in Denmark, and Kythnos Island and Gaidouromantra Microgrid in Greece, with special focus on the deployed ecoTools and technologies applied. For each Demo Site, a description of the energy system in the island and the Demo Site is included. Likewise, an evaluation about the state of energy access and cost is also presented. Then, the use of the ecoToolset in each Demo Site is explained. Based on the technologies and the ecoToolset, a business canvas is proposed. The economic feasibility of the Demo Site is analysed using cash flow models and cash flow diagrams. Finally, the use of financing tools is suggested, adapted to each specific Demo Site.

Section 4 is focused on the Indian Demo Sites: Ghoramara Island and Keonjhar, using the same structure which has been explained for the European Demo Sites.

Finally, Section 5 includes a summary of the main conclusions of Deliverable 8.2.

The Appendixes include a deep review of the regulatory framework which is applied to renewable energies, demand response mechanisms and energy communities in the countries and regions where the Demo Sites are developed. The evolution of this regulatory framework during the last years is described, as well as the most advanced regulation and policies (including the targets in terms of renewable energy penetration or greenhouse gas emissions reduction).

2. Cost-benefit analysis of ecoToolset and its use in the different pilot sites

The RE-EMPOWERED project has, as one of its main objectives, the design, development, and subsequent commercialization of a set of solutions, called “ecoToolset”, specially conceived to allow the use of renewable energies at a large scale. The ecoToolset is a set of digital tools, platforms, and systems with multiple functionalities. The ecoToolset has been designed to allow to select different ecoTools depending on the situation and specific case. EcoTools can interact, allowing the user to benefit from the synergies among different energy vectors. Although the ecoToolset has been tested in the specific needs of four pilot cases in the EU and India, they will be adapted to other projects and situations, as required by each client.

In this chapter, a cost-benefit analysis is carried out, to assess the economic feasibility of the development and commercialization of each ecoTool by the ecoTool designer, as well as for a potential client.

2.1 ecoEMS

ecoEMS is an Energy Management System (EMS), designed to optimize the overall performance of isolated and weakly interconnected systems, in liberalized market environments by increasing the share of renewable energies. More specifically, ecoEMS is a modular system comprising load and renewable energy sources (RES) forecast, unit commitment and economic dispatch and on-line security assessment functions. The objective of ecoEMS is the full exploitation of the RES potential, achieving a penetration above levels of 40%, at reasonable costs in Non-Interconnected Power Systems (NIPSs), such as islands or isolated microgrids.

A financial analysis for the development and commercialization of the ecoEMS tool has been developed, taking into account the total investment cost, the operation and maintenance costs, and the future revenues expected from the sale of the ecoTool to the final clients.

This financial analysis has been carried out considering the feedback and information provided by the ecoTool leader. Two different analyses have been developed: from the point of view of the ecoTool developer, which does an investment in the design, development, and commercialization of the ecoTool, and from the point of view of a final user (a project developer which decides to install the tool in a specific project). To do so, the expected investment cost, the operation and maintenance costs and the future revenues estimated from the sale or use of the ecoTool have been calculated.

From the point of view of the ecoTool developer, the following information has been used:

- Investment cost: The total investment cost to develop the ecoEMS consists of two parts:
    - Design of the tool through research and private contracts is expected to amount to €600,000.
    - Installation cost: Around €5,000, including forecasting training (€3,000), adaptation of other algorithms and parameters (€1,000) and Information and Communication

Technology (ICT) work (€1,000). Installation costs will be optimized through multiple parallel installations.

- Incomes for the project (new clients): It has been estimated that the sale of a license of ecoEMS for an island will be around €40,000, for each island.

  The potential clients of ecoEMS will be local energy communities, islands, districts and neighbourhoods in cities, and possibly small industrial cities. For this reason, it has been estimated that it will be possible to engage two new clients per year. This number will remain constant along the time. For example, in year 20, the number of clients will be 40.

  This involves that the expected income for the ecoTool developer will amount to €80,000 per year.

- Incomes for the project (existing clients): Each client who has begun to use the ecoEMS tool will have to pay a yearly renewal license, which will include the updates in algorithms, at a price of €2,000 per year.

  This renewal license will be paid, each year, by the cumulated number of clients of the previous year, since new users have to pay only the new-user installation license.

  According to this, in the second year, the incomes from existing clients will be €4,000 (2*€2,000). In the twentieth year, the number of old clients will be 38, so the total incomes from existing clients will be €76,000.

- Installation costs: For each ecoEMS new user, the cost for the project developer to install the ecoTool has been estimated to be around €5,000. Considering two new users per year, this cost will remain constant at €10,000.

- Estimated operation and maintenance costs: The ecoEMS will involve a yearly operation and maintenance cost of €1,000 per year, for the retraining and update of the forecasting algorithms.

- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €605,000, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €30,250/year.

- The corporate taxes are considered to be 22%.

- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoEMS tool, from the point of view of the ecoTool developer, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 605,000 €										
Design and development of the ecoTool	- 600,000 €										
Installation costs (€) of the ecoTool	- 5,000 €										
Incomes (€)		80,000 €	84,000 €	88,000 €	92,000 €	96,000 €	100,000 €	104,000 €	108,000 €	112,000 €	116,000 €
Incomes (€)- New licences		80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €
Incomes (€)-Existing licences			4,000 €	8,000 €	12,000 €	16,000 €	20,000 €	24,000 €	28,000 €	32,000 €	36,000 €
Installation costs (€)		- 10,000 €	- 10,000 €	- 10,000 €	- 10,000 €	- 10,000 €	- 10,000 €	- 10,000 €	- 10,000 €	- 10,000 €	- 10,000 €
Operation and maintenance costs (retraining the forecasting algorithms)		- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Depreciation and amortization (€)		- 30,250 €	- 30,250 €	- 30,250 €	- 30,250 €	- 30,250 €	- 30,250 €	- 30,250 €	- 30,250 €	- 30,250 €	- 30,250 €
Profit before taxes (€)		38,750 €	42,750 €	46,750 €	50,750 €	54,750 €	58,750 €	62,750 €	66,750 €	70,750 €	74,750 €
Deferred corporate taxes (€)		- 8,525 €	- 9,405 €	- 10,285 €	- 11,165 €	- 12,045 €	- 12,925 €	- 13,805 €	- 14,685 €	- 15,565 €	- 16,445 €
Net cash flow (€)	- 605,000 €	60,475 €	63,595 €	66,715 €	69,835 €	72,955 €	76,075 €	79,195 €	82,315 €	85,435 €	88,555 €
Accumulated net cash flows (€)	- 605,000 €	- 544,525 €	- 480,930 €	- 414,215 €	- 344,380 €	- 271,425 €	- 195,350 €	- 116,155 €	- 33,840 €	51,595 €	140,150 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)										
Design and development of the ecoTool										
Installation costs (€) of the ecoTool										
Incomes (€)	120,000 €	124,000 €	128,000 €	132,000 €	136,000 €	140,000 €	144,000 €	148,000 €	152,000 €	156,000 €
Incomes (€)- New licences	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €	80,000 €
Incomes (€)-Existing licences	40,000 €	44,000 €	48,000 €	52,000 €	56,000 €	60,000 €	64,000 €	68,000 €	72,000 €	76,000 €
Installation costs (€)	-10,000 €	-10,000 €	-10,000 €	-10,000 €	-10,000 €	-10,000 €	-10,000 €	-10,000 €	-10,000 €	-10,000 €
Operation and maintenance costs (retraining the forecasting algorithms)	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €
Depreciation and amortization (€)	-30,250 €	-30,250 €	-30,250 €	-30,250 €	-30,250 €	-30,250 €	-30,250 €	-30,250 €	-30,250 €	-30,250 €
Profit before taxes (€)	78,750 €	82,750 €	86,750 €	90,750 €	94,750 €	98,750 €	102,750 €	106,750 €	110,750 €	114,750 €
Deferred corporate taxes (€)	-17,325 €	-18,205 €	-19,085 €	-19,965 €	-20,845 €	-21,725 €	-22,605 €	-23,485 €	-24,365 €	-25,245 €
Net cash flow (€)	91,675 €	94,795 €	97,915 €	101,035 €	104,155 €	107,275 €	110,395 €	113,515 €	116,635 €	119,755 €
Accumulated net cash flows (€)	231,825 €	326,620 €	424,535 €	525,570 €	629,725 €	737,000 €	847,395 €	960,910 €	1,077,545 €	1,197,300 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	82,727 €
IRR (%)	11.700%
First positive accumulated cash flow	51,595 €
Payback (years)	Year 9

Table 1. Economic model for the ecoEMS Tool, from the point of view of the ecoTool developer, including the cash flow model and a profitability analysis.

The economic model shown before for ecoEMS shows that the NPV of the project, discounted with a discount rate of 10%, is €82,727, along 20 years. On the other hand, the IRR is 11.700%.

The payback period is 9 years.

Another interesting conclusion is the estimation of an appropriate sale price for the ecoEMS. A cost for the final user of €40,000 could allow the ecoTool developer to recover the investment cost, with an attractive internal rate of return.

The next figure shows the cash flow diagram from the point of view of the ecoTool developer:

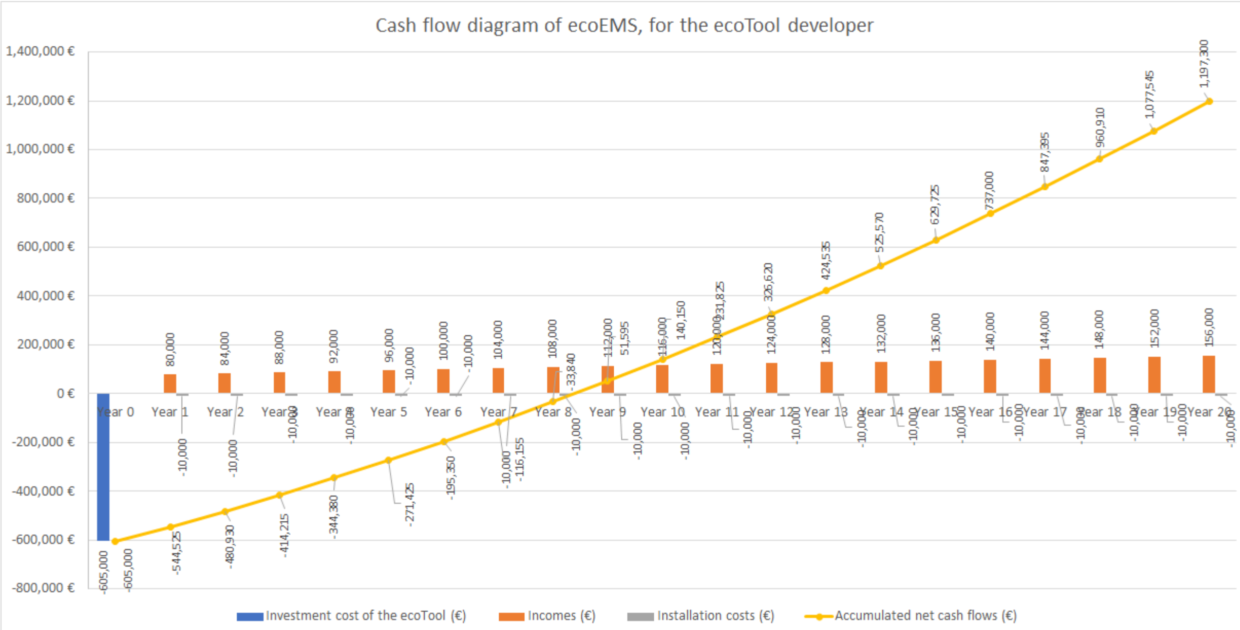

Figure 1. Cash flow diagram of ecoEMS, for the ecoTool developer

Additionally, an economic model for a user which purchases the ecoEMS tool has been developed, from the point of view of the profitability of making such investment.

In this case, the following data have been used:

- Investment cost: The cost of the license of ecoEMS will be around €40,000 for a new client.
- Incomes: The hypothesis is that the ecoEMS tool is installed in an island with the size of Kythnos, with a total renewable non-manageable capacity of 1 MW. It is estimated that the capacity factor is 33%, this is, the total production of the plant is 2,890 MWh/year. In normal cases, 27% of the production would be curtailed because of local grid limitations, this is 781 MWh.

  The ecoEMS software can avoid 10% of these curtailments, leading to an extra electricity production around 78 MWh. If the electricity production cost in the island is around €100/MWh, with diesel generator, then the electric system of the island will be able to save around €7,800 per year.

  In this analysis, it is supposed that the benefits obtained by the renewable energy project owner, due to the reduction in the curtailments, are gains for the entity which purchases the ecoEMS software.
- Operation and maintenance cost: The cost of the renewal and update of the licence of ecoEMS will be around €2,000 per year.

- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €40,000, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €2,000/year.

- The corporate taxes will be 22%.

- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoEMS tool, from the point of view of a final client, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 40,000 €										
Incomes (€)		7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €
Maintenance costs (€)		- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €
Depreciation and amortization (€)		- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €
Profit before taxes (€)	- 40,000 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €
Deferred corporate taxes (€)		- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €
Net cash flow (€)	- 40,000 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €
Accumulated net cash flows (€)	- 40,000 €	- 35,036 €	- 30,072 €	- 25,108 €	- 20,144 €	- 15,180 €	- 10,216 €	- 5,252 €	- 288 €	4,676 €	9,640 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)										
Incomes (€)	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €	7,800 €
Maintenance costs (€)	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €
Depreciation and amortization (€)	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €	- 2,000 €
Profit before taxes (€)	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €	3,800 €
Deferred corporate taxes (€)	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €	- 836 €
Net cash flow (€)	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €	4,964 €
Accumulated net cash flows (€)	14,604 €	19,568 €	24,532 €	29,496 €	34,460 €	39,424 €	44,388 €	49,352 €	54,316 €	59,280 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	2,261.33 €
IRR (%)	10.82%
First positive accumulated cash flow	4,676
Payback (years)	Year 9

Table 2. Economic model for the ecoEMS Tool, including the cash flow model and a profitability analysis, for the final client.

The main result of this analysis is that, for a final user of ecoEMS, the net present value of the use of the ecoEMS tool will amount to €2,261.33 (with a discount rate of 10%), along 20 years, and the IRR is 10.82%. The payback period will be around 9 years.

The following figure shows the cash flow diagram for the ecoEMS ecoTool, from the point of view of an example final user:

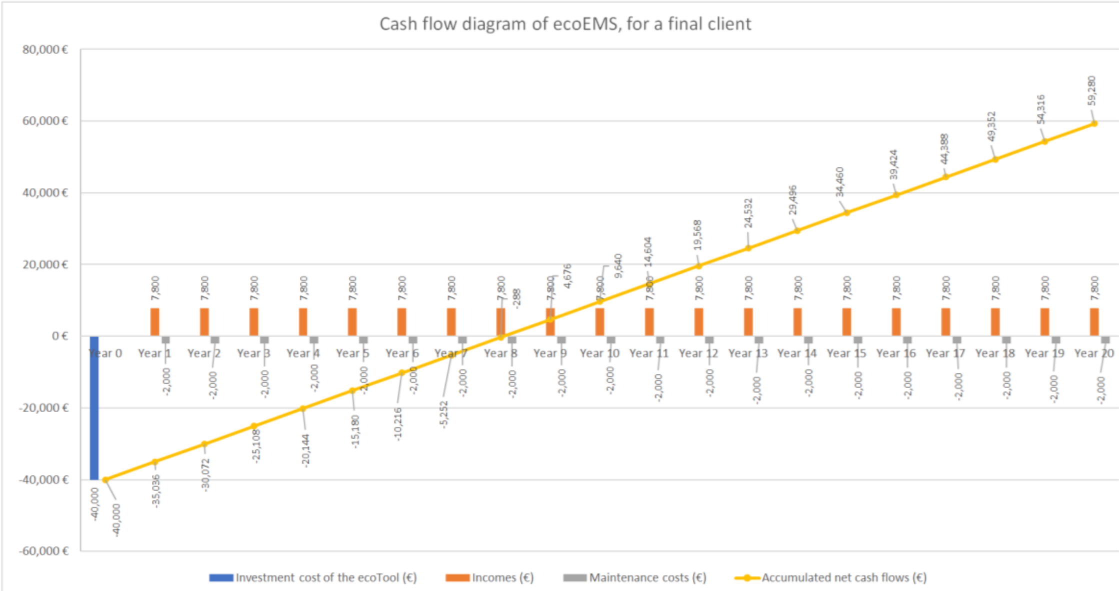

Figure 2. Cash flow diagram of ecoEMS, for the final client

As commented before, an appropriate sale price for the ecoEMS tool would be €40,000 per user. This price would allow the ecoTool developer to recover the investment, and would make the tool attractive for the clients. This price has been chosen, as it allows both the ecoEMS developer and a potential user recover the investment, by obtaining an internal rate of return higher than 10%, and a positive net present value.

2.2 ecoMicrogrid

ecoMicrogrid is an Energy Management System (EMS) specially tailored for microgrids where advanced management algorithms are deployed to optimize the performance, considering synergies with different energy vectors like water management and cooling systems. ecoMicrogrid is used to monitor the state of different microgrid components, including renewable energies production, flexible load consumption, and battery storage charge level, and to forecast the short-level development.

According to the information provided by the ecoTool leader, the following economic sustainability analysis has been carried out, considering an estimation of the revenues, as well as the operation and maintenance costs.

- Investment cost: The development cost of the ecoMicrogrid, for its design, consists of two parts:
    - Design cost: This includes the personnel costs of the researchers and professionals in charge of the design of this ecoTool. It is estimated that 36 person.month will be needed to design the ecoMicrogrid, what involves that, with a PM cost for ICCS-NTUA of €5,000/PM, the total design cost will amount to €180,000.

This cost includes not only the personnel cost of the software development of ecoMicrogrid, but also the energy management module, the load and solar PV production forecast, the outage detection tools, dynamic pricing for the residents, and communal load scheduling.

Besides, it considers the software development for the communication with the microgrid assets, data acquisition and storage in a database, as well as the communication with other ecoTools.

- Installation cost: This includes the personnel cost for the installation of the ecoMicrogrid, as well as the investment cost of the hardware and software.

  The hardware has been an industrial personal computer, with a total cost of around €1,000[1]. This computer has a 5-year warranty.

  Additionally, it has been necessary to install a dedicated software for the data acquisition, industrial communication protocols and data storage. The total cost of the software, including personal cost, has been €4,000.

- Incomes for the project developer (new clients): It has been estimated that the cost of an ecoMicrogrid licence, for a new client (a microgrid operator), will be around €25,000 per user, including the ecoMicrogrid hardware and software.

  Supposing that, during the first year, there are 3 new clients, the incomes will amount to €75,000. It has been estimated that each year, there will be 3 additional microgrids which decide to use the ecoTool, so this level of incomes will remain constant.

- Incomes for the project developer (existing clients): The yearly update of the license for an existing client will cost €1,000 for each license. This cost will be paid by all the clients which have a license.

  Considering that, during the second year, there will be 3 clients, the total incomes coming from the sale of licences will amount to €3,000. Each year, the number of clients will increase by 3, so in year 20, there will be 57 clients, so incomes will be €57,000.

- Estimated operation and maintenance costs: ecoMicrogrid is a software which runs on a dedicated software on site. The operating costs is the electricity consumption of the hardware (with a power of around 400 W), which can be estimated to be around 0.6 kWh/day (estimation based on the technical information on consumption of the system).

  With a year with 365 days, the total consumption of the industrial personal computer will be 215 kWh/year. Considering an electricity price of €0.15/kWh, the yearly cost for each installed ecoMicrogrid will be €32.85/year. This cost has to be multiplied per the number

[1] Note: In Deliverable 8.1, the cost of the industrial computer was estimated to be €4,000. Finally, this cost has been reduced to €1,000, since the size and processing power of the computer was not as large as expected.

of installed ecoMicrogrids. This means that in the first year, with 3 clients, the total cost will be €98.55/year, in the twentieth year, the total cost was €1,971.00.

For the ecoMicrogrid developer, the used software licenses do not need for any renewal or update, so the operation cost will be negligible.

As for the maintenance cost, the industrial computer used to install and operate the ecoMicrogrid will be replaced once along a 10-years period. This cost will amount to €1,000.

Besides, it is necessary to hire a professional who will be in charge of the yearly updates of the tool, as well as the fixing of any bug or problem which can arise. Around 7 PM/year would be needed to carry out these tasks.

Supporting that the cost per person month is €5,000/PM, then the cost of these updates would reach €35,000/year.

- The depreciation and amortization cost has been calculated using the linear amortization method. Considering an investment cost of €185,000, and a lifetime of 20 years, then the depreciation and amortization will amount to €9,100/year.
- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoMicrogrid tool, from the point of view of the ecoTool developer, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 185,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Salaries of the professionals in charge of developing the ecoTool	- 180,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Hardware	- 1,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- 1,000 €
Software licences	- 4,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€) of new clients (installation cost)	- €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €
Incomes (€) of existing clients (licence for the system)	- €	- €	3,000 €	6,000 €	9,000 €	12,000 €	15,000 €	18,000 €	21,000 €	24,000 €	27,000 €
Operation and maintenance costs (€)	- €	- 50,099 €	- 50,197 €	- 50,296 €	- 50,394 €	- 50,493 €	- 50,591 €	- 50,690 €	- 50,788 €	- 50,887 €	- 50,986 €
Professional cost of updating the application	- €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €
Personal computers which are installed in each microgrid	- €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €
Software licences for each microgrid	- €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €
Electricity for the personal computer	- €	- 99 €	- 197 €	- 296 €	- 394 €	- 493 €	- 591 €	- 690 €	- 788 €	- 887 €	- 986 €
Renewal of the hardware											
Depreciation and amortization (€)	- €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €
Profit before taxes (€)	- €	15,801 €	18,703 €	21,604 €	24,506 €	27,407 €	30,309 €	33,210 €	36,112 €	39,013 €	40,915 €
Deferred corporate taxes (€)	- €	- 3,476 €	- 4,115 €	- 4,753 €	- 5,391 €	- 6,030 €	- 6,668 €	- 7,306 €	- 7,945 €	- 8,583 €	- 9,001 €
Net cash flow (€)	- 185,000 €	21,425 €	23,688 €	25,951 €	28,215 €	30,478 €	32,741 €	35,004 €	37,267 €	39,530 €	41,013 €
Accumulated net cash flows (€)	- 185,000 €	- 163,575 €	- 139,887 €	- 113,935 €	- 85,721 €	- 55,243 €	- 22,502 €	12,502 €	49,769 €	89,299 €	130,312 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Salaries of the professionals in charge of developing the ecoTool	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Hardware	- €	- €	- €	- €	- €	- €	- €	- €	- €	- 1,000 €
Software licences	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€) of new clients (installation cost)	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €	75,000 €
Incomes (€) of existing clients (licence for the system)	30,000 €	33,000 €	36,000 €	39,000 €	42,000 €	45,000 €	48,000 €	51,000 €	54,000 €	57,000 €
Operation and maintenance costs (€)	- 54,084 €	- 54,183 €	- 54,281 €	- 54,380 €	- 54,478 €	- 54,577 €	- 54,675 €	- 54,774 €	- 54,872 €	- 54,971 €
Professional cost of updating the application	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €
Personal computers which are installed in each microgrid	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €
Software licences for each microgrid	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €	- 12,000 €
Electricity for the personal computer	- 1,084 €	- 1,183 €	- 1,281 €	- 1,380 €	- 1,478 €	- 1,577 €	- 1,675 €	- 1,774 €	- 1,872 €	- 1,971 €
Renewal of the hardware	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €
Depreciation and amortization (€)	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €	- 9,100 €
Profit before taxes (€)	41,816 €	44,717 €	47,619 €	50,520 €	53,422 €	56,323 €	59,225 €	62,126 €	65,028 €	66,929 €
Deferred corporate taxes (€)	- 9,200 €	- 9,838 €	- 10,476 €	- 11,114 €	- 11,753 €	- 12,391 €	- 13,029 €	- 13,668 €	- 14,306 €	- 14,724 €
Net cash flow (€)	41,716 €	43,980 €	46,243 €	48,506 €	50,769 €	53,032 €	55,295 €	57,558 €	59,821 €	61,305 €
Accumulated net cash flows (€)	172,029 €	216,008 €	262,251 €	310,757 €	361,526 €	414,558 €	469,853 €	527,411 €	587,233 €	648,538 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	116,837.20 €
IRR (%)	16.700%
First positive accumulated cash flow	12,502
Payback (years)	Year 7

Table 3. Economic sustainability analysis for the ecoMicrogrid Tool, including the cash flow model and a profitability analysis, from the point of view of the ecoTool developer

The afore mentioned economic model for the ecoMicrogrid tool has the following results: the net present value of the project amounts to €116,837.20, with a discount rate of 10%, along 20 years. The payback period is 7 years, and the internal rate of return is 16.70%.

The next figure shows the cash flow diagram of the use of the ecoMicrogrid tool, from the point of view of the ecoTool developer:

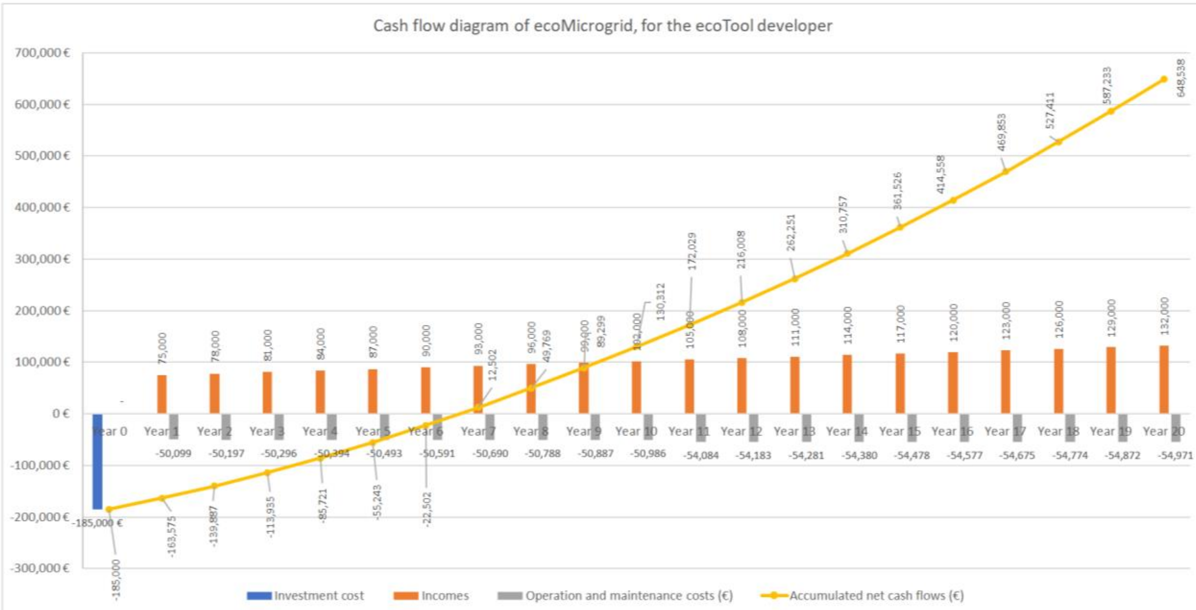

Figure 3. Cash flow diagram of ecoMicrogrid, for the ecoTool developer

The following analysis considers the case of a client which buys the ecoMicrogrid tool, to evaluate the level of economic savings which can make the investment profitable:

- Investment cost: As described before, the cost of the installation of an ecoMicrogrid tool is estimated to be €25,000.
- Incomes: The ecoMicrogrid tool generates several cost savings for a microgrid operator, due to different aspects of energy management:
  - Operation cost reduction: It has been estimated that the use of the ecoMicrogrid tool can reduce operational cost in a microgrid by up to 60%, although this depends on the case. The analyses carried out in the Gaidouromantra microgrid have resulted in savings of 50% of the diesel generator operation costs.
  - Curtailment reduction: The ecoTool also contributes to a reduction of curtailment, especially when it is used along with demand side management measures, or by combining electricity, heating and cooling management. The specific level of savings depends on the case, however, the ecoMicrogrid advanced algorithms have proven to allow for more efficient energy dispatch, minimizing curtailments, and maximizing renewable energy penetration.
  - Monitoring and fault identification: The ecoMicrogrid tool has monitoring capacities which enable swift and accurate identification of faults and malfunctions. This makes easier to carry out efficient and cost-effective maintenance procedures.
  - Increased reliability and reduced blackouts: Apart from leading to relevant economic costs, the use of ecoMicrogrid can increase the reliability of the power grid, reducing the frequency and duration of blackouts and disruptions. The

optimization of the grid operations, and the early detection of potential failures, lead to an increase in the reliability and resilience of the energy supply.

The total amount of these incomes or savings is difficult to estimate without taking a specific case study. However, the following hypotheses are going to be considered:

  - Only the curtailment reduction will be considered.
  - A solar PV plant with a total yearly production of 1,000 MWhe/year (approximately, a 500-kW solar PV plant).
  - The solar PV plant is owned by the user of ecoMicrogrid or, alternatively, the benefits derived from the use of the ecoTool are transferred from the solar PV plant owner to the microgrid operator.
  - Electricity price: €0.09/kWh.
  - Reduction of curtailments: 20%.

This leads to losses of 200 MWhe/year, worth €18,000/year.

- Operation and maintenance cost: The cost of the renewal and update of the licence of ecoMicrogrid is estimated to be around €1,000 per year.
- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €25,000, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €1,250/year.
- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoMicrogrid tool, from the point of view of the user, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 25,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€)		18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €
Curtailment reduction (€)		18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €
Operation and maintenance costs (€)		- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Yearly licence		- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Depreciation and amortization (€)		- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €
Profit before taxes (€)		15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €
Deferred corporate taxes (€)		- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €
Net cash flow (€)		13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €
Accumulated net cash flows (€)	- 25,000 €	- 11,465 €	2,070 €	15,605 €	29,140 €	42,675 €	56,210 €	69,745 €	83,280 €	96,815 €	110,350 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€)	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €
Curtailment reduction (€)	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €	18,000 €
Operation and maintenance costs (€)	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Yearly licence	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Depreciation and amortization (€)	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €	- 1,250 €
Profit before taxes (€)	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €	15,750 €
Deferred corporate taxes (€)	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €	- 3,465 €
Net cash flow (€)	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €	13,535 €
Accumulated net cash flows (€)	123,885 €	137,420 €	150,955 €	164,490 €	178,025 €	191,560 €	205,095 €	218,630 €	232,165 €	245,700 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	90,231.08 €
IRR (%)	54.131%
First positive accumulated cash flow	2,070.00 €
Payback (years)	Year 2

Table 4. Economic model for the ecoMicrogrid ecoTool, including the cash flow model and a profitability analysis, for the final client.

In this case study, the use of the ecoMicrogrid ecoTool is clearly beneficial for the client. Under the hypotheses before described, the investment in the ecoTool is recovered in the second year. A net present value of €90,231.08 is obtained after twenty years (with a discount rate of 10%), and the internal rate of return is higher than 50%.

The following figure shows the cash flow diagram for this ecoTool, from the point of view of the final client:

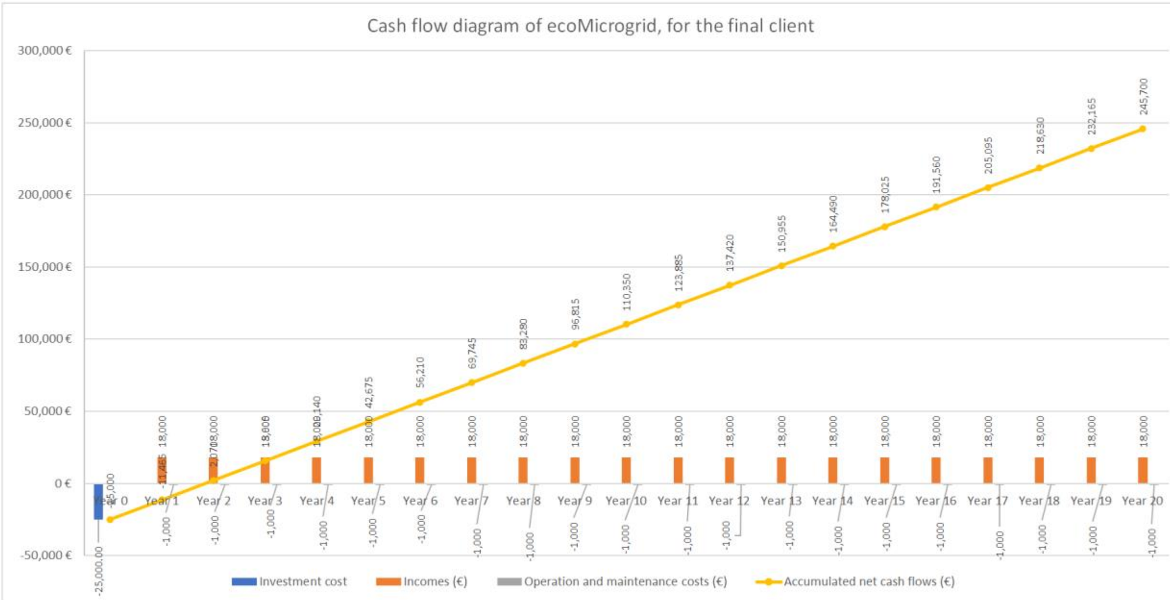

Figure 4. Cash flow diagram of ecoMicrogrid, for the final client

2.3 ecoPlanning

ecoPlanning is a tool developed by the Electric Energy Systems Laboratory of ICCS-NTUA, used to support the decision-making process for the deployment of new electricity generation units (conventional and renewable) in the electric systems of non-interconnected islands (NIIs) in a mid-term horizon. ecoPlanning carries out the following studies: 7-Year energy planning for assessing the deployment plan of new conventional production units; analysis of the renewable energy hosting capacity in the power system, and interconnection assessment by performing steady state simulations of the electric system to evaluate the interconnection advantages and reports. ecoPlanning allows defining different scenarios, considering the electricity demand forecast and the composition of the electric system (types of production units, technical and economic characteristics, operation rules, etc.). The tool reports the operation of the generation units and several results about the energy production in terms of quality, fuel consumption and cost, CO_2 emissions, etc. It makes it possible to design and develop high-RES energy systems, taking into account the flexibility offered by demand response mechanisms and other energy carriers, such as cooling.

According to the economic information provided by the ecoPlanning developer, the following economic sustainability analysis has been developed:

- Investment cost: The total investment cost to develop the ecoPlanning consists of two parts:
  - Design of the tool through research and private contracts has amounted to €250,000.
  - Installation cost: Around €2,000, divided into the adaptation of other algorithms and parameters (€1,000) and ICT work (€1,000).

- Incomes for the project (new clients): For a new client, the sale of a license to use the ecoPlanning will be around €50,000 for each island.

  Supposing that during the first year, 1 island will purchase the ecoPlanning tool, the incomes for the tool developer will amount to €50,000. Since the number of potential clients is limited, it is supposed that the incomes will remain constant along the 20 years of lifetime, €50,000 per year.

- Incomes for the project (existing clients): It is not expected to charge a yearly fee to the existing ecoPlanning tool.
- Estimated operation and maintenance costs: It has been supposed that the ecoPlanning tool will need yearly retraining and update of the forecasting algorithms, at a cost of €1,000 per year.
- The depreciation and amortization cost has been calculated using the linear amortization method. Considering an investment cost of €252,000, and a lifetime of 20 years, then the depreciation and amortization will amount to €12,600/year.
- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoPlanning tool, from the point of view of the ecoTool developer, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 252,000 €										
Design and development of the ecoTool	- 250,000 €										
Installation costs (€) of the ecoTool	- 2,000 €										
Incomes (€)		50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €
Installation costs (€)		- 5,000 €	- 5,000 €	- 5,000 €	- 5,000 €	- 5,000 €	- 5,000 €	- 5,000 €	- 5,000 €	- 5,000 €	- 5,000 €
Operation and maintenance costs (retraining the forecasting algorithms)		- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Depreciation and amortization (€)		- 12,600 €	- 12,600 €	- 12,600 €	- 12,600 €	- 12,600 €	- 12,600 €	- 12,600 €	- 12,600 €	- 12,600 €	- 12,600 €
Profit before taxes (€)		31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €
Deferred corporate taxes (€)		- 6,908 €	- 6,908 €	- 6,908 €	- 6,908 €	- 6,908 €	- 6,908 €	- 6,908 €	- 6,908 €	- 6,908 €	- 6,908 €
Net cash flow (€)	- 252,000 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €
Accumulated net cash flows (€)	- 252,000 €	- 214,908 €	- 177,816 €	- 140,724 €	- 103,632 €	- 66,540 €	- 29,448 €	7,644 €	44,736 €	81,828 €	118,920 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)										
Design and development of the ecoTool										
Installation costs (€) of the ecoTool										
Incomes (€)	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €	50,000 €
Installation costs (€)	-5,000 €	-5,000 €	-5,000 €	-5,000 €	-5,000 €	-5,000 €	-5,000 €	-5,000 €	-5,000 €	-5,000 €
Operation and maintenance costs (retraining the forecasting algorithms)	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €	-1,000 €
Depreciation and amortization (€)	-12,600 €	-12,600 €	-12,600 €	-12,600 €	-12,600 €	-12,600 €	-12,600 €	-12,600 €	-12,600 €	-12,600 €
Profit before taxes (€)	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €	31,400 €
Deferred corporate taxes (€)	-6,908 €	-6,908 €	-6,908 €	-6,908 €	-6,908 €	-6,908 €	-6,908 €	-6,908 €	-6,908 €	-6,908 €
Net cash flow (€)	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €	37,092 €
Accumulated net cash flows (€)	156,012 €	193,104 €	230,196 €	267,288 €	304,380 €	341,472 €	378,564 €	415,656 €	452,748 €	489,840 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	63,785
IRR (%)	13.56%
First positive accumulated cash flow	7,644
Payback (years)	Year 7

Table 5. Economic model for the ecoPlanning Tool, including the cash flow model and a profitability analysis.

According to the economic model for the ecoPlanning tool, the net present value of the project, discounted with a discount rate of 10%, is €63,785, along 20 years. On the other hand, the IRR is 13.56%.

The payback period is 7 years.

This analysis also shows that the investment would be recovered if one new client is identified each year, and at the end of the analysed 20-years period, there are 20 clients.

The following figure shows the cash flow diagram for ecoPlanning:

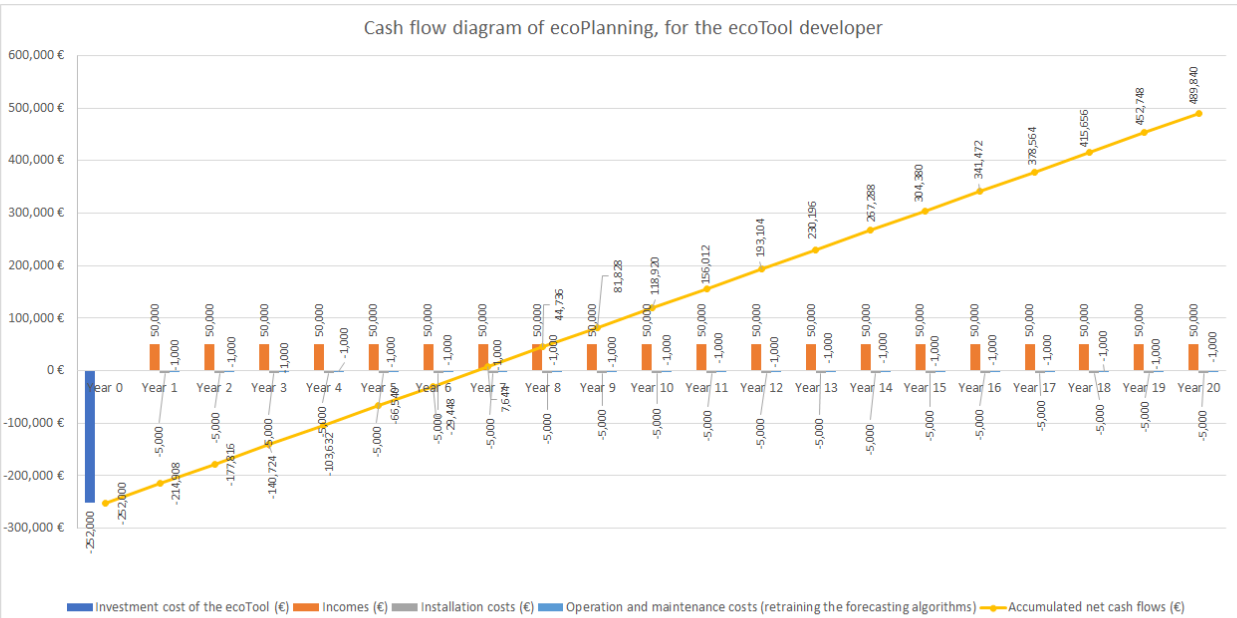

Figure 5. Cash flow diagram of ecoPlanning, for the ecoTool developer

In principle, for the user of ecoPlanning, direct incomes are not expected, so an economic model has not been developed. ecoPlanning will be a good supporting tool to design the future evolution of the energy system of the island, and will make sure that this development is appropriate.

2.4 ecoDR

ecoDR is the tool focused on the development of advanced metering infrastructure (AMI) with inbuilt load controller and protection functionalities. Additionally to measurement and billing of household energy consumption, ecoDR facilitates remote monitoring and control of non-critical loads based on user preference. Over-current protection functionalities are included in the smart meter to make it work as an over-current relay.

This tool is available to communicate with ecoMicrogrid to access services such as demand-side management and implement scheduling of critical/non-critical loads via load shedding. If the renewable energy generation is not enough to cover the demand, the tool can create limits to the power and energy demand of all non-critical consumptions. It limits fairly the consumption of all consumers, avoiding situations of overload or blackouts.

Based on the information provided by the ecoTool designer, an economic model, which includes the expected cash flows for the ecoDR tool, has been developed. It changes compared to the estimates made in 2022, as the ecoTool designer has been able to provide more accurate information about the investment cost, operation and maintenance costs, and expected incomes:

- Investment cost: To develop the ecoDR ecoTool, the following investment costs have been considered:
    - Installation of 4 Smart meters, 2 for the Indian Demo Sites (Keonjhar and Ghoramara) and 4 for the European Demo Sites (Bornholm and Kythnos).

      The total investment cost of such smart meters is ₹24,000, equivalent to €266.40[2].
    - Design cost of the ecoDR ecoTool: It includes the manpower needed for the schematic, the design of the PCB (Printed Circuit Board), and other activities.

      The design cost is approximately ₹200,000, equivalent to €2,220.00.
    - Development of the ecoDR ecoTool: During the development phase, it is expected that three iterations will be needed. The total development costs are expected to reach ₹200,000, equivalent to €2,220.00.

      This cost includes all the consumables, components, development boards, PCBs, etc.
    - Test and measurement of the ecoTool: Development of tests, using tools such as oscilloscopes and multimetres, and the need for loads, sources, power supply, and so on. The total cost for tests and measurement is expected to be ₹200,000, or €2,220.00.

  The total investment cost for ecoDR amounts to ₹624,000, this is, €6,926.40.

[2] Note: In all the document, an exchange rate of 1 €= 90.09 ₹ will be used. It is an average exchange rate considering its evolution during the evolution of the exchange rate along the last year.

- Incomes for the project: These incomes will come from the sale of the developed ecoDR tool to new users.
    - An installation price for the final clients of ₹300 per piece, this is, €3.33. It is expected to sell between 3,000 and 5,000 pieces per year.

      Taking an average of 4,000 pieces per year, the total installation price would be ₹1,200,000, or €13,320.00.
    - The total incomes, for the first year, from the sale of licences for technology licencing is expected to be around ₹500,000, or €5,550.00.
    - It is expected that during the first year, 20 clients will purchase the ecoDR tool. Since then, a yearly increase of 10% is expected in the number of clients which will use the tool. This means that, in year 20, there will be 122 new clients.

  Thus, the expected income for the first year will be €18,870.00, with an increase of 10% per year.
- Estimated installation costs: In this cost, it is included the operation and maintenance cost of the ecoTool, as well as the cost for commercializing it.

  This cost includes the installation cost for each smart meter, which is around ₹6,000, this is, €66.60, and the labour cost to install it, which amounts to ₹300 per piece, this is, €3.33.

  Considering 20 clients for the first year, then the installation cost would be ₹120,000 for the smart meters, and ₹1,200,000 for the 4,000 pieces per year (€1,332 and €13,320).
- Operation and maintenance costs: It is supposed that there is a warranty period of 2 years, when there are not operation and maintenance costs.

  After these first two years, 10% faults in the installed devices can be expected. Each fault involves the replacement of the entire module, costing each module between ₹8,000 and ₹10,000 (average of ₹9,000, or €99.90).

  For example, in year 3, the total number of installed modules will be 42 (20 clients in the year 1 + 22 clients in year 2). This involves a total operation and maintenance cost of ₹37,800 (10%*42 clients*₹9,000), equivalent to €419.58.
- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €6,926.40, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €346.32/year.
- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoDR tool, from the point of view of the ecoTool developer, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	-6,926.40 €										
Smart meters (x 4 units)	-266.40 €										
Design of the ecoTool	-2,220.00 €										
Material needed to develop the ecoTool	-2,220.00 €										
Test and measurement	-2,220.00 €										
Incomes (€)		18,870.00 €	20,757.00 €	22,832.70 €	25,115.97 €	27,625.68 €	30,390.14 €	33,428.21 €	36,772.91 €	40,452.56 €	44,500.18 €
Licence fees		5,550.00 €	6,105.00 €	6,715.50 €	7,387.05 €	8,125.20 €	8,938.28 €	9,831.83 €	10,815.56 €	11,897.81 €	13,088.29 €
Installation fee		13,320.00 €	14,652.00 €	16,117.20 €	17,728.92 €	19,500.48 €	21,451.86 €	23,596.38 €	25,957.35 €	28,554.75 €	31,411.89 €
Installation costs (€)- New clients		-14,652.00 €	-16,117.20 €	-17,715.60 €	-19,460.52 €	-21,431.88 €	-23,583.06 €	-25,927.38 €	-28,554.75 €	-31,418.55 €	-34,542.09 €
Smart meters		-1,332.00 €	-1,465.20 €	-1,598.40 €	-1,731.60 €	-1,931.40 €	-2,131.20 €	-2,331.00 €	-2,597.40 €	-2,863.80 €	-3,130.20 €
Labour costs		-13,320.00 €	-14,652.00 €	-16,117.20 €	-17,728.92 €	-19,500.48 €	-21,451.86 €	-23,596.38 €	-25,957.35 €	-28,554.75 €	-31,411.89 €
Operation and maintenance costs (€)		0.00 €	0.00 €	-419.58 €	-659.34 €	-919.08 €	-1,208.79 €	-1,528.47 €	-1,878.12 €	-2,267.73 €	-2,697.30 €
Depreciation and amortization (€)		-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €
Profit before taxes (€)		3,871.68 €	4,293.48 €	4,351.20 €	4,649.79 €	4,928.40 €	5,251.97 €	5,626.04 €	5,993.72 €	6,419.96 €	6,914.47 €
Deferred corporate taxes (€)		-851.77 €	-944.57 €	-957.26 €	-1,022.95 €	-1,084.25 €	-1,155.43 €	-1,237.73 €	-1,318.62 €	-1,412.39 €	-1,521.18 €
Net cash flow (€)	-6,926.40 €	3,366.23 €	3,695.23 €	3,740.26 €	3,973.16 €	4,190.47 €	4,442.85 €	4,734.63 €	5,021.42 €	5,353.89 €	5,739.60 €
Accumulated net cash flows (€)	-6,926.40 €	-3,560.17 €	135.06 €	3,875.32 €	7,848.48 €	12,038.95 €	16,481.80 €	21,216.43 €	26,237.85 €	31,591.74 €	37,331.35 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)										
Smart meters (x 4 units)										
Design of the ecoTool										
Material needed to develop the ecoTool										
Test and measurement										
Incomes (€)	48,948.78 €	53,845.55 €	59,228.21 €	65,153.39 €	71,668.26 €	78,834.14 €	86,717.09 €	95,387.85 €	104,926.64 €	115,418.36 €
Licence fee	14,396.70 €	15,836.93 €	17,420.06 €	19,162.76 €	21,078.90 €	23,186.51 €	25,505.03 €	28,055.25 €	30,860.78 €	33,946.58 €
Installation fee	34,552.08 €	38,008.62 €	41,808.15 €	45,990.63 €	50,589.36 €	55,647.63 €	61,212.06 €	67,332.60 €	74,065.86 €	81,471.78 €
Installation costs (€)- New clients	-38,015.28 €	-41,804.82 €	-46,003.95 €	-50,586.03 €	-55,650.96 €	-61,242.03 €	-67,339.26 €	-74,059.20 €	-81,458.46 €	-89,596.98 €
Smart meters	-3,463.20 €	-3,796.20 €	-4,195.80 €	-4,595.40 €	-5,061.60 €	-5,594.40 €	-6,127.20 €	-6,726.60 €	-7,392.60 €	-8,125.20 €
Labour costs	-34,552.08 €	-38,008.62 €	-41,808.15 €	-45,990.63 €	-50,589.36 €	-55,647.63 €	-61,212.06 €	-67,332.60 €	-74,065.86 €	-81,471.78 €
Operation and maintenance costs (€)	-3,166.83 €	-3,686.31 €	-4,255.74 €	-4,885.11 €	-5,574.42 €	-6,333.66 €	-7,172.82 €	-8,091.90 €	-9,100.89 €	-10,209.78 €
Depreciation and amortization (€)	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €	-346.32 €
Profit before taxes (€)	7,420.35 €	8,008.10 €	8,622.20 €	9,335.93 €	10,096.56 €	10,912.13 €	11,858.69 €	12,890.43 €	14,020.97 €	15,265.28 €
Deferred corporate taxes (€)	-1,632.48 €	-1,761.78 €	-1,896.88 €	-2,053.91 €	-2,221.24 €	-2,400.67 €	-2,608.91 €	-2,835.89 €	-3,084.61 €	-3,358.36 €
Net cash flow (€)	6,134.19 €	6,592.63 €	7,071.64 €	7,628.35 €	8,221.64 €	8,857.78 €	9,596.09 €	10,400.86 €	11,282.67 €	12,253.23 €
Accumulated net cash flows (€)	43,465.54 €	50,058.18 €	57,129.81 €	64,758.16 €	72,979.80 €	81,837.58 €	91,433.67 €	101,834.53 €	113,117.20 €	125,370.44 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	38,716.06 €
IRR (%)	54.8%
First positive accumulated cash flow	135.06 €
Payback (years)	Year 2

Table 6. Economic model for ecoDR, including the cash flow model and a profitability analysis, from the point of view of the ecoTool developer.

According to the model provided before, the business model proposed for the ecoDR ecoTool has the following economic results: the net present value of the project (with a discount rate of 10%) amounts to €38,716.06 along 20 years, and the IRR is 54.8%.

On the other hand, the payback period is 2 years.

The next figure shows the cash flow diagram of the use of the ecoDR tool, from the point of view of the ecoTool developer:

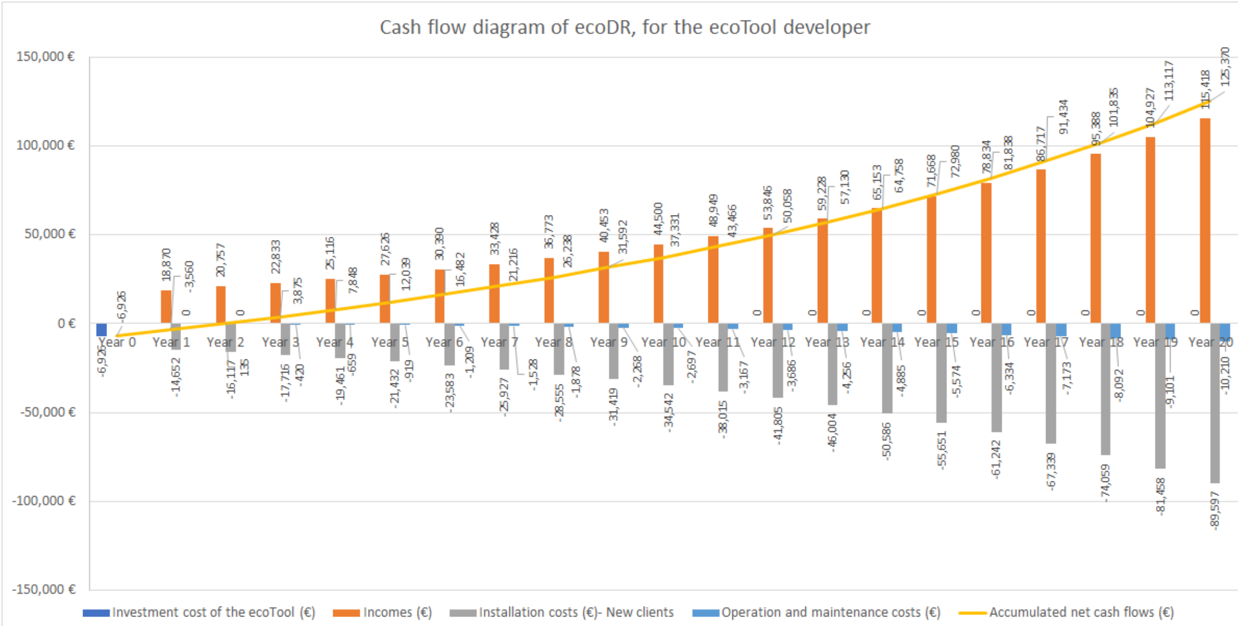

Figure 6. Cash flow diagram of ecoDR, for the ecoTool developer

2.5 ecoPlatform

The ecoPlatform tool is a lightweight, cloud-based platform with the primary objective of providing the RE-EMPOWERED tools with a secure and reliable interface to the deployed distributed energy infrastructure. In addition, ecoPlatform is capable of managing, processing, and handling the heterogeneous data and command stream from the RE-EMPOWERED tools, metering infrastructure, supervisory control, and data acquisition (SCADA) systems, microgrid central controllers (MGCCs), and selected controllable assets.

ecoPlatform ensures that all the rest of ecoTools are interconnected and integrated, and is provided as a Platform-as-a-Service (PaaS). Besides, it enables final customers or operators to freely customize the applications and acquire the data streams needed for operation.

The sustainability analysis has been carried out from two different points of view: the ecoTool developer, DTU, and a potential user. As an example of the final user, the case of the Bornholm Demo Site is considered. The used information has been obtained from the ecoPlatform developer.

Firstly, the case study for the ecoTool developer, DTU is carried out. The information provided by DTU about investment cost, operation and maintenance costs and incomes is as follows:

- Investment cost: The following investment cost is expected for the ecoPlatform tool:
  - Development of the software needed for ecoPlatform: €100,000, including the design of ecoPlatform and its development.
  - Implementation and installation of the ecoTool in the Bornholm Demo Site, the SCADA and the engineering needed: €60,000.

- Citizen involvement campaign to encourage the participation in the use of the ecoPlatform: €10,000.

  The total investment cost for ecoPlatform, in the Bornholm Demo Site, amounts to €170,000.

- Incomes for the ecoTool designer: The developer would obtain incomes from the sale and commercialization of the ecoPlatform tool to new users. The following assumptions have been made:
  - An installation price for the final clients of €3,000 per each ecoPlatform tool.
  - It is expected that during the first year, 5 clients will begin to use the ecoPlatform tool. Since then, a yearly increase of 10% is expected in the number of clients which will use the tool. This means that, in year 20, there will be 37 new clients.

    This involves an expected income for the first year of €15,000 (5 clients x €3,000), and in the year 20, the income will amount to €111,000.
  - It has been supposed that each client will need to renew its license yearly, at a price of €500 for each ecoPlatform.

    This price will be applied to the accumulated number of clients obtained during the previous years.

    Thus, in the second year, the total incomes from licenses renewal will amount to €2,500, while in the year 20, it will be €154,000.
- Estimated operation and maintenance costs: The following costs have been estimated for the useful lifetime of ecoPlatform of 20 years:
  - Operation and maintenance cost and demo purchase of electricity: €15,000 during the first three years, this is, €5,000/year.
  - Professional cost for updating the application: It is estimated that 0.1 professionals will be needed per year (around 1.2 months).

    Considering a personnel cost of €5,000 per PM, then this cost will amount to €6,000 per year.
  - Cloud server as cloud database storage: A cloud server will be needed, with a cost of €60 per year.
  - Renewal of the domain: This cost would amount to €15 per year.
- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €170,000, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €8,500/year.
- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoPlatform tool, from the point of view of the ecoTool developer, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 170,000 €										
Development of the software needed for ecoPlatform	- 100,000 €										
Implementation and installation of the ecoTool in the demo site	- 60,000 €										
Campaign to increase the citizen involvement	- 10,000 €										
Incomes (€) of new clients (installation cost)		15,000 €	18,000 €	21,000 €	24,000 €	27,000 €	30,000 €	33,000 €	36,000 €	39,000 €	42,000 €
Incomes (€) of existing clients (licence for the system)		- €	2,500 €	5,500 €	9,000 €	13,000 €	17,500 €	22,500 €	28,000 €	34,000 €	40,500 €
Operation and maintenance costs (€)		- 11,075 €	- 11,075 €	- 11,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €
Operation and maintenance and demo purchase of electricity		- 5,000 €	- 5,000 €	- 5,000 €							
Professional cost of updating the application		- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €
Cloud server as cloud database storage		- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €
Renewal of the domain		- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €
Depreciation and amortization (€)		- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €
Profit before taxes (€)	- €	- 4,575 €	925 €	6,925 €	18,425 €	25,425 €	32,925 €	40,925 €	49,425 €	58,425 €	67,925 €
Deferred corporate taxes (€)	- €	1,007 €	- 204 €	- 1,524 €	- 4,054 €	- 5,594 €	- 7,244 €	- 9,004 €	- 10,874 €	- 12,854 €	- 14,944 €
Net cash flow (€)	- 170,000 €	4,932 €	9,222 €	13,902 €	22,872 €	28,332 €	34,182 €	40,422 €	47,052 €	54,072 €	61,482 €
Accumulated net cash flows (€)	- 170,000 €	- 165,069 €	- 155,847 €	- 141,946 €	- 119,074 €	- 90,743 €	- 56,561 €	- 16,140 €	30,912 €	84,984 €	146,465 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)										
Development of the software needed for ecoPlatform										
Implementation and installation of the ecoTool in the demo site										
Campaign to increase the citizen involvement										
Incomes (€) of new clients (installation cost)	45,000 €	51,000 €	57,000 €	63,000 €	69,000 €	75,000 €	84,000 €	93,000 €	102,000 €	111,000 €
Incomes (€) of existing clients (licence for the system)	47,500 €	55,000 €	63,500 €	73,000 €	83,500 €	95,000 €	107,500 €	121,500 €	137,000 €	154,000 €
Operation and maintenance costs (€)	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €	- 6,075 €
Operation and maintenance and demo purchase of electricity										
Professional cost of updating the application	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €
Cloud server as cloud database storage	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €	- 60 €
Renewal of the domain	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €	- 15 €
Depreciation and amortization (€)	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €	- 8,500 €
Profit before taxes (€)	77,925 €	91,425 €	105,925 €	121,425 €	137,925 €	155,425 €	176,925 €	199,925 €	224,425 €	250,425 €
Deferred corporate taxes (€)	- 17,144 €	- 20,114 €	- 23,304 €	- 26,714 €	- 30,344 €	- 34,194 €	- 38,924 €	- 43,984 €	- 49,374 €	- 55,094 €
Net cash flow (€)	69,282 €	79,812 €	91,122 €	103,212 €	116,082 €	129,732 €	146,502 €	164,442 €	183,552 €	203,832 €
Accumulated net cash flows (€)	215,747 €	295,558 €	386,680 €	489,891 €	605,973 €	735,704 €	882,206 €	1,046,647 €	1,230,199 €	1,434,030 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	272,564.40 €
IRR (%)	19.88%
First positive accumulated cash flow	30,912.00 €
Payback (years)	Year 8

Table 7. Economic model for the ecoPlatform Tool, from the point of view of the ecoTool developer, including the cash flow model and a profitability analysis.

The previously described model shows that the development of the ecoPlatform tool will lead to a net present value of €272,564.40, with an Internal Rate of Return of 19.88%, and a payback period of 8 years.

The next figure shows the cash flow diagram of the use of the ecoPlatform tool, from the point of view of the ecoTool developer:

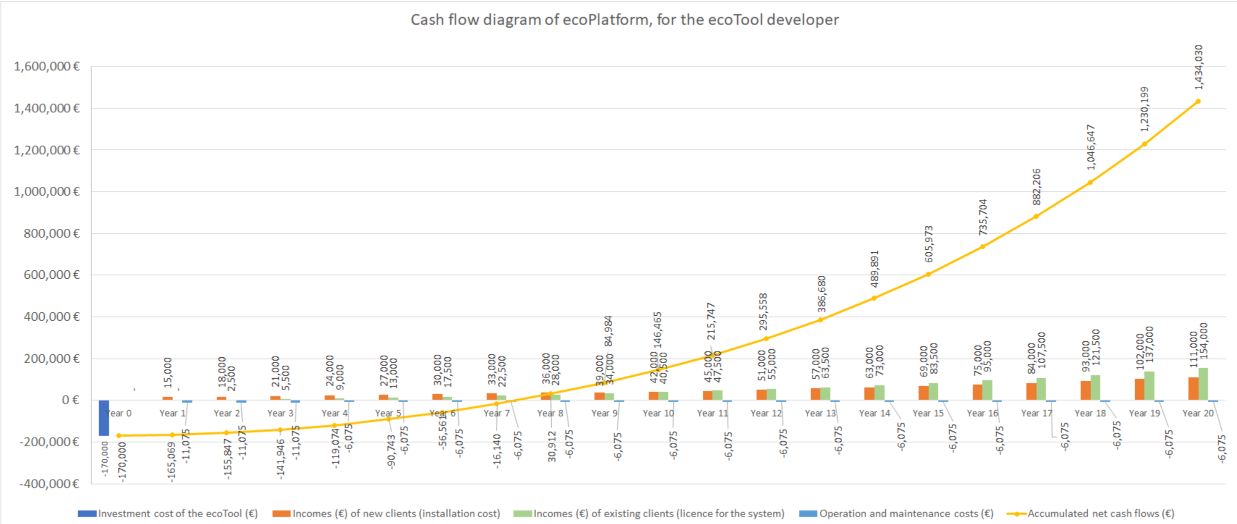

Figure 7. Cash flow diagram of ecoPlatform, for the ecoTool developer

On the other hand, the analysis from the point of view of a potential ecoPlatform user is as follows, taking as an example, the case of the Bornholm Demo Site:

- Investment cost: The installation fee for the ecoPlatform has been estimated to be €3,000 for each user.
- Incomes for the use of the tool: The ecoPlatform will reduce the losses of the solar PV plant of Bornholm.

  It has been estimated that the reduction of the losses will be around 5% of the production. Supposing that the solar PV production is 22,000 kWh (a solar PV plant with a total installed capacity of 20 MW, with 1,100 equivalent hours), then the losses will be reduced by 1,100 kWh/year.

  Supposing that the cost of electricity is 0.05 €/kWh, then the total incomes for the project will amount to €55,000/year, as the reduction of losses from the solar PV plant.
- Estimated operation and maintenance cost: The yearly licence of ecoPlatform, for the user (e.g., the Bornholm Demo Site) is estimated to be €500.00 per year.
- To simplify the case study, it has been considered that the ecoTool user is a non-for-profit entity, and that it does not pay corporate taxes.
- Financial costs have not been considered.

Based on the previously described hypotheses, the cash flow model for a final user, taking as example the Bornholm Demo Site, would be as follows:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Installation fee (€)	- 3,000 €										
Benefit of the ecoTool for the demo site (€)- Avoidance of 20% of losses of solar PV plants		55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €
Operation and maintenance costs (€)		- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €
Net cash flow (€)	- 3,000 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €
Accumulated net cash flows (€)	- 3,000 €	51,500 €	106,000 €	160,500 €	215,000 €	269,500 €	324,000 €	378,500 €	433,000 €	487,500 €	542,000 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Installation fee (€)										
Benefit of the ecoTool for the demo site (€)- Avoidance of 20% of losses of solar PV plants	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €	55,000 €
Operation and maintenance costs (€)	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €	- 500 €
Net cash flow (€)	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €	54,500 €
Accumulated net cash flows (€)	596,500 €	651,000 €	705,500 €	760,000 €	814,500 €	869,000 €	923,500 €	978,000 €	1,032,500 €	1,087,000 €

Discount rate (%)	10%

NPV	460,989.22 €
IRR (%)	1816.67%
First positive accumulated cash flow	51,500
Payback (years)	Year 1

Table 8. Economic model for the ecoPlatform Tool, from the point of view of the final user, including the cash flow model and a profitability analysis- Case of Bornholm Island.

As it can be seen, the use of the ecoPlatform tool is very beneficial for the final user, obtaining a net present value above €450,000, and an internal rate of return of 1,816.67%. Indeed, and considering the high level of energy savings derived from the use of the ecoPlatform, the sale price of the tool could be much higher.

Taking into account the previously described hypotheses, the investment cost is recovered in the first year.

However, a price of €3,000 for the installation fee is considered as appropriate, as the ecoPlatform tool cannot be installed alone. The user should purchase other tools of the ecoToolset.

Based on the previously described cash flows, a cash flow diagram can be also prepared for the ecoPlatform user:

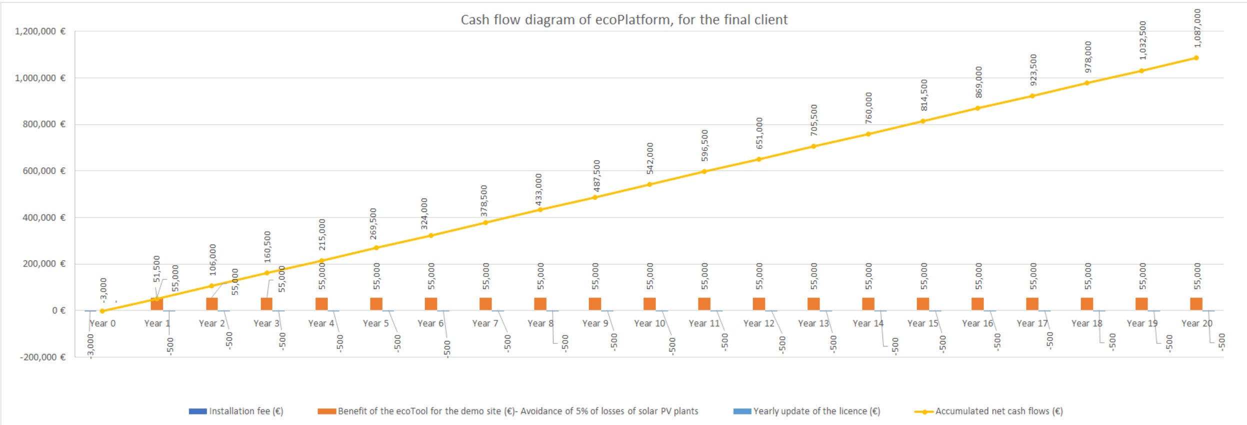

Figure 8. Cash flow diagram of ecoPlatform Tool, for the final user- Case of Bornholm Island

2.6 ecoMonitor

ecoMonitor is a tool to develop a portable digital control platform, with multiple sensors and a microcontroller-based processing unit to monitor real-time different ambient air quality parameters, such as the concentration of CO, NO_2, SO_2, O_3, PM2.5 and PM10 microparticles, as well as ambient temperature and relative humidity. The sensor readings are submitted to other ecoTools such as ecoMicrogrid and ecoPlatform, for their processing and analysis.

It is battery-powered with solar panel-based charger units, and it is aimed to be used in remote environmental monitoring. The sensor readings are processed in real time in the control platform and the data are transmitted by suitable communication protocols to a data platform for remote monitoring, display and analysis.

Based on the information provided by the ecoMonitor leader, an economic model to evaluate the economic sustainability of the development and commercialization of the ecoTool has been prepared. This model takes into account the investment cost, the operation and maintenance costs, and the incomes from the sale of the tool.

To design this economic model, the following information has been used:

- Investment cost: To develop the ecoMonitor ecoTool, the following investment costs have been considered:
    - Design cost of the ecoMonitor ecoTool: It includes the manpower needed for the schematic, the design of the PCB (Printed Circuit Board), and other activities.

      The design cost is approximately ₹200,000, equivalent to €2,220.00.
    - Material cost needed to develop the ecoMonitor ecoTool: This includes the fabrication of the PCB. The total material costs are approximately ₹600,000, or €6,660.00.
    - Test and measurement of the ecoTool: Development of tests, using tools such as oscilloscopes and multimetres, and the need for loads, sources, power supply, and so on. The total cost for tests and measurement is expected to be ₹500,000, or €5,550.00.

  The total investment cost for ecoDR amounts to ₹1,300,000, this is, €14,430.00.
- Incomes for the project: These incomes will come from the sale of the developed ecoMonitor tool to new users.
    - An installation price for the final clients of ₹300 per piece, this is, €3.33. It is expected to sell between 3,000 and 5,000 pieces per year.

      Taking an average of 4,000 pieces per year, the total installation price would be ₹1,200,000, or €13,320.00.
    - The total incomes, for the first year, from the sale of licences for technology licencing is expected to be around ₹500,000, or €5,550.00.

- It is expected that during the first year, 30 clients will purchase the ecoMonitor tool. Since then, a yearly increase of 10% is expected in the number of clients which will use the tool. This means that, in year 20, there will be 182 new clients.

  Thus, the expected income for the first year will be €18,870.00, with an increase of 10% per year.

- Estimated installation costs: In this cost, it is included the operation and maintenance cost of the ecoTool, as well as the cost for commercializing it.

  The installation fee amounts to ₹300 per piece, or €3.33. Considering an average of 4,000 pieces, the total installation cost would be ₹1,200,000, or €13,320.00, for the first year.

  This cost is directly passed to the final client.

- Operation and maintenance costs: It is supposed that there is a warranty period of 2 years, when there are not operation and maintenance costs.

  After these first two years, 10% faults in the installed devices can be expected. Each fault involves the replacement of the entire module, costing each module between ₹75,000 and ₹100,000 (average of ₹87,500, or €971.25).

  For example, in year 3, the total number of installed modules will be 63 (30 clients in the year 1 + 33 clients in year 2). This involves a total operation and maintenance cost of ₹551,250 (10%*63 clients*₹87,500), equivalent to €6,119.

- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €15,662.65, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €721.50/year.

- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoMonitor tool, from the point of view of the ecoTool developer, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 14,430 €										
Design of the ecoTool (manpower for schematic, PCB design)	- 2,220 €										
Material needed to develop the ecoTool	- 6,660 €										
Test and measurement	- 5,550 €										
Incomes (€)		18,870 €	20,757 €	22,833 €	25,116 €	27,626 €	30,390 €	33,428 €	36,773 €	40,453 €	44,500 €
Licence fee		5,550 €	6,105 €	6,716 €	7,387 €	8,125 €	8,938 €	9,832 €	10,816 €	11,898 €	13,088 €
Installation fee		13,320 €	14,652 €	16,117 €	17,729 €	19,500 €	21,452 €	23,596 €	25,957 €	28,555 €	31,412 €
Operation and maintenance cost (€)		- €	- €	- 6,119 €	- 9,615 €	- 13,500 €	- 17,774 €	- 22,436 €	- 27,584 €	- 33,217 €	- 39,433 €
Installation costs (€)		- 13,320 €	- 14,652 €	- 16,117 €	- 17,729 €	- 19,500 €	- 21,452 €	- 23,596 €	- 25,957 €	- 28,555 €	- 31,412 €
Depreciation and amortization (€)		- 722 €	- 722 €	- 722 €	- 722 €	- 722 €	- 722 €	- 722 €	- 722 €	- 722 €	- 722 €
Profit before taxes (€)		23,699 €	26,141 €	22,708 €	22,166 €	21,529 €	20,833 €	20,103 €	19,283 €	18,412 €	17,434 €
Deferred corporate taxes (€)		- 5,214 €	- 5,751 €	- 4,996 €	- 4,877 €	- 4,736 €	- 4,583 €	- 4,423 €	- 4,242 €	- 4,051 €	- 3,836 €
Net cash flow (€)	- 14,430 €	19,206 €	21,111 €	18,434 €	18,011 €	17,514 €	16,971 €	16,402 €	15,763 €	15,083 €	14,320 €
Accumulated net cash flows (€)	- 14,430 €	4,776 €	25,887 €	44,321 €	62,332 €	79,846 €	96,818 €	113,219 €	128,982 €	144,065 €	158,385 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)										
Design of the ecoTool (manpower for schematic, PCB design)										
Material needed to develop the ecoTool										
Test and measurement										
Incomes (€)	48,949 €	53,846 €	59,228 €	65,153 €	71,668 €	78,834 €	86,717 €	95,388 €	104,927 €	115,418 €
Licence fee	14,397 €	15,837 €	17,420 €	19,163 €	21,079 €	23,187 €	25,505 €	28,055 €	30,861 €	33,947 €
Installation fee	34,552 €	38,009 €	41,808 €	45,991 €	50,589 €	55,648 €	61,212 €	67,333 €	74,066 €	81,472 €
Operation and maintenance cost (€)	-46,232 €	-53,710 €	-61,966 €	-71,096 €	-81,099 €	-92,075 €	-104,118 €	-117,327 €	-131,896 €	-147,921 €
Installation costs (€)	-34,552 €	-38,009 €	-41,808 €	-45,991 €	-50,589 €	-55,648 €	-61,212 €	-67,333 €	-74,066 €	-81,472 €
Depreciation and amortization (€)	-722 €	-722 €	-722 €	-722 €	-722 €	-722 €	-722 €	-722 €	-722 €	-722 €
Profit before taxes (€)	16,392 €	15,251 €	13,961 €	12,499 €	10,926 €	9,225 €	7,383 €	5,395 €	3,170 €	722 €
Deferred corporate taxes (€)	-3,606 €	-3,355 €	-3,071 €	-2,750 €	-2,404 €	-2,029 €	-1,624 €	-1,187 €	-697 €	-159 €
Net cash flow (€)	13,508 €	12,617 €	11,611 €	10,471 €	9,244 €	7,917 €	6,480 €	4,929 €	3,194 €	1,285 €
Accumulated net cash flows (€)	171,892 €	184,510 €	196,121 €	206,592 €	215,836 €	223,752 €	230,232 €	235,162 €	238,356 €	239,640 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	116,464
IRR (%)	134.921%
First positive accumulated cash flow	4,776
Payback (years)	Year 1

Table 9. Economic model for the ecoMonitor Tool, including the cash flow model and a profitability analysis, from the point of view of the ecoTool developer.

According to the model provided before, the business model proposed for the ecoMonitor eco tool: the net present value of the project (with a discount rate of 10%) amounts to €116,464 along 20 years, and the IRR is 134.921%.

On the other hand, the payback period is 1 year. These values are very high. They are foreseen for the development of the ecoTool in India. There, inflation rates are higher than in the European Union, and this makes that the profitability for projects is expected to be higher. However, the number of ecoTools which can be installed is limited by the growing cost of replacing the devices which fail. Even if the number of new clients is expected to grow, the maximum number of clients is limited to the need of covering the cost of replacing the existing devices, with the new incomes coming from the new clients.

The next figure shows the cash flow diagram of the use of the ecoMonitor tool, from the point of view of the ecoTool developer:

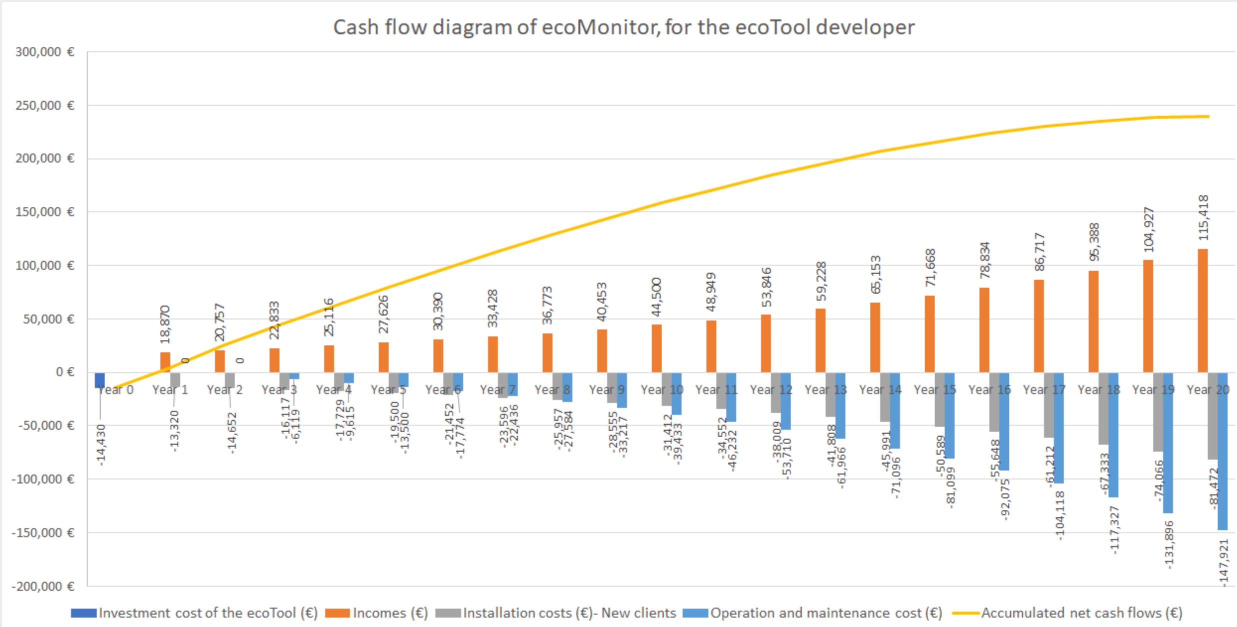

Figure 9. Cash flow diagram of ecoMonitor, for the ecoTool developer

2.7 ecoCommunity

ecoCommunity is a digital platform, designed to improve the engagement of citizens, energy communities and demand aggregators, their active participation, and the technology acceptance in the four Demo Sites. ecoCommunity can be used to coordinate energy users of an energy system, as members of a local energy community. The main functionalities of ecoCommunity are the display of dynamic prices for the residential loads, the demand-side management of non-critical loads, electronic billing, payment, and a feedback portal.

With ecoCommunity, users can monitor their energy data (i.e., energy generation and consumption), and have access to different services with the objective of helping them to define their energy profile. It also offers useful information about billing information, and allows users to use digital platforms through payment gateway interfaces.

According to the updated economic information provided by the ecoCommunity tool developer, two different economic models have been prepared: the first one considers the point of view of the ecoTool developer (the business of designing, commercializing, manufacturing, and sale of the ecoTool to final clients), and the point of view of the client which decides to become a user of ecoCommunity.

First of all, the analysis has been prepared for the ecoTool developer, considering the following information:

- Investment cost: ecoCommunity is an Android mobile application, and the total investment cost to develop it includes the design of the tool:
  - Design of the tool, by a software engineer or developer. The ecoCommunity tool can be considered as a medium complexity application, which includes user login,

customized UI, fetching data from other websites and tools, API integration, push notifications, cloud data storage and so on.

Considering a development time around 2-3 months, and an average hourly professional cost of €40, then the total development cost will be around €12,500.

  - Cloud database or server: The cost of the cloud database or server depends on the amount of data which has to be stored. In the case of ecoCommunity and the RE-EMPOWERED Demo Sites, the amount of information can be stored in free servers, so no cost has to be considered.

- Incomes for the project (new clients): The price of the ecoCommunity license has been estimated to be around €1,000, for each user.

  It is expected that, during the first year, 7 users will purchase the ecoCommunity tool. This number will increase by 10% year by year. This involves that, in year 20, there will be 45 new clients.

  The forecasted income for the ecoTool developer will amount to €7,000 in year 1, and to €45,000 in year 20.

- Incomes for the project (existing clients): It is forecast that each client who uses the ecoCommunity will have to pay a yearly renewal license, including the updates in algorithms, at a price of €100 per year.

  This renewal licence will be paid, each year, by the cumulated number of clients of the previous year, since new users have to pay only the new-user installation licence.

  This means that, in year 2, €700 will be paid as renewal licence, and in year 20, this concept will amount to €4,100.

- Estimated operation and maintenance costs: The operation and maintenance costs of the ecoCommunity tool will include the following components:

  - Professional cost of updating the application: This cost includes the cost of a software designer who will oversee updating and maintaining the application, year by year. This cost can depend on the changes made, however, an average development time of 10 days per year can be considered.

    In that case, the professional cost would be €1,500 per year.

  - Cloud server: The ecoCommunity tool has been developed using free services for the cloud server, which is a cloud database storage. However, the standard cost of a cloud server depends on the storage and the computational requirements, but it is among €50 and €100 per year (average of €75/year).

  - Payment gateway services: The bill payment module of the tool uses different payment gateway services, including credit and debit card, and online banking. The cost of the payment gateway services is associated to the transaction charge for each transaction. This cost ranges from 1% to 3% of the transaction amount (an average of 2% has been taken).

- Community manager: In the Indian Demo Site, many consumers do not have smartphones or Internet access, and they cannot work properly with the ecoCommunity tool. For this reason, it is necessary to hire a community manager, who will use and interact with the tool on behalf of several users. In some cases, the community manager will be a member of the community, who will be voluntary, and will not be paid for this task.

- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €12,500, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €625/year.

- The corporate taxes are considered to be 22%.

- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoCommunity tool, from the point of view of the ecoTool developer, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 12,500 €										
Salaries of the professionals in charge of developing the ecoTool	- 12,500 €										
Incomes (€)		7,000 €	8,700 €	9,800 €	10,900 €	12,000 €	13,100 €	14,200 €	15,300 €	16,400 €	18,500 €
Incomes (€) of new clients (installation cost)		7,000 €	8,000 €	9,000 €	10,000 €	11,000 €	12,000 €	13,000 €	14,000 €	15,000 €	17,000 €
Incomes (€) of existing clients (licence for the system)		- €	700 €	800 €	900 €	1,000 €	1,100 €	1,200 €	1,300 €	1,400 €	1,500 €
Operation and maintenance costs (€)		- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €
Professional cost of updating the application		- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €
Cloud server as cloud database storage		- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €
Payment gateway services		- 140 €	- 174 €	- 196 €	- 218 €	- 240 €	- 262 €	- 284 €	- 306 €	- 328 €	- 370 €
Depreciation and amortization (€)		- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €
Profit before taxes (€)		4,800 €	6,500 €	7,600 €	8,700 €	9,800 €	10,900 €	12,000 €	13,100 €	14,200 €	16,300 €
Deferred corporate taxes (€)		- 1,056 €	- 1,430 €	- 1,672 €	- 1,914 €	- 2,156 €	- 2,398 €	- 2,640 €	- 2,882 €	- 3,124 €	- 3,586 €
Net cash flow (€)	- 12,500 €	4,369 €	5,695 €	6,553 €	7,411 €	8,269 €	9,127 €	9,985 €	10,843 €	11,701 €	13,339 €
Accumulated net cash flows (€)	- 12,500 €	- 8,131 €	- 2,436 €	4,117 €	11,528 €	19,797 €	28,924 €	38,909 €	49,752 €	61,453 €	74,792 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)										
Salaries of the professionals in charge of developing the ecoTool										
Incomes (€)	20,700 €	22,900 €	25,100 €	27,300 €	30,500 €	33,800 €	37,100 €	40,400 €	44,700 €	49,100 €
Incomes (€) of new clients (installation cost)	19,000 €	21,000 €	23,000 €	25,000 €	28,000 €	31,000 €	34,000 €	37,000 €	41,000 €	45,000 €
Incomes (€) of existing clients (licence for the system)	1,700 €	1,900 €	2,100 €	2,300 €	2,500 €	2,800 €	3,100 €	3,400 €	3,700 €	4,100 €
Operation and maintenance costs (€)	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €	- 1,575 €
Professional cost of updating the application	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €
Cloud server as cloud database storage	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €
Payment gateway services	- 414 €	- 458 €	- 502 €	- 546 €	- 610 €	- 676 €	- 742 €	- 808 €	- 894 €	- 982 €
Depreciation and amortization (€)	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €	- 625 €
Profit before taxes (€)	18,500 €	20,700 €	22,900 €	25,100 €	28,300 €	31,600 €	34,900 €	38,200 €	42,500 €	46,900 €
Deferred corporate taxes (€)	- 4,070 €	- 4,554 €	- 5,038 €	- 5,522 €	- 6,226 €	- 6,952 €	- 7,678 €	- 8,404 €	- 9,350 €	- 10,318 €
Net cash flow (€)	15,055 €	16,771 €	18,487 €	20,203 €	22,699 €	25,273 €	27,847 €	30,421 €	33,775 €	37,207 €
Accumulated net cash flows (€)	89,847 €	106,618 €	125,105 €	145,308 €	168,007 €	193,280 €	221,127 €	251,548 €	285,323 €	322,530 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	91,000.89 €
IRR (%)	51.265%
First positive accumulated cash flow	4,117
Payback (years)	Year 3

Table 10. Economic model for the ecoCommunity Tool, including the cash flow model and a profitability analysis, from the point of view of the ecoTool developer.

The results of the economic model shown for the ecoCommunity tool are as follows: the net present value of the project, discounted at a rate of 10% is €91,000.89, along 20 years. The Internal Rate of Return is 51.27%, and the payback period is 3 years.

The following figure shows the cash flow diagram for ecoCommunity, from the point of view of the ecoTool developer:

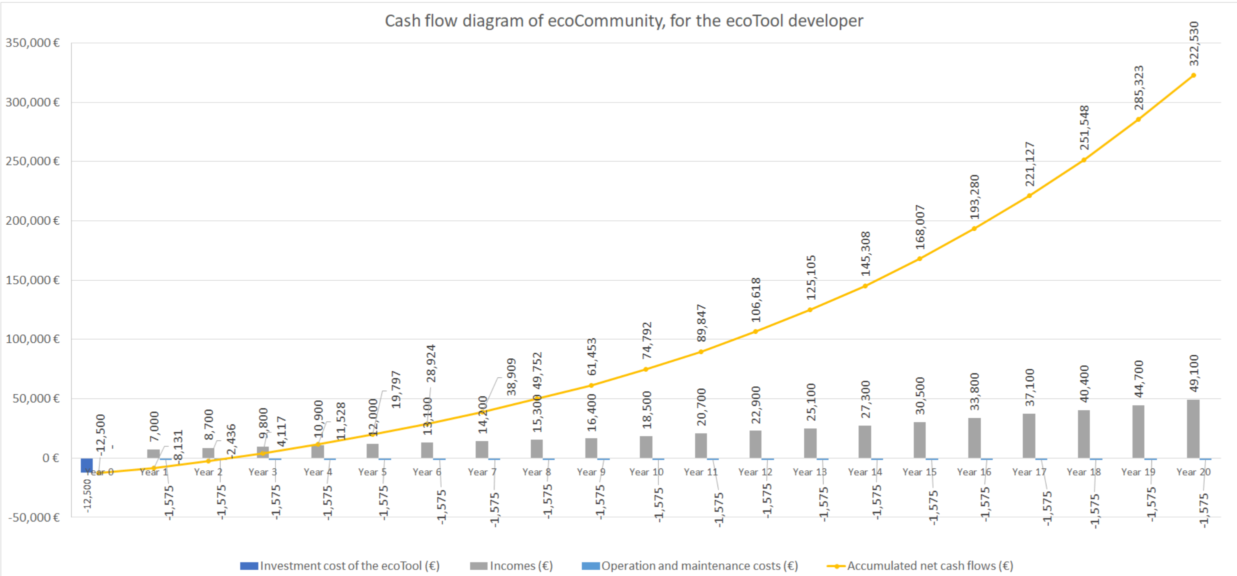

Figure 10. Cash flow diagram of ecoCommunity, for the ecoTool developer

If the case of a user which purchases the ecoCommunity tool is analysed, then it is possible to evaluate if it would be profitable for an energy community to purchase the ecoTool:

- Investment cost: It is supposed that the cost of the licence of ecoCommunity will be €1,000 for a new client.
- Incomes: The ecoCommunity tool does not generate revenues for the user. Instead, it can be used as a supporting tool which makes easier to carry out different activities in the energy community. This will lead to relevant economic savings, as described before:
    - Consumption data, billing, and payments: ecoCommunity tool can make the generation of monthly energy billings automatic for all users. It also enables an easy way to pay bills for the consumers.

      In the case of Indian Demo Sites, if the ecoCommunity tool is not installed, it is necessary to hire a professional which will record the consumption data, prepare the bills and collect the payment from each user.

      The manual preparation of bills and payment control can take around 0.2-0.5 man-hour for each consumer and month.

      Considering that in Ghoramara microgrid there are 500 households, then the use of ecoCommunity can avoid the need for hiring two professionals, each year.

In India, the average salary is €400/month. Taking into account that the professionals in charge or preparing the energy invoices are not highly qualified, then the cost can be lower, around €200/month.

This involves that, for the energy community, the total avoided cost can be around €4,800/year (2 professionals, 12 months per year with a salary of €200/month).

- Coordination of community loads: ecoCommunity is a platform which enables energy community to coordinate the use of communal loads shared by many consumers and large private loads.

  The platform also enables agreement between the users and the Demo Site leader. This avoids the need for hiring a professional in charge of coordinating the activity.

  Each consumer interaction can take, if the ecoCommunity is not installed, around 0.2 man-hour. To avoid overestimating the salaries saved by ecoCommunity, this cost is considered to be included in the professionals which would prepare the electricity invoices.

- Weather notifications: The ecoCommunity tool offers users weather notifications from the Indian Meteorological Department website. If users are aware of the high probability of some extreme events, like cyclones or floods, then they can take measures to minimize the potential damages to the community. This will avoid the repair and replacement cost of different devices.

- Tutorial and step-by-step guides: ecoCommunity offers manuals, video tutorials and step-by-step guides on troubleshooting and repair of different devices of the microgrid. This will help the energy community to solve different minor problems in the system on themselves, avoiding the need for a technical expert.

  If the cost of each technical intervention is around €1/hour, each intervention lasts 0.5 hours, and each community member needs 1 intervention per year (500 community members), then the savings derived from these guides would be around €250 per year.

- Operation and maintenance cost: The cost of the renewal and update of the licence of ecoCommunity will be around €100 per year.
- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €1,000, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €50/year.
- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoCommunity tool, from the point of view of the final client, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 1,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€)	- €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €
Avoided personal cost of reviewing the consumption data	- €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €
Avoided personal cost of solving incidents	- €	250 €	250 €	250 €	250 €	250 €	250 €	250 €	250 €	250 €	250 €
Operation and maintenance costs (€)	- €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €
Depreciation and amortization (€)	- €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €
Profit before taxes (€)	- 1,000 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €
Net cash flow (€)	- 1,000 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €
Accumulated net cash flows (€)	- 1,000 €	3,950 €	8,900 €	13,850 €	18,800 €	23,750 €	28,700 €	33,650 €	38,600 €	43,550 €	48,500 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€)	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €	5,050 €
Avoided personal cost of reviewing the consumption data	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €	4,800 €
Avoided personal cost of solving incidents	250 €	250 €	250 €	250 €	250 €	250 €	250 €	250 €	250 €	250 €
Operation and maintenance costs (€)	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €	- 100 €
Depreciation and amortization (€)	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €	- 50 €
Profit before taxes (€)	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €	4,900 €
Net cash flow (€)	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €	4,950 €
Accumulated net cash flows (€)	53,450 €	58,400 €	63,350 €	68,300 €	73,250 €	78,200 €	83,150 €	88,100 €	93,050 €	98,000 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	41,142.14 €
IRR (%)	495.0%
First positive accumulated cash flow	3,950
Payback (years)	Year 1

Table 11. Economic model for the ecoCommunity Tool, including the cash flow model and a profitability analysis, for the final client.

As it can be seen, the results from the economic model for the final user of ecoCommunity (taking as an example the Ghoramara microgrid) show that the net present value of the use of the tool amounts to €41,142.14, along 20 years, and the IRR is 495.0%. The payback period will be around 1 year, considering the savings in the professional costs avoided. These results can seem to be very positive, however, they are due to the large reduction in the personnel costs. Before the installation of ecoCommunity, two professionals were expected to be engaged to read energy consumptions of each client, prepare invoices, and make sure that invoices are paid. These activities can be done automatically by the ecoTool.

The following figure shows the cash flow diagram for a final user of the ecoCommunity tool:

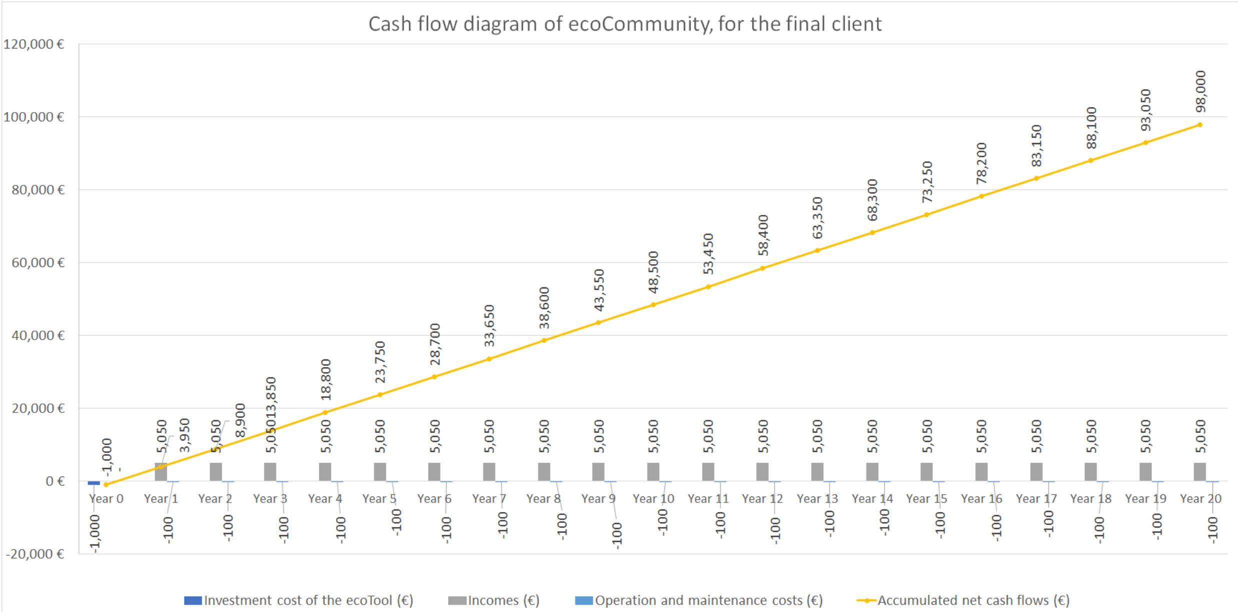

Figure 11. Cash flow diagram of ecoCommunity, for the final client

In other cases, where the energy community is better connected, and there is not a need for employees who prepare manually the electricity invoices, the economic savings will be much lower.

2.8 ecoResilience

ecoResilience is the tool designed to develop cyclone resilient support structures for both ground-mounted solar photovoltaic (PV) arrays and wind turbines, for their use in tropical Indian regions. In these regions, severe cyclones are common, with maximum wind speeds of more than 240 km/h. The tool optimized the design of solar PV facilities to minimize the aerodynamic wind loads through numerical simulations, scale-down wind tunnel testing, and field tests. To do this, the designed solar PV structures are aerodynamic, and have curved plates with concave and convex surfaces.

In the case of wind turbines, hybrid structures resistant to cyclones have been designed to withstand extreme weather conditions, where the designed tower facilitates the removal and reinstallation of wind turbine blades during normal operating conditions. Different turbine heights have been tested using numerical simulations and field tests.

The designed wind turbine has some characteristics which make it more resistant to extreme weather events:

- The support structure can be made rigid.
- Blades can be removed, to minimize the loads that they have to withstand during extreme weather events, such as cyclones.
- The height of the tower can be reduced, using a mechanically operated chain pulley drive.

- The designed wind turbine support structure has some parts fixed (truss), while other parts are movable (monopole). The top monopole structure can be brought down, to give access to the wind turbine blades, which can be then removed.

The economic sustainability analysis for the ecoResilience tool will be carried out from three different point of views:

- The ecoResilience tool developer, this is, the designer and developer of the ecoResilience, CSIR-CMERI. The developer invests an amount in the design of the ecoTool, and has to recover it by selling it to clients.
- The ecoResilience tool user, this is, clients who decide to purchase ecoResilience, and install it in their project.

Economic information about the expected investment cost, the operation and maintenance costs, and the expected future revenues has been obtained from the ecoTool developer.

Economic sustainability analysis from the point of view of the ecoResilience tool developer:

The hypotheses to prepare this model are as follow:

- Investment cost: The total investment cost to develop the ecoResilience ecoTool is expected to amount to ₹4,648,000, this is, €56,000.
- Incomes for the project: The following table includes the cost difference between the investment cost of a 20-kW ground mounted solar PV plant with the ecoResilience tool, and without it:

Components	Cost for conventional plant (₹)	Cost for a plant with ecoResilience (₹)	Note
Foundation (civil works, sand filling, reinforcement, and shuttering)	80,000	100,000	The foundation cost is slightly higher, due to the high probability of cyclones (deep boring for column foundation due to low bearing capacity of soil)
Solar PV panel cost	600,000	600,000	There are not differences
Material cost (galvanized to resist rusting)	220,000	320,000	A box structure is used rather than angles to withstand cyclonic loads. Concave and convex structures are used at the ends.
Labour cost	50,000	100,000	Additional labour for welding, cutting, and assembling the solar PV plant due to movable aerodynamic structure
Total	950,000	1,120,000	The difference will be ₹170,000

Table 12. Difference in the cost of a solar PV plant (20 kW) with the ecoResilience tool and without it.

As can be seen, the ecoResilience tool will have an additional cost of ₹170,000, this is, €1,887, for a 20-kW solar PV plant.

The technology is expected to be used for solar PV plants with a power capacity between 50 kW and 100 kW. If an average size of 100 kW per project is considered, then the additional cost of installing ecoResilience would be ₹850,000, or 5*₹170,000 (€9,435).

Besides, the clients will be charged a technology license fee (non-exclusive basis) of ₹500,000 (€5,550). Therefore, the total income per client will be ₹1,350,000 (€14,985).

It is expected that 2 clients will purchase the ecoResilience tool each year. Thus, the expected income per year will be €29,970 (2 clients x €14,985).

- Installation costs: The installation cost of the ecoResilience tool will be around ₹850,000 per unit, this is, €9,435.

  Thus, considering 2 clients per year, the installation cost for the ecoResilience developer will be €18,870.

- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €56,000, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €2,800/year.

- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoResilience tool, from the point of view of the ecoTool developer, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	-56,000.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
Incomes (€)	0.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €
Installation costs (€)	0.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €
Depreciation and amortization (€)	0.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €
Profit before taxes (€)	0.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €
Deferred corporate taxes (€)	0.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €
Net cash flow (€)	-56,000.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €
Accumulated net cash flows (€)	-56,000.00 €	-46,726.00 €	-37,452.00 €	-28,178.00 €	-18,904.00 €	-9,630.00 €	-356.00 €	8,918.00 €	18,192.00 €	27,466.00 €	36,740.00 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
Incomes (€)	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €	29,970.00 €
Installation costs (€)	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €	-18,870.00 €
Depreciation and amortization (€)	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €	-2,800.00 €
Profit before taxes (€)	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €	8,300.00 €
Deferred corporate taxes (€)	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €	-1,826.00 €
Net cash flow (€)	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €	9,274.00 €
Accumulated net cash flows (€)	46,014.00 €	55,288.00 €	64,562.00 €	73,836.00 €	83,110.00 €	92,384.00 €	101,658.00 €	110,932.00 €	120,206.00 €	129,480.00 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	129,480.00 €
IRR (%)	12.616%
First positive accumulated cash flow	8,918
Payback (years)	Year 7

Table 13. Economic model for the ecoResilience Tool, including the cash flow model and a profitability analysis, from the point of view of the ecoTool developer.

According to the model provided before, the business model proposed for the ecoResilience eco tool is as follows: the net present value of the project (with a discount rate of 10%) amounts to €129,480 along 20 years, and the IRR is 12.616%.

On the other hand, the payback period is 7 years.

The following figure shows the cash flow diagram of ecoResilience, from the point of view of the ecoTool developer:

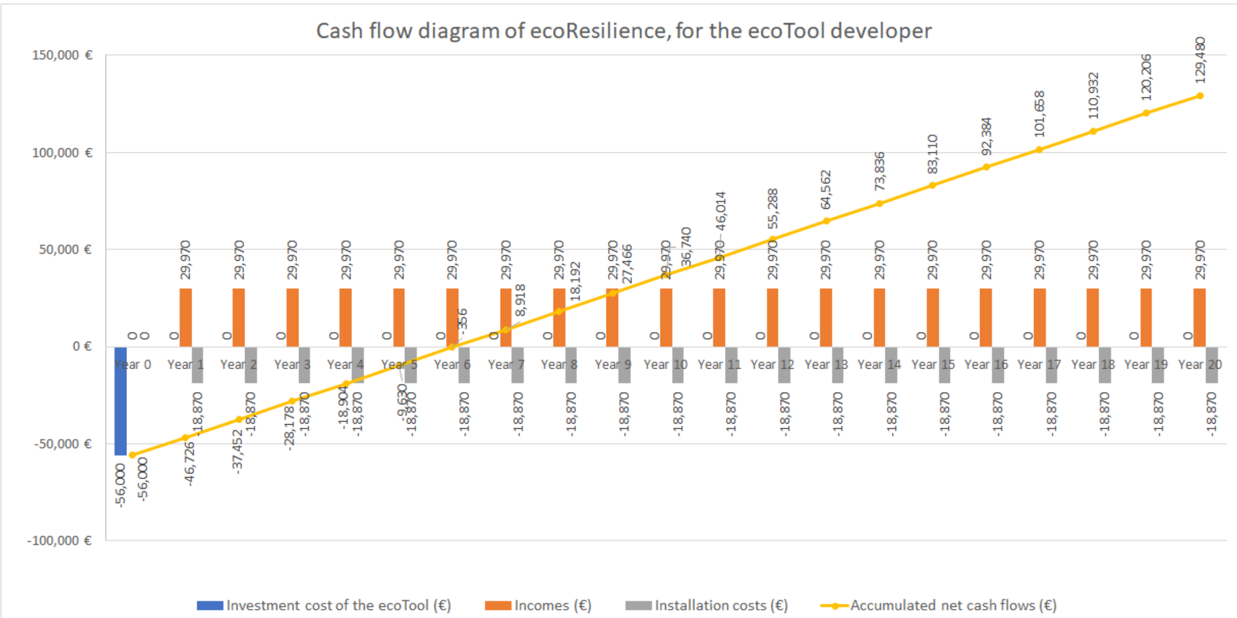

Figure 12. Cash flow diagram of ecoResilience, for the ecoTool developer

<u>Economic sustainability analysis from the point of view of a user of the ecoResilience tool:</u>

It has been also possible to evaluate the economic profitability of installing the ecoResilience tool for the final client, this is, the project developer of the solar PV plant.

In this model, the following information has been used:

- Investment cost: For the company which purchases the ecoResilience tool, the investment cost is the difference between a 100-kW solar PV plant with the tool, and without it. From Table 12 (which includes data for a 20-kW solar PV plant), it is obtained that the extra cost of ecoResilience is ₹850,000, this is, €9,435.

  Besides, it is necessary to include the technology licence fee, with an amount of ₹500,000. Therefore, the total investment cost would be ₹1,350,000, this is, €14,985.

- Incomes: The ecoResilience tool, itself, does not involve any additional electricity production compared to a solar PV plant without the component. For this reason, the revenues from the electricity sale to the market will not be considered, as they will not be higher due to the ecoResilience tool.

Instead of this, the income will be the avoided cost if the site experiences a severe cyclone. The ecoResilience tool will reduce the damages to the installed solar PV plant if a severe cyclone arrives to the site.

It has been estimated that such cyclone arrives each 10 years, and that the damage to the solar PV plant is around 70% of the investment cost. From Table 12, the total investment cost of the plant is ₹5,600,000 (5 x ₹1,120,000), so the damage would be ₹3,920,500 (€43,512). This amount is the income for the owner of the solar PV plant, due to the installation of ecoResilience.

- Estimated maintenance costs: The use of the ecoResilience tool involves an increase of the operation and maintenance costs, due to the need to check the proper lubrication of movable parts. The increase in these costs is expected to be around ₹50,000, for a 100-kW solar PV plant (€555) per year.
- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €14,985, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €749/year.
- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

The following table includes the cash flows for the ecoResilience tool, from the point of view of a final client, during a period of 20 years:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 14,985 €										
Additional foundation costs	- 1,110 €										
Additional solar panel costs	- €										
Additional material costs	- 5,550 €										
Additional labour costs	- 2,775 €										
Additional labour costs	- 5,550 €										
Incomes (€)											43,512 €
Maintenance costs (€)		- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €
Depreciation and amortization (€)		- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €
Profit before taxes (€)		- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	42,208 €
Deferred corporate taxes (€)		287 €	287 €	287 €	287 €	287 €	287 €	287 €	287 €	287 €	- 9,286 €
Net cash flow (€)	- 14,985 €	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	33,671 €
Accumulated net cash flows (€)	- 14,985 €	- 15,253 €	- 15,521 €	- 15,789 €	- 16,057 €	- 16,325 €	- 16,593 €	- 16,861 €	- 17,130 €	- 17,398 €	16,274 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)										
Additional foundation costs										
Additional solar panel costs										
Additional material costs										
Additional labour costs										
Incomes (€)										43,512 €
Maintenance costs (€)	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €	- 555 €
Depreciation and amortization (€)	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €	- 749 €
Profit before taxes (€)	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	- 1,304 €	42,208 €
Deferred corporate taxes (€)	287 €	287 €	287 €	287 €	287 €	287 €	287 €	287 €	287 €	- 9,286 €
Net cash flow (€)	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	- 268 €	33,671 €
Accumulated net cash flows (€)	16,006 €	15,738 €	15,470 €	15,201 €	14,933 €	14,665 €	14,397 €	14,129 €	13,861 €	47,532 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	862.77 €
IRR (%)	10.457%
First positive accumulated cash flow	16,274
Payback (years)	Year 10

Table 14. Economic model for the ecoResilience Tool, including the cash flow model and a profitability analysis, for the final client.

The results from the economic model show that, for a final user of ecoResilience, the net present value of using this tool will amount to €862.77 (with a discount rate of 10%), along 20 years, and the IRR is 10.457%. The payback period will be around 10 years.

The results of the economic sustainability analysis are not very positive. However, they do not include the impact of not having electricity supply during the time when a standard solar PV plant, without the ecoResilience tool is not available due to an extreme weather event.

Besides, the cash flow diagram for a final client of the ecoResilience tool has been prepared.

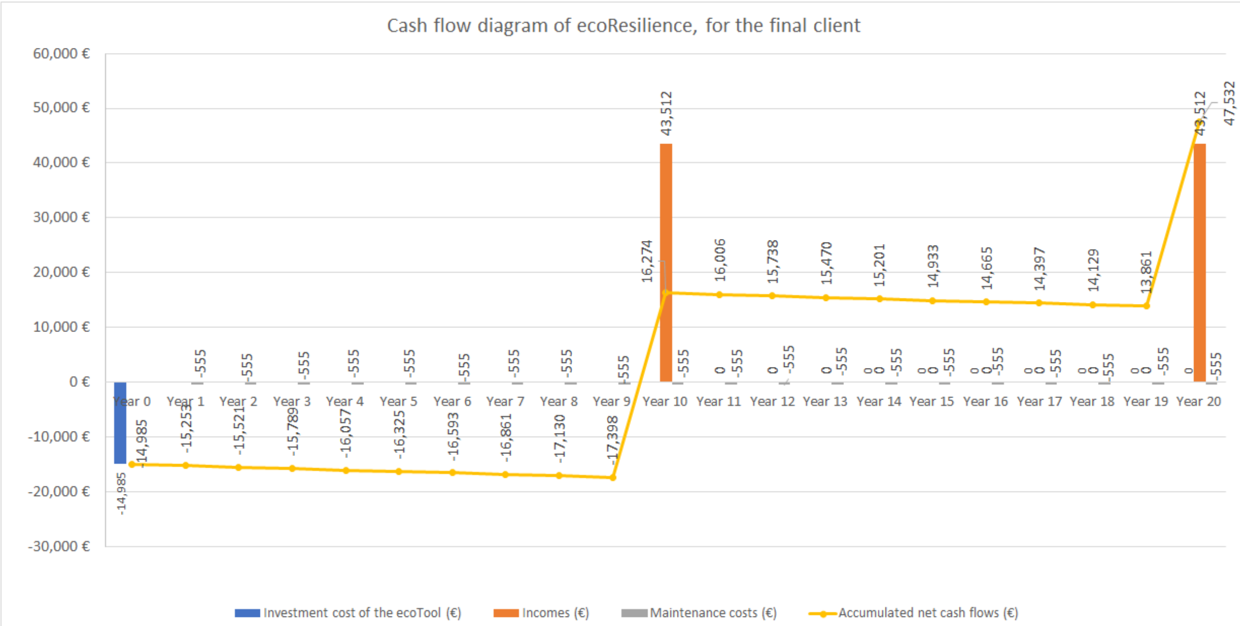

Figure 13. Cash flow diagram of ecoResilience, for the final user

The cash flow diagram has an unusual form, as the incomes are only obtained considering the avoided costs of replacing the solar PV plant, in the years when a cyclone is expected to happen.

2.9 ecoConverter

ecoConverter is the tool related to the development of several power electronic converters and their control, for DC/AC multi-source microgrids. Two power electronic converters, a 30 kW DC/AC inverter and a 50 kW DC/DC partial power converter (PPC) for multi-string PV architecture are developed. Additionally, an Intelligent Power Module (IPM) based inverter, a power quality conditioner (STATCOM), a load flow controller, a SiC based DC/DC converter and an FPGA (Field Programmable Gate Array) based digital control platform have been developed.

The objective of ecoConverter is to form a local AC grid providing ancillary services and extracting the maximum power from solar PV panels under partial shading conditions.

According to the information provided by the ecoConverter developer, an economic sustainability analysis has been prepared:

- Investment cost: During the RE-EMPOWERED project, two converters have been developed:
  - A 10-kW high power DC-DC converter to integrate the battery energy storage system of 100 kWh used in the Ghoramara Demo Site. The total cost for developing this tool has amounted to ₹200,000, equivalent to €2,220.
  - Development of a power electronic converter interface to integrate a wind turbine of 5 kW. The total cost for developing this tool has been approximately ₹150,000, this is, €1,665.

The total investment cost for ecoConverter amounts to ₹350,000, this is, €3,885.

- Incomes for the project: The financial model considers the commercialization of the developed ecoTool to new users. The commercialization plan considers the following assumptions:
    - An installation price for the final clients of ₹500, (€5.55). This includes the equipment cost and the labour cost.
    - It is expected that during the first year, 100 clients will purchase the ecoConverter tool. Since then, a yearly increase of 10% is expected in the number of clients which will use the tool. This means that, in year 20, there will be 616 new clients.

  Thus, the expected income for the first year will be €555 (10 clients x €5.55), while in the year 20, the income will amount to €3,419 (616 clients x €5.55).
- Estimated operation and maintenance costs: In this cost, it is included the operation and maintenance cost of the ecoTool, as well as the cost for commercializing it:
    - Installation cost of the ecoConverter tool: The installation cost of the ecoConverter tool will be negligible.
    - Operation and maintenance cost of the ecoConverter tool in Ghoramara. Around 10% of the investment cost annually, this is, ₹35,000, or €389/year.
- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €3,885, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €389/year.
- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool	- 3,885 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Development of 10 kW high power DC-DC converter to integrate batteries of 100 kWh	- 2,220 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Development of power electronic converter interface to integrate wind turbine of 5 kW	- 1,665 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes	- €	555 €	611 €	672 €	738 €	810 €	894 €	982 €	1,082 €	1,193 €	1,315 €
Operation and maintenance costs	- €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €
Depreciation and amortization (€)	- €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €
Profit before taxes (€)	- €	- 28 €	28 €	89 €	155 €	228 €	311 €	400 €	500 €	611 €	733 €
Deferred corporate taxes (€)	- €	6 €	- 6 €	- 20 €	- 34 €	- 50 €	- 68 €	- 88 €	- 110 €	- 134 €	- 161 €
Net cash flow (€)	- 3,885.00 €	173 €	216 €	264 €	315 €	372 €	437 €	506 €	584 €	670 €	766 €
Accumulated net cash flows	- 3,885 €	- 3,712 €	- 3,497 €	- 3,233 €	- 2,918 €	- 2,546 €	- 2,109 €	- 1,603 €	- 1,019 €	- 349 €	417 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Development of 10 kW high power DC-DC converter to integrate batteries of 100 kWh	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Development of power electronic converter interface to integrate wind turbine of 5 kW										
Incomes (€)	1,449 €	1,593 €	1,754 €	1,931 €	2,126 €	2,337 €	2,570 €	2,825 €	3,108 €	3,419 €
Operation and maintenance costs (€)	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €	- 389 €
Depreciation and amortization (€)	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €	- 194 €
Profit before taxes (€)	866 €	1,010 €	1,171 €	1,349 €	1,543 €	1,754 €	1,987 €	2,242 €	2,525 €	2,836 €
Deferred corporate taxes (€)	- 190 €	- 222 €	- 258 €	- 297 €	- 339 €	- 386 €	- 437 €	- 493 €	- 556 €	- 624 €
Net cash flow (€)	870 €	982 €	1,108 €	1,246 €	1,398 €	1,562 €	1,744 €	1,943 €	2,164 €	2,406 €
Accumulated net cash flows (€)	1,286 €	2,269 €	3,376 €	4,622 €	6,020 €	7,582 €	9,326 €	11,269 €	13,433 €	15,840 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	1,800.01 €
IRR (%)	13.814%
First positive accumulated cash flow	417
Payback (years)	Year 10

Table 15. Economic model for the ecoConverter Tool, including the cash flow model and a profitability analysis.

From the analysis described before, it is possible to obtain a net present value for the ecoConverter tool of €1,800 (with a discount rate of 10%), and an IRR of 13.814%.

The payback period is 10 years.

According to the cash flow model which is shown in Table 15, it is possible to obtain the cash flow diagram for the use of ecoConverter:

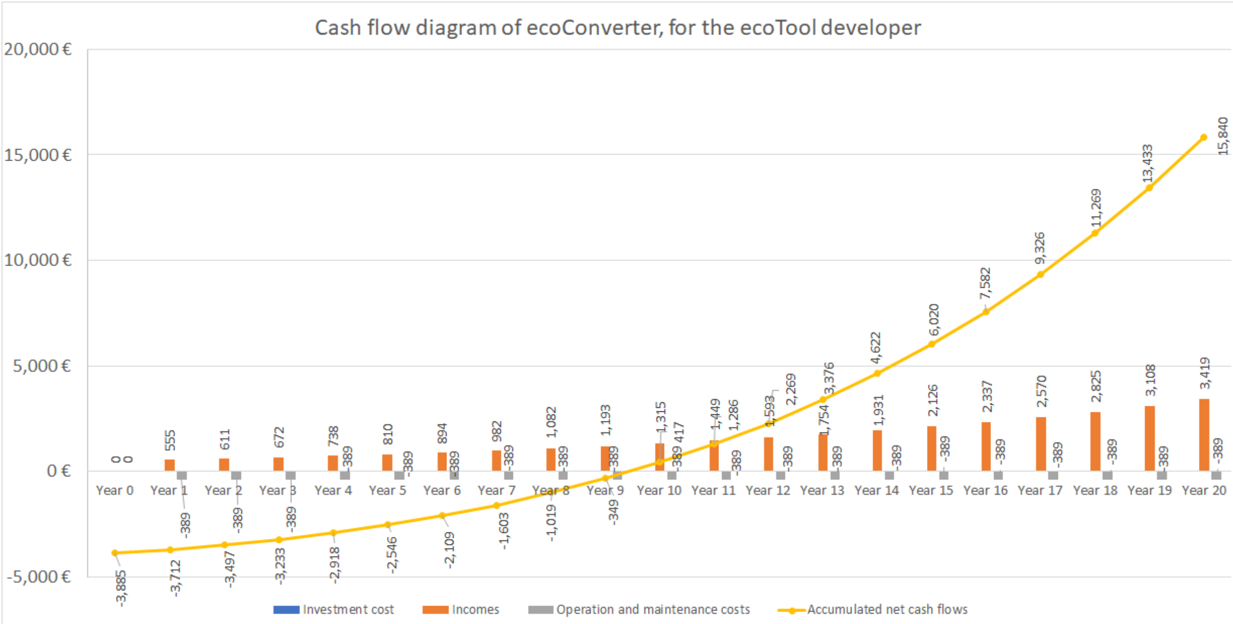

Figure 14. Cash flow diagram of ecoConverter

2.10 ecoVehicle

ecoVehicle is the tool related to the development of electric means of transport (land and marine), along with the needed charging infrastructure, power electronics and drive systems, in the two Indian Demo Sites: Ghoramara Island and Keonjhar Microgrid. ecoVehicle has been deployed for two different vehicles: electric three wheelers and small boats.

Two charging stations will be developed, one at Ghoramara island with three charging points at 1.5 kW each, and the other at the Keonjhar with two charging points at 1.5 kW each. In the case of Ghoramara Island, the objective is to facilitate the use of electric boats instead of fossil fuel boats for transport between the island of Ghoramara and nearby islands, such as Nayachar, Kakdwip, Haldia, Gangasagar, Dimond Harbour and others, around 10-60 km far from Ghoramara.

Apart from the e-Boat, four electric three wheelers or rickshaws will be deployed, with the objective of improving the local transportation.

From these systems, two electric three wheelers will be installed at the Keonjhar Demo Site, while the other two electric three wheelers and the electric boat will be installed at the Ghoramara island.

Based on the information provided by the ecoVehicle developer, the following economic models have been prepared. Firstly, the model for the Keonjhar Demo Site is described, and then, the model for Ghoramara Island.

The first economic model has been prepared for Keonjhar, and is based on the following information:

- Investment cost: To develop the ecoVehicle ecoTool, the following investment costs have been considered:
    - Purchase of 2 units of electric three wheelers. Each three wheeler costs ₹200,000, which is equivalent to €2,220.
    - Modification of the seating of the electric rickshaws and installation of the ecoVehicle tool set. ₹40,000, equivalent to €444.
    - Installation of one charging point for the electric rickshaws. ₹70,000. (€777)
    - Another charging point has already developed by VNIT, with a power of 1.5 kW, and a cost of ₹35,000 (€389).

  The total investment cost for ecoVehicle in Keonjhar amounts to ₹545,000, this is, €6,050.

- Incomes from the project: The business model for ecoVehicle involves the leasing of electric rickshaws by local users, for 1-day periods.

  The payments received for each e-3 wheeler are estimated to be ₹135,000 per year, equivalent to €1,498.50/year. Thus, the total incomes will be ₹270,000 per year. This price is expected to be increased by 10%.

- Estimated operation and maintenance costs: The following costs are expected for the ecoVehicle in the Keonjhar Demo Site:
    - Operation cost for the electric rickshaw: The electric rickshaw is expected to be charged once a day, from the charging station. The total electricity needed will be around 10 kWh/day (for the 2 electric rickshaws), with a total estimated cost of ₹100.

      Supposing that the electric rickshaws are used 300 days per year, then the total operation cost for these vehicles will amount to ₹30,000, this is, €333.
    - Maintenance cost for the battery of the electric rickshaws: The batteries have to be replaced each 4-5 years, with a total cost of ₹70,000 for each electric rickshaw.

      This involves that, each 5 years, the cost of replacing the batteries in Keonjhar will amount to €1,554.
    - Maintenance cost for the motor controller: Each electric rickshaw has a motor controller. It is estimated that it will be necessary to replace this device at least once during the expected lifetime of the rickshaw.

      The cost of each replacement will amount to ₹10,000, this is, €111. Since there are two electric rickshaws, then, in the year 10, there will be an expenditure of ₹20,000 (€222) to replace the motor controller.
- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €6,050, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €302/year.
- The corporate taxes are considered to be 22%.
- In the economic model, no financial costs are considered.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 6,050 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric rickshaw (2 units)	- 4,440 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Modification of seating of electric rickshaw and installation of the ecoTool set (2 units)	- 444 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
One charger for electric vehicle	- 777 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Developed charger of 1.5 kW	- 389 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes - Electric rickshaw (€)	- €	2,997 €	3,297 €	3,626 €	3,989 €	4,388 €	4,827 €	5,309 €	5,840 €	6,424 €	7,067 €
Operation and maintenance costs (€)	- €	- 333 €	- 333 €	- 333 €	- 333 €	- 1,887 €	- 333 €	- 333 €	- 333 €	- 333 €	- 2,109 €
Operation and maintenance costs - Electric rickshaw electricity (€)	- €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €
Operation and maintenance costs- Rickshaw battery replacement (€)	- €	- €	- €	- €	- €	- 1,554 €	- €	- €	- €	- €	- 1,554 €
Operation and maintenance costs- Rickshaw motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- 222 €
Depreciation and amortization (€)	- €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €
Profit before taxes (€)	- 6,050 €	2,362 €	2,661 €	2,991 €	3,354 €	2,198 €	4,191 €	4,674 €	5,205 €	5,789 €	4,655 €
Deferred corporate taxes (€)	- €	- 520 €	- 585 €	- 658 €	- 738 €	- 484 €	- 922 €	- 1,028 €	- 1,145 €	- 1,274 €	- 1,024 €
Net cash flow (€)	- 6,050 €	2,144 €	2,378 €	2,635 €	2,918 €	2,017 €	3,572 €	3,948 €	4,362 €	4,818 €	3,934 €
Accumulated net cash flows (€)	- 6,050 €	- 3,905 €	- 1,527 €	1,109 €	4,027 €	6,044 €	9,616 €	13,564 €	17,926 €	22,744 €	26,677 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric rickshaw (2 units)										
Modification of seating of electric rickshaw and installation of the ecoTool set (2 units)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
One charger for electric vehicle	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Developed charger of 1.5 kW	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes - Electric rickshaw (€)	7,773 €	8,551 €	9,406 €	10,346 €	11,381 €	12,519 €	13,771 €	15,148 €	16,663 €	18,329 €
Operation and maintenance costs (€)	- 333 €	- 333 €	- 333 €	- 333 €	- 1,887 €	- 333 €	- 333 €	- 333 €	- 333 €	- 1,887 €
Operation and maintenance costs - Electric rickshaw electricity (€)	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €
Operation and maintenance costs- Rickshaw battery replacement (€)	- €	- €	- €	- €	- 1,554 €	- €	- €	- €	- €	- 1,554 €
Operation and maintenance costs- Rickshaw motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Depreciation and amortization (€)	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €	- 302 €
Profit before taxes (€)	7,138 €	7,915 €	8,770 €	9,711 €	9,192 €	11,884 €	13,136 €	14,513 €	16,028 €	16,140 €
Deferred corporate taxes (€)	- 1,570 €	- 1,741 €	- 1,929 €	- 2,136 €	- 2,022 €	- 2,614 €	- 2,890 €	- 3,193 €	- 3,526 €	- 3,551 €
Net cash flow (€)	5,870 €	6,476 €	7,143 €	7,877 €	7,472 €	9,572 €	10,548 €	11,622 €	12,804 €	12,892 €
Accumulated net cash flows (€)	32,548 €	39,024 €	46,167 €	54,044 €	61,516 €	71,088 €	81,636 €	93,259 €	106,063 €	118,954 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	33,051.56 €
IRR (%)	44.679%
First positive accumulated cash flow	1,109
Payback (years)	Year 3

Table 16. Economic model for the ecoVehicle Tool in the Keonjhar Demo Site, including the cash flow model and a profitability analysis.

As can be seen, the business model proposed for the use of ecoVehicle in Keonjhar, involving two electric rickshaws, will have a net present value (with a discount rate of 10%) of €33,051.56, along 20 years, while the IRR will be 44.679%.

Additionally, the payback period is 3 years.

On the other hand, it is possible to obtain the cash flow diagram for the use of ecoVehicle in the Keonjhar Demo Site:

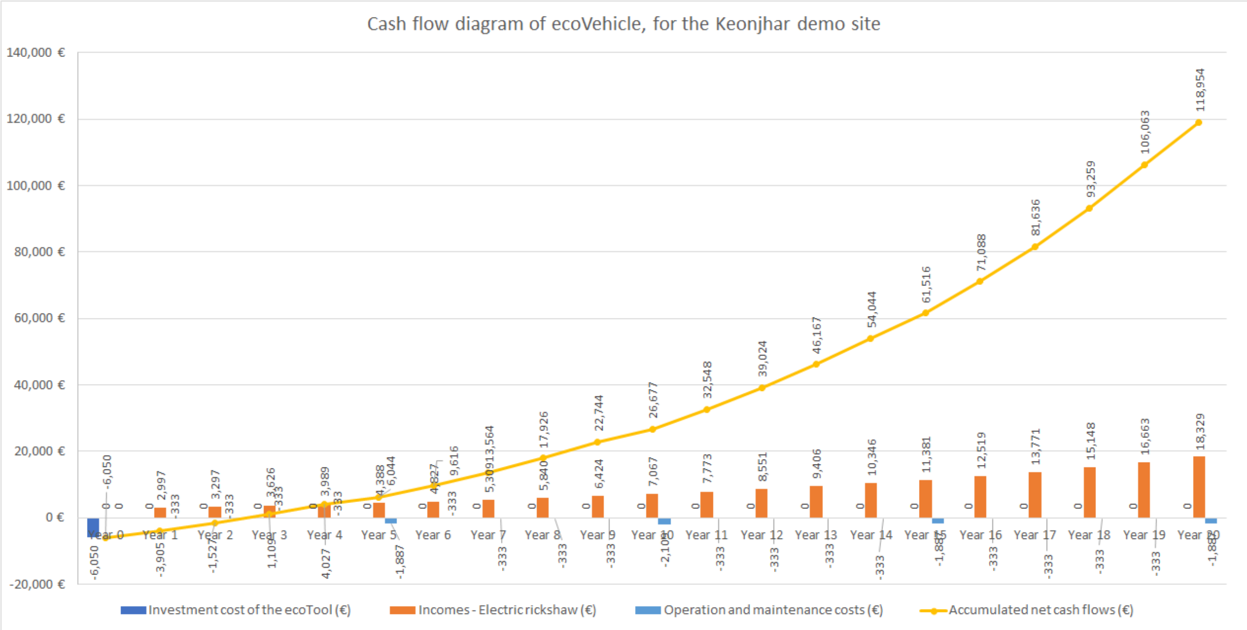

Figure 15. Cash flow diagram of ecoVehicle, for the Keonjhar Demo Site

Once the financial model for ecoVehicle in Keonjhar has been defined, it is possible to calculate the model for the Ghoramara Demo Site.

- Investment cost: To develop the ecoVehicle ecoTool, the following investment costs have been considered:
    - Purchase and modification of 2 units of electric three wheelers: ₹400,000, this is, €4,440.00.
    - Modification of the seating of the electric rickshaws and installation of the ecoVehicle tool set. ₹40,000, equivalent to €444.00.
    - Purchase of electric boat, able to carry 15-16 people: ₹4,000,000, this is, €44,400.
    - Installation of a solar PV plant for the charging station, including solar PV panels with a total peak power capacity of 12 kWp, battery storage with a capacity of 72 kWh, and an inverter (12.5 kVA). The total cost of such facility will amount to ₹140,000, this is, €1,554.
    - Installation of three 3.3 kW AC charging points for the electric rickshaws and electric boat. ₹200,000. (€2,220).
    - A 1.5 kW rated conventional DC charging point has already developed by VNIT, with a power of 1.5 kW, and a cost of ₹35,000 (€389).

  The total investment cost for ecoVehicle in Ghoramara amounts to ₹4,815,000, this is, €53,447.

- Incomes from the project: The business model for ecoVehicle involves the leasing of electric rickshaws by local users, for 1-day periods, and the leasing of the electric boat.

Considering a use of the electric boat of 2 round trips per day, and that each travel will have an average of 15 passengers, and that the tariff for using the electric boat will be ₹25 (€0.278) for each passenger, the total incomes per day will be ₹750 (€8,33). If the boat is used 300 days per year, the total incomes would be ₹273,750/year (€3,038.63/year).

Additionally, it has been estimated that the three e-3 wheelers will be used 30 times per day. The tariff to be paid by users will be ₹25/trip (€0.278). Finally, each e-3 wheeler will be used 300 days per year. Thus, the total incomes from the e-3 wheelers will amount to ₹225,000/year, or €2,497.50/year.

Besides, the fee is expected to increase by 10% each year.

- Estimated operation and maintenance costs: The following costs are expected for the ecoVehicle in the Ghoramara Demo Site:
  - Operation cost for the electric rickshaw: The electric rickshaw is expected to be charged once a day, from the charging station. As described in the financial model of the ecoVehicle in the Keonjhar Demo Site, the total operation cost will be ₹30,000, this, is €333 per year.
  - Maintenance cost for the battery of the electric rickshaws: Similarly to the Keonjhar Demo Site, it will be necessary to replace the batteries of the rickshaws each 4-5 years, at a cost of ₹70,000 for each electric rickshaw, this is, a total of €1,554.
  - Maintenance cost for the motor controller of the electric rickshaws: The cost of replacing the motor controller of the two electric rickshaws of Ghoramara will amount to ₹20,000 (€222), in the year 10.
  - Operation cost for the electric boat: It is expected that the electricity needed for the boat will come from solar PV panels installed in the roof of the electric boat, there will not be a cost related to the electricity consumption of the electric boat.
  - Maintenance cost for the battery of the electric boat: The expected useful lifetime of the battery of the electric boat will be, similarly to electric rickshaws, 4-5 years. Each replacement of the battery will have a cost of ₹120,000, this is, €1,332.
  - Maintenance cost for the motor controller of the electric boat: Electric boats have a motor controller which has a warranty period of 1 year. If 1 replacement of this element is forecast for the 20-years useful lifetime, the cost of this replacement will amount to ₹50,000, this is, €555.
  - Operation and maintenance cost of the solar PV plant: This cost will be of ₹41,667 (₹125,000 for the first 3 years), this is, €463 per year.
- Similarly to other financial and economic models, the depreciation and amortization cost is linear.

  Since the total investment cost is €53,447, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to 2,672 €/year.
- The corporate taxes are considered to be 22%.

- In the economic model, no financial costs are considered.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the ecoTool (€)	- 53,447 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric rickshaw (2 units)	- 4,440 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Modification of seating of electric rickshaw and installation of the ecoTool set (2 units)	- 444 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric boat	- 44,400 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Solar PV plant (12 kWp), battery storage (72 kWh), inverter (12.5 kVA)	- 1,554 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Three chargers for electric vehicle	- 2,220 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Developed charger of 1.5 kW	- 389 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€)	- €	5,536 €	6,090 €	6,699 €	7,369 €	8,105 €	8,916 €	9,808 €	10,788 €	11,867 €	13,054 €
Incomes- Electric boat (€)	- €	3,039 €	3,342 €	3,677 €	4,044 €	4,449 €	4,894 €	5,383 €	5,921 €	6,514 €	7,165 €
Incomes-Electric rickshaw (€)	- €	2,498 €	2,747 €	3,022 €	3,324 €	3,657 €	4,022 €	4,424 €	4,867 €	5,354 €	5,889 €
Operation and maintenance costs (€)	- €	- 796 €	- 796 €	- 796 €	- 796 €	- 3,682 €	- 796 €	- 796 €	- 796 €	- 796 €	- 4,459 €
Operation and maintenance costs - Electric rickshaw (€)	- €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €
Operation and maintenance costs- Boat battery replacement (€)	- €	- €	- €	- €	- €	- 1,332 €	- €	- €	- €	- €	- 1,332 €
Operation and maintenance costs- Boat motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- 555 €
Operation and maintenance costs- Rickshaw battery replacement (€)	- €	- €	- €	- €	- €	- 1,554 €	- €	- €	- €	- €	- 1,554 €
Operation and maintenance costs- Rickshaw motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- 222 €
Operation and maintenance solar PV plant	- €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €
Depreciation and amortization (€)	- €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €
Profit before taxes (€)	- €	2,068 €	2,622 €	3,231 €	3,901 €	1,752 €	5,448 €	6,340 €	7,321 €	8,399 €	5,923 €
Deferred corporate taxes (€)	- €	- 455 €	- 577 €	- 711 €	- 858 €	- 385 €	- 1,199 €	- 1,395 €	- 1,611 €	- 1,848 €	- 1,303 €
Net cash flow (€)	- 53,447 €	4,286 €	4,717 €	5,192 €	5,715 €	4,039 €	6,922 €	7,617 €	8,382 €	9,224 €	7,292 €
Accumulated net cash flows (€)	- 53,447 €	- 49,161 €	- 44,443 €	- 39,251 €	- 33,536 €	- 29,498 €	- 22,576 €	- 14,958 €	- 6,576 €	2,648 €	9,940 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the ecoTool (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric rickshaw (2 units)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Modification of seating of electric rickshaw and installation of the ecoTool set (2 units)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric boat	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Solar PV plant (12 kWp), battery storage (72 kWh), inverter (12.5 kVA)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Three chargers for electric vehicle	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Developed charger of 1.5 kW	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€)	14,359 €	15,795 €	17,375 €	19,112 €	21,023 €	23,126 €	25,438 €	27,982 €	30,780 €	33,858 €
Incomes- Electric boat (€)	7,881 €	8,670 €	9,537 €	10,490 €	11,539 €	12,693 €	13,962 €	15,359 €	16,895 €	18,584 €
Incomes-Electric rickshaw (€)	6,478 €	7,126 €	7,838 €	8,622 €	9,484 €	10,433 €	11,476 €	12,624 €	13,886 €	15,274 €
Operation and maintenance costs (€)	- 796 €	- 796 €	- 796 €	- 796 €	- 3,682 €	- 796 €	- 796 €	- 796 €	- 796 €	- 3,682 €
Operation and maintenance costs - Electric rickshaw (€)	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €	- 333 €
Operation and maintenance costs- Boat battery replacement (€)	- €	- €	- €	- €	- 1,332 €	- €	- €	- €	- €	- 1,332 €
Operation and maintenance costs- Boat motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Operation and maintenance costs- Rickshaw battery replacement (€)	- €	- €	- €	- €	- 1,554 €	- €	- €	- €	- €	- 1,554 €
Operation and maintenance costs- Rickshaw motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Operation and maintenance solar PV plant	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €	- 463 €
Depreciation and amortization (€)	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €	- 2,672 €
Profit before taxes (€)	10,891 €	12,327 €	13,907 €	15,644 €	14,670 €	19,658 €	21,971 €	24,514 €	27,313 €	27,505 €
Deferred corporate taxes (€)	- 2,396 €	- 2,712 €	- 3,060 €	- 3,442 €	- 3,227 €	- 4,325 €	- 4,834 €	- 5,393 €	- 6,009 €	- 6,051 €
Net cash flow (€)	11,168 €	12,288 €	13,520 €	14,875 €	14,115 €	18,006 €	19,809 €	21,794 €	23,976 €	24,126 €
Accumulated net cash flows (€)	21,108 €	33,395 €	46,915 €	61,790 €	75,905 €	93,910 €	113,720 €	135,513 €	159,489 €	183,615 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	21,415.66 €
IRR (%)	13.777%
First positive accumulated cash flow	2,648
Payback (years)	Year 9

Table 17. Economic model for the ecoVehicle Tool in the Ghoramara Demo Site, including the cash flow model and a profitability analysis.

The economic model of Ghoramara is profitable, having a net present value (with a discount rate of 10%) of €21,415.66, along 20 years. On the other hand, the IRR is 13.777%, and the payback period is 9 years.

On the other hand, the cash flow diagram for the Ghoramara Demo Site is as follows:

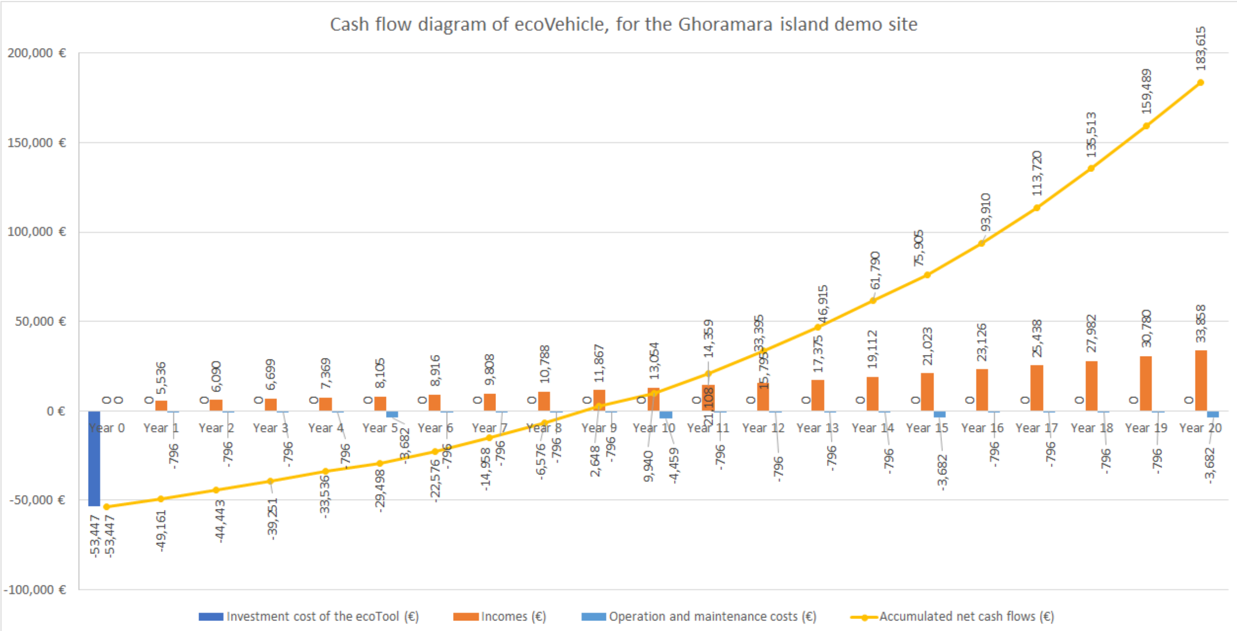

Figure 16. Cash flow diagram of ecoVehicle, for the Ghoramara Demo Site

3. Energy system and Business models applied in EU

In this chapter, the Demo Sites in the European Union which are considered in RE-EMPOWERED are described, and the most appropriate business models are proposed. Besides, an economic sustainability analysis is carried out, along with the selection of the available financing tools.

3.1 Bornholm Island: Denmark

The island of Bornholm is located in the Baltic Sea, South of Sweden, Northeast of Germany, and North of Poland.

Bornholm has a total population of 39,229 inhabitants in the second quarter of 2024[3], a surface of 588.36 km^2, and a coastline of 158 km. The Demo Site includes three towns in the eastern part of Bornholm, which are connected with a District Heating Network (DHN): Østerlars, Østermarie and Gudhjem, and the heat plant in Østerlars, that uses straw as fuel. The population of the Demo Site is 2,500 inhabitants, and its surface is 9.4 km^2.

The electricity access rate is 100%. In 2022, the average disposable income in the Bornholm Island reached DKK 226,145[4] (€30,393.89[5]), while for the whole country of Denmark, the average income was DKK 267,335 (€35,929.82). Similarly to the analysis carried out for 2020, the average income in Bornholm is below the total average for Denmark, being 84.59% of the Danish average.

Bornholm Regional Municipality is the sole local authority or “kommune" in the whole island. Until 2002, there were five different municipalities: Allinge-Gudhjem, Hasle, Nexø, Rønne and Aakirkeby, but on May 29th, 2001, they decided to merge into only one authority. Rønne is the largest city on the island.

3.1.1. Energy system and Business models in Denmark and Bornholm Island

Bornholm Island is not isolated, instead, there is a 60 kV AC submarine power cable which connects the island to the Scandinavian electricity grid. With a 60 MW transmission capacity, this cable can provide the island with all the electricity it needs.

However, the island counts on its own local resources to produce electricity, and can operate without the connection to the mainland, using the combined heat and power (CHP) plant in Rønne.

Local electricity production is based on biomass, wind, and solar PV. In 2022, the local generation covered 75% of the whole electricity consumption, with 63% of the consumption covered with renewable energies.

The following table includes the evolution of the power generation by power source, during the period 2009-2022:

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[3] Source: Statistics Denmark- Population at the first day of the quarter by marital status, age, sex, region and time.
[4] Source: Statistics Denmark- Average disposable income by age, municipality groups and time.
[5] Average Exchange rate for 2022: 1 DKK= 0.1344 €.

	2009		2017		2018	
Power source	kWh	%	kWh	%	kWh	%
Sea cable connected to the mainland	131,727,570	51%	80,499,920	33%	92,796,402	38%
Biogas	7,037,073	3%	8,361,740	3%	8,409,932	3%
Solar PV	7,500	0%	7,874,100	3%	22,159,993	9%
Wind	68,397,437	27%	91,573,898	37%	82,836,269	34%
Fossil fuel plants	47,295,854	18%	25,271,586	10%	13,707,766	6%
Wood chips plant	3,435,510	1%	32,135,281	13%	24,617,758	10%
Total	**257,900,944**	**100%**	**245,716,525**	**100%**	**244,528,120**	**100%**
	2019		2020		2022	
Power source	kWh	%	kWh	%	kWh	%
Sea cable connected to the mainland	73,551,904	30%	59,742,200	25%	57,434,124	25%
Biogas	7,790,708	3%	19,829,479	8%	15,966,351	7%
Solar PV	28,557,729	12%	30,442,370	13%	30,683,068	13%
Wind	96,707,674	40%	103,575,948	44%	82,564,203	36%
Fossil fuel power plant	8,011,661	3%	5,514,960	8%	15,648,746	13%
Wood chip power plant	28,325,628	12%	18,831,995	2%	29,043,588	7%
Total	**242,945,304**	**100%**	**237,936,952**	**100%**	**231,340,080**	**100%**

Table 18. Evolution of the power generation mix in Bornholm Island, for the years 2009, 2017, 2018, 2019, 2020 and 2022[6]

According to the available information, there has been an important shift from relying on the connection to the mainland, which covered 51% of the electricity generation in 2009, to being more independent. In 2022, this sea cable connection only supplied 25% of the electricity needs.

The following figure shows the breakdown of electricity generation in Bornholm in the last available year, 2022:

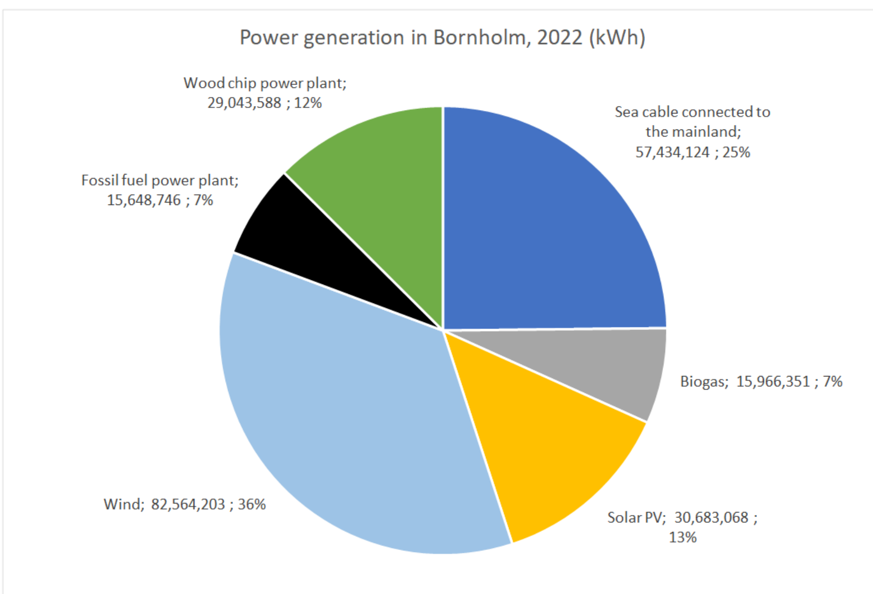

Figure 17. Breakdown of the power generation in Bornholm, year 2022[7]

[6] Source: Bornholms Varme A/S.
[7] Source: Bornholms Varme A/S.

As can be seen in the previous figure, in 2022, the main electricity generation source was wind power, with 36%. It was followed by the connection to the mainland, with 25%. Solar PV made 13% and the power production with the wood chip power plant a 12%.

Power generation with fossil fuels was only 7%, 15,648 GWh.

As for the heat generation in the island, the whole heat production system in Bornholm consists of:

- A 35 MW woodchip and straw fuelled combined heat and power plant.
- Decentralized district heating networks.

All urban areas can receive heat from these district heating plants.

The following table shows the evolution in the heat production in the Bornholm Island, for the period 2009-2022:

	2009		2017		2018	
Heat source	**kWh**	**%**	**kWh**	**%**	**kWh**	**%**
Wood chips heat plant	-	0%	56,000,000	16%	57,154,000	16%
Straw heat plant	48,600,000	14%	79,858,000	22%	85,798,000	24%
Waste (BOFA)	49,000,000	15%	49,000,000	14%	49,000,000	14%
Individual oil boilers	105,258,000	31%	25,094,000	7%	18,000,000	5%
Individual biomass boilers	25,000,000	7%	25,000,000	7%	25,000,000	7%
Fossil fuel power plant	101,677,850	30%	18,576,320	5%	29,128,974	8%
Wood chip power plant	8,244,150	2%	97,525,680	27%	83,774,026	24%
Biogas	-	0%	7,000,000	2%	7,265,000	2%
Total	**337,780,000**	**100%**	**358,054,000**	**100%**	**355,120,000**	**100%**
	2019		**2020**		**2022**	
Power source	**kWh**	**%**	**kWh**	**%**	**kWh**	**%**
Wood chips heat plant	64,555,000	18%	54,087,000	16%	53,131,100	15%
Straw heat plant	87,387,000	24%	81,306,000	24%	92,150,100	26%
Waste (BOFA)	47,733,611	13%	47,733,611	14%	50,421,556	14%
Individual oil boilers	15,000,000	4%	15,000,000	4%	15,000,000	4%
Individual biomass boilers	26,000,000	7%	26,000,000	8%	25,000,000	7%
Fossil fuel power plant	783,314	0%	765,028	0%	8,248,857	2%
Wood chip power plant	111,118,686	31%	100,513,527	30%	94,981,143	27%
Biogas	6,188,000	2%	14,733,000	4%	12,931,000	4%
Total	**358,765,611**	**100%**	**340,138,166**	**100%**	**351,863,756**	**100%**

Table 19. Evolution of the heat generation in Bornholm Island, for the years 2009, 2017, 2018, 2019, 2020 and 2022[8]

The table shows a clear change in the heat generation. In 2009, the wood chips heat plant had not been installed, and the most relevant heat sources were individual oil boilers and the fossil fuel power plant, which produced around 61% of the heat needs of the island.

Since 2017, the island has relied much more on the wood chips combined heat and power plant, which produces among 40% and 50% of the total heat needs of the island. Straw covers approximately 25% of the heat need.

[8] Source: Bornholms Varme A/S.

Finally, households have also decided to replace individual oil boilers for individual biomass boilers. Their needs have also been reduced due to connection to the district heating.

In the following figure, the breakdown of heat needs in Bornholm in 2022 is shown:

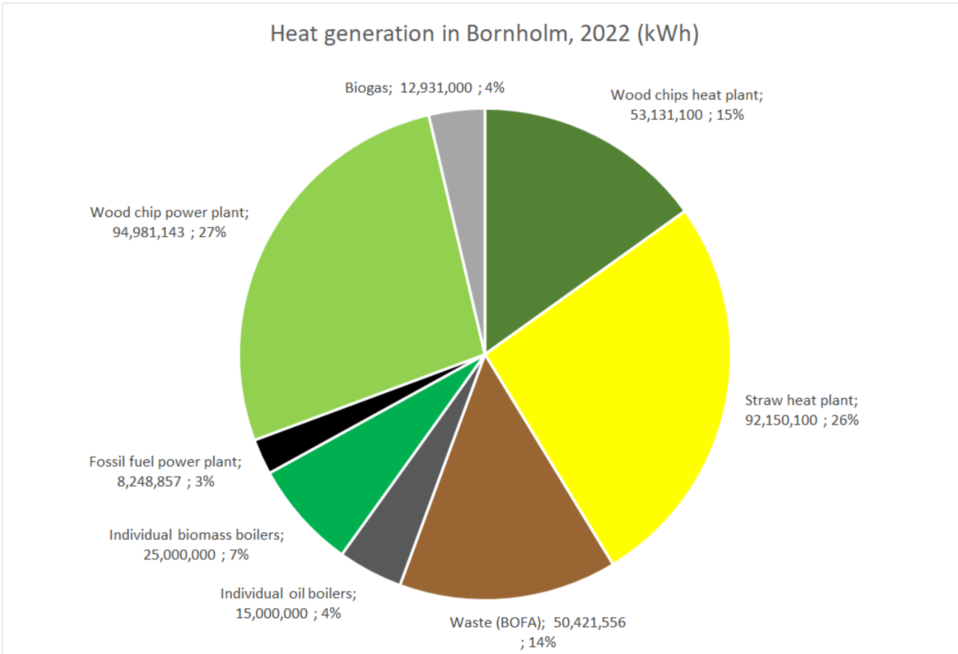

Figure 18. Breakdown of the heat generation in Bornholm, year 2022[9]

The Demo Site considered in the RE-EMPOWERED project focuses on three towns in the eastern part of Bornholm, namely Østerlars, Østermarie and Gudhjem. These three cities are connected in a district heating network (DHN), which provides heat to a total of 600 consumers.

The Demo Site district heating network consist of the following infrastructure:

- The Østerlars heat plant, including a 4 MW boiler fed with locally produced straw. The total production of the plant is around 18,000 MWh/year.
- Four electric boilers of a rated power of 0.6 MW (a total of 2.4 MW) for reserve and peak loads.
- 1-2 MW wood pellet boiler for backup.
- A 1,500 m^3 hot water storage tank, with a capacity of 80 MWh.
- 93 kW from rooftop solar PV.

The city of Gudhjem is connected to the heat plant by a 5.6 km high temperature transmission pipe (approximately 95°C). Water is distributed at a temperature of around 70°C, and returns at approximately 41°C.

[9] Source: Bornholms Varme A/S.

These plants generate the heat, which is fed into the local district heating network, as shown in the following graph:

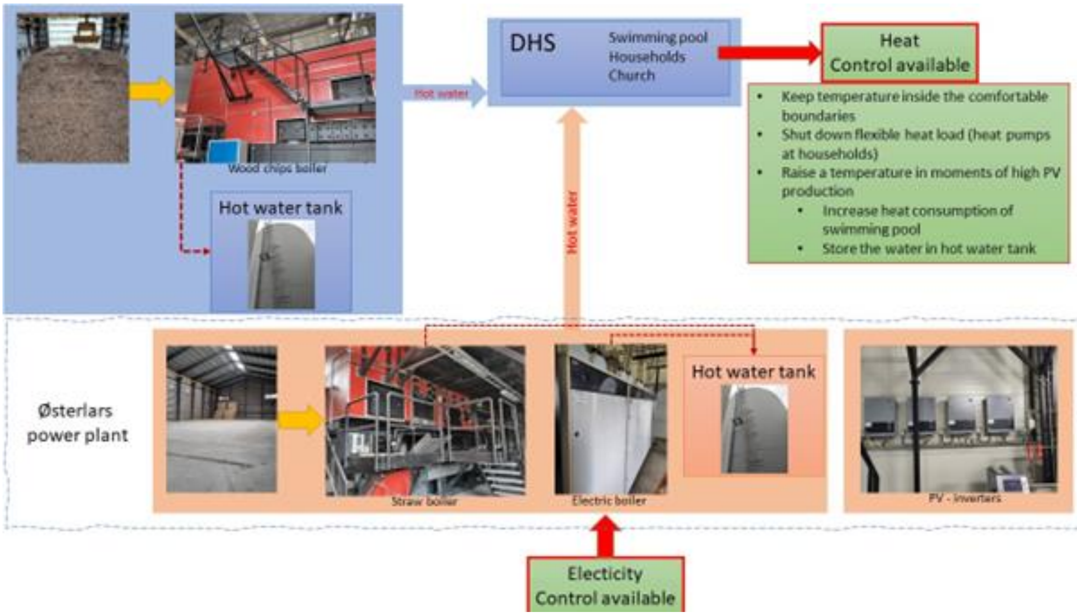

Figure 19. Heat production and storage units in Østerlars heat plant

The hot water produced by the district heating network is fed into the radiators or heat exchangers owned by consumers. The return water, which flows from the user to the heat source, is recirculated to the straw boiler and electric boilers to be heated again and goes back to the users. Besides, the combustion gases are cleaned in a bag filter, followed by a scrubber where the combustion gases are condensed by heat exchange from the district heating network. This involves that the temperature of the combustion gases is reduced to approximately 45 ^{o}C, and the temperature of the return from the district heating network is raised.

In moments when the heat demand is very high and cannot be met with the boilers, or the heat production is too low, the heat can be taken from the hot water storage tank. Alternatively, if the heat demand is low or the production is very high, the excess of heat can be stored in the hot water tank.

The electricity production in the Demo Site comes from the following plants:

- 93 kW of rooftop solar PV in the Østerlars heat plant.
- Two 10 MW_{DC} (7.5 MW_{AC}) solar PV plants near Østerlars, in Aakirkeby, connected to the grid. They make a total of 20 MW_{DC} and 15 MW_{AC} in inverter capacity. These power plants are owned by European Energy A/S, which has the operation and maintenance contract for the plants, and potential access to high quality production data from the two solar PV plants.
- 6 small solar PV plants between around 15 kW_{AC} and 325 kW_{AC}, owned by Bornholms Varme and its sister companies, for peak shaving and production-side flexibility.

- A new 20 MW solar PV plant near to the Østerlars heat plant is being planned. It will be built if the business case turns out to be positive.

Regarding the consumption side, Bornholm has a total energy demand of 900 GWh per year, including power, heat, and transport.

The local district heating and the woodchip and straw local combined heat and power plant are fed with large amounts of local biomass. In particular, heat and power plants on Bornholm use approximately 20,000 tonnes/year of straw and 50,000 tonnes/year of woodchips in total.

In the Demo Site, the total yearly energy consumption is as follows:

- Total heat yearly consumption: 18 GWh_{th}.
- Total heat yearly production: 18 GWh_{th}.
- Total fuel yearly consumption: 4,500 tonnes of straw.
- Estimated heat losses in the grid: Approximately 20%.
- Total power yearly consumption: 10-15 GWh_{e}.
- Total power yearly local production: 1 GWh_{e}.

The average electricity consumption of each family is around 4,000- 5,000 kWh/year, while the average heating consumption per house is around 15,000-20,000 kWh/year.

The Østerlars district heating network supplies around 600 consumers, which are mostly households, but also business, public buildings (such as schools), a church, and a swimming pool. The largest consumption is the use of hot water for room heating and hot water taps, by consumers.

The most relevant stakeholders of the energy sector in Bornholm are the following:

- DSO (Distribution System Operator): TREFOR El-Net Øst A/S
- TSO (Transmission System Operator): Energinet.dk. It is a state-owned company, responsible for ensuring the constant and reliable electricity supply through the transmission grid.
- Energy supplier:
  - Renewable electricity: European Energy A/S (20 MW solar PV plant), among others. For example, some of the 37 MW wind energy plants are owned by a subsidiary of Bornholms Energi & Forsyning A/S, while others are privately owned. There are also many small prosumers with distributed solar PV plants.
  - Electricity: Bornholms Energi A/S and other minor commercial suppliers.
  - Straw for the Østerlars heat plant: Local farmers.
- Heat producer: Bornholms Varme A/S operates the Demo Site heat production plant.
- Electric Mobility Manager: Several commercial actors.

- Heat Storage Manager: The hot water storage tank is operated by Bornholms Varme A/S.

Bornholms Energi & Forsyning Holding A/S (BEOF), translated as "Bornholms Energy and Supply" is a holding company which owns shares in independent companies, which respectively, are in charge of the power grid, electricity and heat production in Bornholm, as well as the water and hot water supply, and the management of wastewater. The companies which make part of the holding are[10]:

- Bornholms Energi & Forsyning A/S: This company offers services to other companies of the holding group, and carries out commercial activities related to the Bornholms Energi & Forsyning core competencies, related to energy products and services. It also provides services to Bornholm Regional Municipality.
- Bornholm Energi A/S: This branch supplies and commercializes electricity in Bornholm.
- Bornholm El-Produktion A/S: This company sells and buys electricity in the Nordic wholesale market, using the cable connection with the mainland. It also has an agreement with Energinet.dk to supply reserve capacity and regulating power.

  Besides, it also operates the fossil fuel plants which generate electricity for the Bornholm Island if the electricity supply through the power cable connected to Sweden is cut, or is reduced. It also can be asked to produce an additional amount of electricity using these power plants, if other large electricity suppliers in Nordpool have any problems to produce electricity.
- Bornholms Vand A/S: It is in charge of the water supply to Bornholm citizens and businesses, including the extraction, distribution and sale of water in the Bornholm Regionskommune. It supplies water to around 12,000 households and businesses.
- Bornholms Varme A/S: This company oversees the heat supply to households and businesses in the Bornholm Regionskommune. It operates both the heat production plant, and the hot water storage tanks.
- Bornholms Spildevand A/S: It owns, operates and maintains the public sewers, treatment plants, etc., in the municipality. The company has to carry out the construction projects and operational tasks related to the public wastewater facilities, according to the wastewater management plan.

Bornholm island has plenty of renewable energy resources. Indeed, it is proposed to use a combination of four energy vectors: biomass, district heating, electricity, and transport, to maximize the use of renewable energy.

The district heating operated by Bornholms Varme A/S can use biomass (local woodchips, straw, and manure) to produce heat and electricity. Electricity can be used to produce heat when the

[10] Source: Bornholms Energi & Forsyning. Selskaber & bestyrelser. Website: https://www.beof.dk/om-os-1/organisation

production from solar PV plants is higher with electric boilers, heat pumps, and in the future, P2X-production.

Besides, electricity can be used in transport, using electric cars and ships.

3.1.2. Access and cost of energy supply in Bornholm Island

Bornholm citizens and businesses have a good access to electricity, and 100% of the population and businesses have a continuous and stable electricity and heat supply. Although Bornholm is an island, there exists a 60 kV AC submarine cable which connects the Bornholm Island with the Scandinavian grid, ensuring that, if the local electricity generation in the island is lower (e.g., due to a reduction in the wind or solar PV resource), the electricity demand can be covered by increasing electricity imports from Sweden, through the sea cable. Besides, Sweden has connections by cable to the surrounding countries, namely, Norway, England, the Netherlands and Germany.

Despite having the connection to the mainland, the Bornholm Island is also prepared to work in “island mode”. This means that, if the supply from Sweden is disrupted, due to a breakdown in the sea cable or any other reason, the local energy production units in Bornholm can increase the power generation, and avoid any power shortage.

As the Bornholm Island is expected to increase the installed renewable energy capacity, and, ultimately, is trying to become into a carbon-neutral island by 2025, it will lack firm power capacity, based on fossil fuels, to adapt the generation to the demand, not relying only on wind and solar PV production. For this reason, the RE-EMPOWERED project has tested the ecoTool set.

Regarding electricity prices, the electricity market in Denmark, and in the Bornholm Island, is totally liberalized. There are different electricity retail companies, which define their own tariffs. Each consumer can select a supplier and a contract, and change it if wished. For instance, it is possible to select a fixed price, or a price depending on the hourly spot price. There is not any subsidization of electricity prices in the country. In Bornholm Island, most consumers purchase electricity to the local provider, Bornholms Energi A/S. On average, 95% of the electricity bill depends on the consumption (variable term), what encourages consumers to optimize electricity consumption.

There is also a separate DSO tariff, offered by TREFOR El-Net Øst, which is independent from the supplier, and which depends only on the type of customer, and how it is connected to the electricity grid.

In the following figure, it is possible to analyse the evolution of the prices for domestic consumers in Denmark, compared to the European Union, and two neighbouring countries: Germany and Sweden, during the period 2007-2023. In this case, the comparison considers consumers with a band of consumption between 2,500 and 5,000 kWh per year, which are the most common ones.

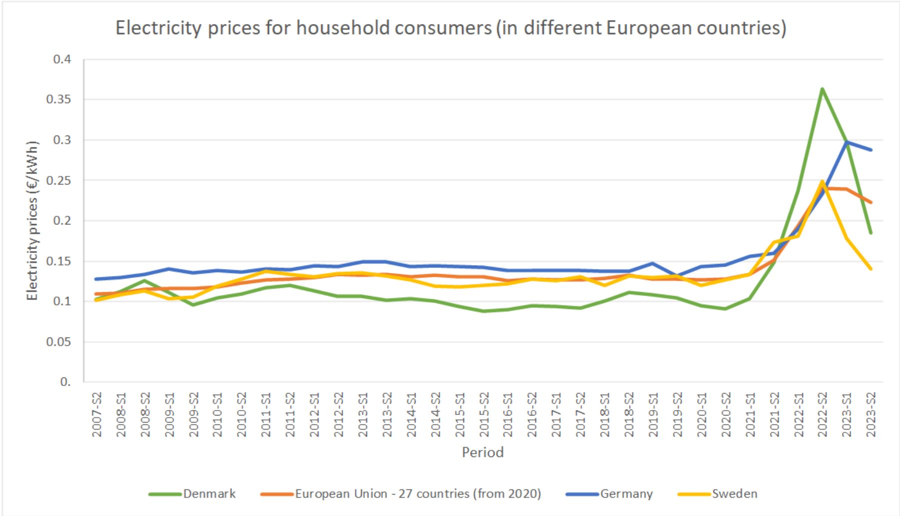

Figure 20. Evolution of the electricity prices for household consumers in Denmark and other European countries (Eurostat, 2024).

Electricity prices for household consumers in Denmark were lower than the average of the European Union until the second semester of 2021. However, they reached a maximum in the second semester of 2022, when they peaked to €0.3636/kWh, among the highest in all the European Union (only Belgium, Ireland and Greece had higher prices). Since then, the price has gone down, by 49% between 2022 and 2023. The last available price is for the second semester of 2023, when it reached €0.1846/kWh. This price is 83% of the average European Union price.

The differences between the electricity prices in the countries are mainly driven by subsidies and allowances offered to household consumers in each country. Besides, the increase in the energy and supply costs specially affected Denmark, and for this reason, the electricity prices in the country grew more than in other zones.

The following graph shows the evolution of the electricity prices for different levels of consumption for household consumers in Denmark:

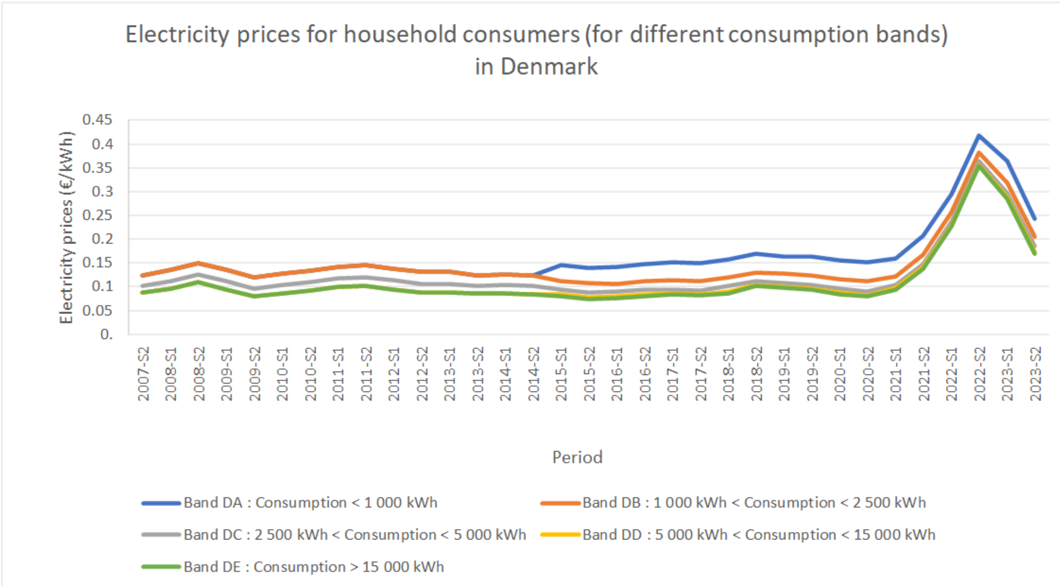

Figure 21. Evolution of the electricity prices for different consumption bands of household consumers in Denmark[11] (Eurostat, 2024).

As can be seen from Figure 21, the evolution of prices for all consumption bands is similar, and depends on the wholesale markets. Generally, consumers which are in the bands with the highest consumption (above 15,000 kWh/year) can obtain lower prices per kWh of electricity, as they are offered better prices. The consumption band of less than 1,000 kWh/year has the highest prices, with a difference of approximately €7 cents/kWh compared to the highest consumption band.

Prices went up sharply since the second half of 2021, reaching a maximum in the second semester of 2022, and going down since then. The absolute increase in all prices was similar, around €26 cents/kWh in this period. This means that, in percentage, the increase in price has been higher for the consumers with highest consumption levels (prices in 2022 were 257% of the prices in 2021 for consumers with a consumption higher than 15,000 kWh/year), while for the consumers with the highest price and the lowest consumption, the increase was 202%, from €0.2066/kWh in the first semester of 2021, to €0.4173/kWh in the second semester of 2022. Prices at the end of 2023 were still between 60% and 90% higher than the average prices until 2021.

In general, the final electricity prices for the consumers include different components, such as the energy and supply, the network cost, the renewable taxes, capacity taxes, environmental taxes, and so on. Some of these costs are higher for the lower-level consumption clients, which explains that the prices for the bands with the lowest consumptions have higher prices per kWh.

[11] Note: Until 2015, there were only three different consumption bands: consumption lower than 2,500 kWh/year, consumption band between 2,500 kWh/year and 5,000 kWh/year, and consumption higher than 5,000 kWh/year. This changed in 2015, and for this reason the band DA and DB merge until the first semester of 2015, as the bands DD and DE do.

The following figure includes the same analysis, for the electricity prices for industrial consumers in different countries. The following graph has been elaborated for industrial consumers with a level of consumption between 20,000 and 70,000 kWh/year.

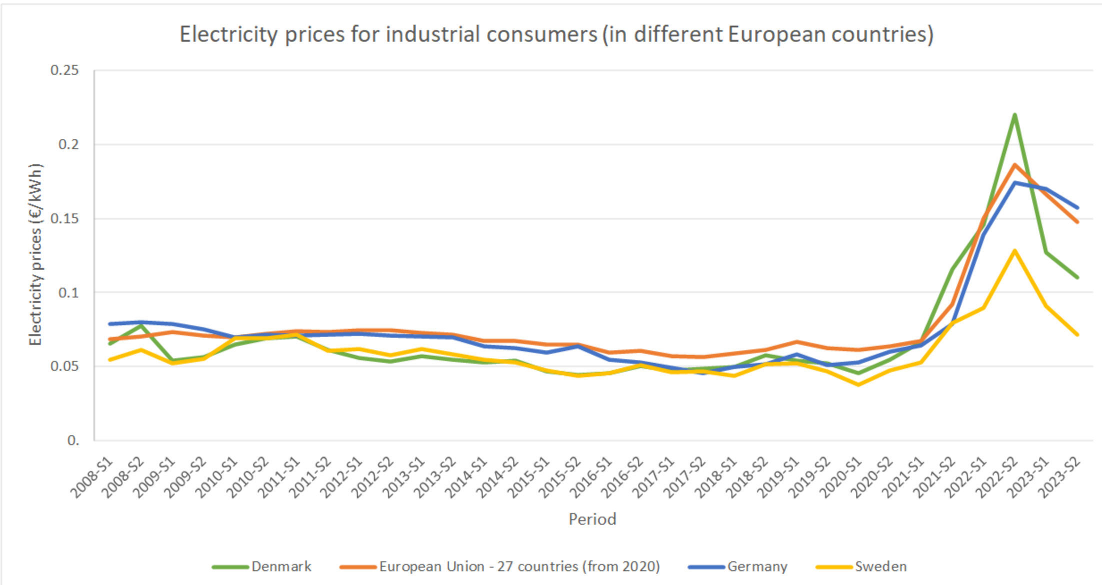

Figure 22. Evolution of the electricity prices for industrial consumers in Denmark and other European countries (Eurostat, 2024).

Historically, the electricity price in Denmark was coupled with the price in Sweden, and was lower than the average price of the European Union, specially between 2011 and 2020. However, in the first semester of 2021 the price in Denmark went up to €0.1154/kWh, with a difference of €0.023/kWh compared to the average European price. In the second semester of 2022, the Danish electricity price reached a maximum of €0.220/kWh, 18% higher than the average European price. Since then, the price has halved, and in the second semester of 2023, it was €0.110/kWh, far less than the European Union average (€0.1479/kWh).

The following graph includes the analysis of the evolution of electricity prices for industrial consumers, in Denmark, for different consumption bands. In general terms, the evolution is parallel to prices for domestic consumers, although tariffs present bigger variations. The level of prices is considerably lower than for domestic consumers, being generally below €0.10/kWh. Even in the second semester of 2022, when prices peaked, the maximum prices were below €0.35/kWh.

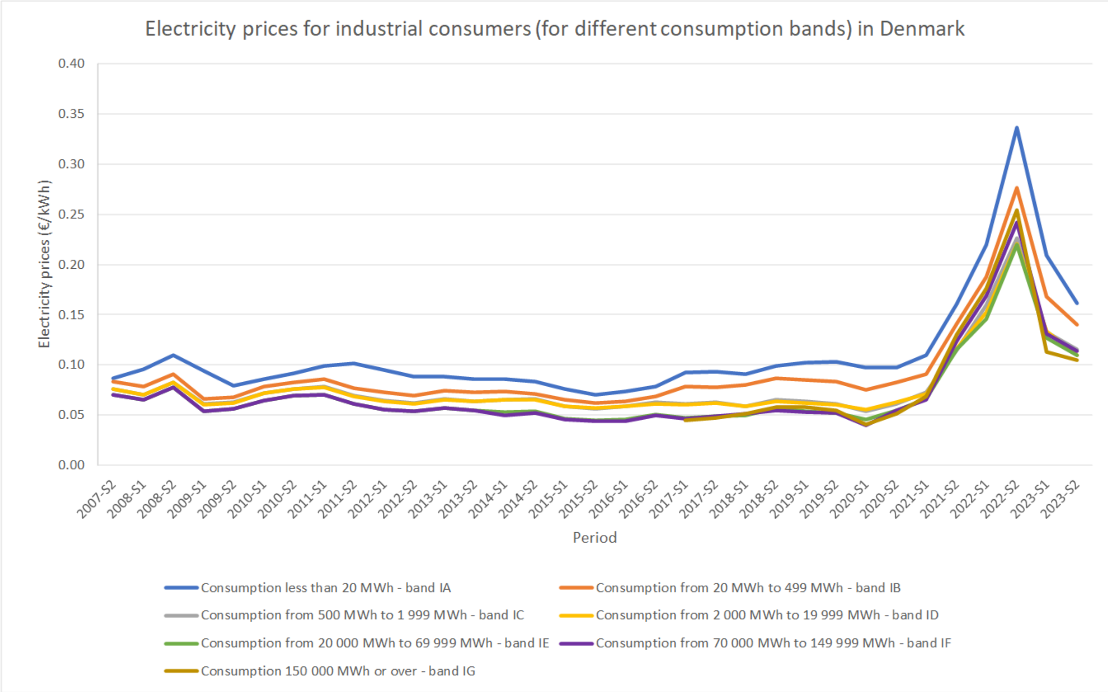

Figure 23. Evolution of the electricity prices for different consumption bands of industrial consumers in Denmark (Eurostat, 2024).

Between the second semester of 2021 and the second semester of 2022, prices for industrial consumers have doubled, which raised relevant concerns between industrial users. The prices which have grown the most correspond to the lowest consumption levels, which reached €0.3363/kWh, with an increase of €0.1756/kWh compared to 2021. During 2023, prices went down again, to prices between €0.10 and €0.16/kWh. However, they are still between €0.04 and €0.07/kWh higher than the average price between 2007 and the first semester of 2021.

3.1.3. Use of the ecoTools in Bornholm Island

The objective of the Demo Site is to analyse ways to increase the penetration of renewable energies, in a community which currently uses a high amount of renewable energy. For this purpose, the electric boilers and the solar PV production will be integrated, in such a way that the excess of electricity production from the solar PV plant will be used in the electric boilers to produce heat. This will demonstrate that it is possible to use the excess of electricity produced with the solar PV plants balancing the excess electricity generation and the use of electric boilers. When the district heating network has lower consumption of heat, the excess heat can be stored in the hot water storage tank.

This design will be used, if results to be successful, to more intelligently control a hypothetical solar PV plant which would be connected “behind the meter” to the electric boilers.

The Demo Site will use the following ecoTools: ecoPlatform, ecoEMS, ecoCommunity, ecoMonitor and ecoDR.

<u>Mapping UCs and, ecoTools in Bornholm Island</u>

The following table includes a summary of the Use Cases which have been developed in WP02, associated with each ecoTool, for demonstration and deployment. Detailed information can be found in Deliverable 2.1: Report on requirements for each demo, use cases and KPIs definition

The table includes the Use Cases which will be applied in the Bornholm Demo Site, and the proposed business models.

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Association with New BM
ecoEMS	EMS_1UC1	Real time monitoring and system data visualization	EMS_2UC1.1	Real time system monitoring and data acquisition and visualization	Demand response mechanism
			EMS_2UC1.2	Module manager: intercommunications and data exchange	
	EMS_1UC2	Forecasts, Unit Commitment, Economic Dispatch, Multi-optimization	EMS_2UC2.1	Mid-term and short-term RES and load forecasting	Use of the district heating and electric boilers to store energy
			EMS_2UC2.2	Forecasting model training	
			EMS_2UC2.3	Unit Commitment and Economic Dispatch algorithms	
			EMS_2UC2.4	Multi-energy vector management of operation	
ecoDR	DR_1UC1	Increased energy monitoring at demand side	DR_2UC1.1	Real time monitoring of energy consumption	Demand response mechanisms
ecoPlatform	PT_1UC1	Microgrid data acquisition	PT_2UC1.1	Connect to sensors and acquire data through designated communication networks and protocols	Flexible demand mechanisms
			PT_2UC1.2	Data cleansing to ensure consistency and human machine interface	
	PT_1UC2	Platform as a service for dependent tools integration	PT_2UC2.1	Facilitate data exchange between dependent tools	
			PT_2UC2.2	Facilitate access to controllable assets for dependent tools	
	PT_1UC3	Data storage and cloud server	PT_1UC3.1	Route the microgrid data and data from dependent tools to cloud database	
			PT_1UC3.2	Facilitate archived data access for dependent tools using API	
ecoMonitor	MON_1UC1	Drinking water quality surveillance	MON_2UC1.1	Acquisition and monitoring of water quality	
			MON_2UC1.2	Data processing and evaluation	
ecoCommunity	CM_1UC3	Outreach forum	CM_2UC3.1	Feedback and suggestions from users about the tools	Flexible demand mechanisms
			CM_2UC3.2	Reporting of problems	
			CM_2UC3.3	Forum to share experiences	
	CM_1UC4	Guidance and Training	CM_2UC4.1	Training material (troubleshooting)	
			CM_2UC4.2	Easy-to-use multimedia material and step-by-step guides (walkthroughs)	

Table 20. Association of ecoTools and UCs in the Bornholm Island Demo Site: RE-EMPOWERED

3.1.4. Business Canvas and proposed Business Models

The objective of the Demo Site is to leverage flexibility in all parts of the energy system of Bornholm, increasing the share of renewable energy sources. This will be obtained by increasing the use of electricity by the district heating, to replace heat production from fossil fuels and biomass for electricity produced with solar PV plants and, in the future, offshore wind energy. As the solar PV and wind power capacity increases in the island of Bornholm, it is expected that the electricity production will be used to produce heat. Besides, a demand-side management mechanism will be applied to move or reduce peak demand.

To do this, it is necessary to ensure that the electricity production and demand are balanced. In these cases, the electric boilers will be used to produce heat from electricity in these moments when production is higher. The use of the forecast demand, flexible storage and integration of prosumers will be key to reach these objectives.

In the Bornholm Demo Site, Bornholms Varme A/S is analysing the possibility to use the heat produced by electric boilers when electricity spot prices and grid fees are lower, and when the renewable energy production is higher.

To forecast when there will be the lowest spot prices, to produce heat from the electric boilers, it is necessary to have an advanced control of district heating systems, ensuring that the heat produced from electric boilers when electricity prices are lower can be totally stored.

Electric boilers are very flexible, cheap to be installed, have low operation and maintenance costs, and need for limited space.

When the spot electricity price is lower (or electricity production from renewable energy plants is higher), then the electric boilers inject heat into the accumulation tanks (both in the 1,500 m^3-80 MWh tank at the Østerlars heat plant, and in each of the 100 litres hot water storage water tanks installed by most district heating consumers). Demand response measures can be also applied, offering a price discount to these customers which are able to adapt their consumption to the surpluses of renewable energy generation.

A new demand response measure which has been developed in the Demo Site is the installation of the Neogrid IoT devices, which have been installed at each demo participating in the RE-EMPOWERED project. These systems are used to schedule heating loads and heat storage with a defined programme and intelligently. They will be used to absorb the excess solar PV production, by switching on electric boilers when the electric generation is higher.

The following business canvas has been defined for Bornholm Island, in Denmark.

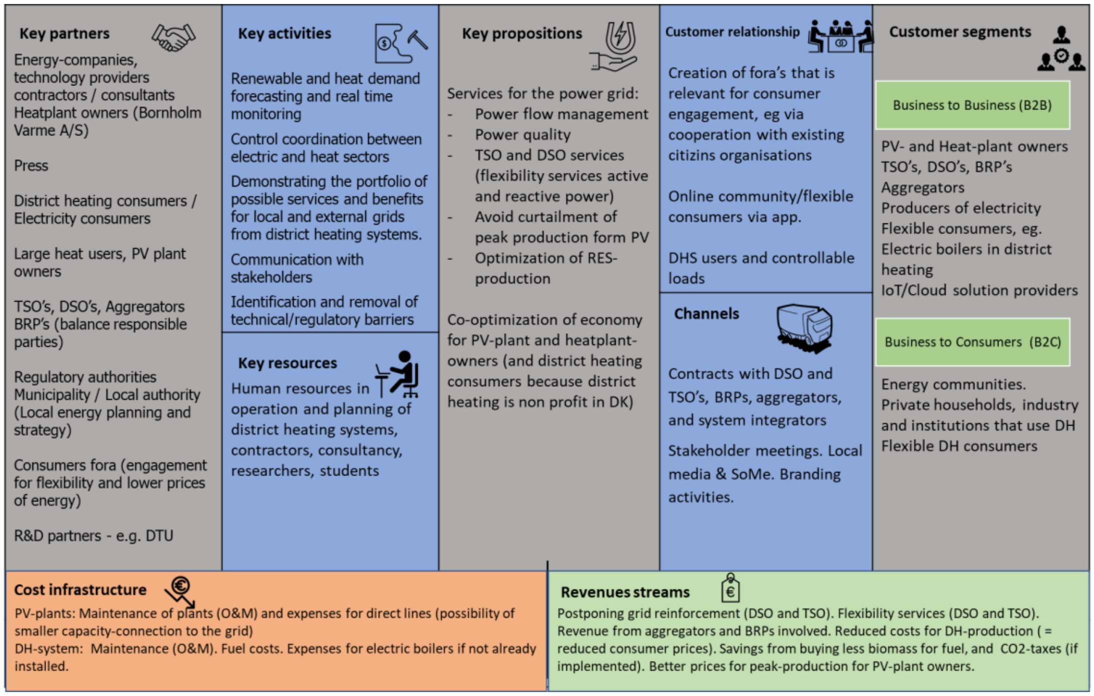

Figure 24. Proposed business canvas to Bornholm Demo Site

Proposed business model

The replacement of biomass to produce heat for electricity is profitable depending on the price of both energy vectors: biomass and electricity.

According to the estimations of Bornholms Varme A/S, the price of straw for the district heating boiler is around €17.9/MWh. This price is obtained considering a price of approximately €75/tonne of straw, and a net heat value of the straw of 4.2 MWh/tonne of straw.

On the other hand, the price of electricity used to produce heat with the electric boilers is around 250 DKK/MWh, made up by the following concepts:

Part of electricity price	DKK/MWh	€/MWh	Note
Spot price	50	6.70	Based on Nordpool. In 2020, minimum price: -318 DKK/MWh, maximum price: 1,894 DKK/MWh
Retail price	5	0.67	Estimate for large consumer
TSO fee/tariff	110	14.74	For 2021, from Energinet.dk
DSO fee/tariff	66	8.84	For 2021, from Trefor El-Net Øst, B-high, low price
Energy tax	4	0.54	For 2021
Total	246	31.49	

Table 21. Average electricity price in Bornholm

This involves that, in general, the heat generation from electric boilers is considerably more expensive than the use of straw boilers, so it is not competitive to produce heat with electricity instead of straw.

However, it is possible to propose a number of different alternatives to make electricity cheaper, and to allow to enhance the integration of renewable energies in the Bornholm energy system.

- The first alternative would be to use the 2.4 MW electric boilers to offer balancing services for the TSO, receiving payments for this. If Bornholms Varme A/S can receive payments for these services, then the electricity price of using the electric boilers would be balanced with the payments received.

  Bornholms Varme A/S began with this service in 2022, cooperating with the aggregator Nordic Power Balance. In that case, Bornholm Varme A/S only has to offer the capacity to switch on the electric boilers to offer frequency down-regulation services, in the FCR-D (frequency containment reserve for disturbances) market in the East Denmark grid (DK2).

  In practice, the electric boilers are only switched on for short bursts at a time, with a minimum electricity consumption. This means that the electricity consumption would be low, compared to the payments received from the frequency down-regulation services offered by Bornholms Varme A/S.

- A relevant component of the electricity prices are the TSO and DSO tariffs, which reached €23.59/MWh in 2020, this is, around 75% of the electricity price. If the solar PV plants sell the electricity directly to the district heating, using a power purchase agreement, and the district heating is directly connected to the plants, then the TSO and DSO tariffs are not charged for the electricity.

Thus, an appropriate business model to make the solar PV plants (and offshore wind farms) more profitable would be to avoid selling the electricity directly to the wholesale market. In that case, the consumer (Bornholms Varme A/S, owner of the district heating plant) would not be charged with the TSO and DSO fees.

Using a power purchase agreement between the solar PV or offshore wind farm owner, and Bornholms Varme A/S, it would be possible to define an electricity price, between the spot price and the retail price. This would lead to higher incomes for the solar PV or offshore wind farm owner, while the expenses in electricity by Bornholms Varme A/S would be reduced. The cost of the connection of the solar PV or offshore wind farm to the district heating could be paid by the solar PV or offshore wind farm developer, or shared with Bornholms Varme A/S.

To do so, it is essential to match the electricity demand by Bornholms Varme A/S, and the production of European Energy A/S, main owner of the solar PV plants. This production-consumption matching can be carried out using different models:

- It can be difficult to adapt the electricity production from solar PV and the future offshore wind farms, which depends on the availability of variable renewable energy resources, to the consumption.

The district heating network and the accumulation hot water tanks can be used as an energy storage system. If the electricity production is higher than the consumption, the renewable energy plants have two options: to sell the electricity to the wholesale market, or to use it in the electric boilers to produce heat and storage it in the district heating network.

- Besides, the use of the electricity generation by renewable energy sources (solar PV, the future offshore wind farms) to produce heat which is stored in the district heating network can reduce renewable energy curtailment, maximizing the use of electricity when generation exceeds demand.
- Another alternative is to adapt the hours when the district heating network provides the clients with heat. Instead of fixed hours, the system can increase the heat supply when the electricity generation is higher than the electricity consumption. Heat can be directly provided by the electric boilers, using the electricity surpluses. At the same time, the heat supply would be reduced when the electricity production is lower.
- Additionally, demand response mechanisms can be developed. The electricity consumption profile of clients can be adapted to the availability of electricity generated from solar PV and offshore wind plants. This would reduce electricity production surpluses, and would flatten peak demands (peak-shaving).

The combination of all these measures can lead to a minimization of the operation cost, using electricity generation to produce heat when prices or demand are lower, and having an alternative to store excess renewable electricity generation.

Finally, the new renewable energy plants can be used to offer services to the electricity grid, including flexibility services (active demand services) and reactive power services (from large solar PV inverters).

Community engagement

To reach the expected objectives of the Bornholm Demo Site, it is essential to reach a high participation by the citizens, which will be, ultimately, the beneficiaries of the tools which will be developed in the RE-EMPOWERED project.

First of all, it is necessary to remark that Danish citizens are highly committed to sustainable development, and that they have shown a certain willingness-to-pay (WTP) if the electricity comes from renewable energies.

It can be also mentioned that, in Denmark, there are not public grants which encourage citizens to install renewable energies or to take energy efficiency measures in their homes. In general, citizens are very aware of the need to reduce the greenhouse gas emissions derived from energy use, and make these investments by themselves. This is also derived from the fact that around 95% of the energy bills depends on the energy consumption.

In Denmark, the electricity market is totally liberalized, and each citizen can choose the provider. Some of the electricity suppliers offer to their clients electricity with renewable energy origin certificates. In some cases, these electricity tariffs are higher than that offered by large investor-owned companies. Some individuals can have pro-environmental attitudes and decide to pay the difference, whenever they are guaranteed that the electricity comes from renewable energy sources, and this behaviour can be encouraged by public environmental awareness campaigns. These campaigns can be also focused on the local production of the electricity, in local energy projects, or in utilities owned by local bodies.

The objective of RE-EMPOWERED is to show that it is possible to create flexibility in both the heat and the power grids, involving citizens and the community to participate in the project.

The future evolution of the electricity prices in Denmark is very important to ensure the success of the project. Since one of the objectives of the Demo Site is to electrify the heat production, and to inject this heat into the heat grid, the electricity price should remain at a cost that it is competitive compared to the use of biomass.

All the district heating consumers have digital smart meters, which allow them to take detailed information about consumption, temperatures, and flow in the network, not only for electricity, but also for heat and water consumption. All consumers also have hot water storage tanks, with a capacity of at least 100 litres. In Gudhjem, all consumers have a Danfoss ECL2010 computer installed, which controls the charging of the hot water tanks, and the temperature of the entering water to the household radiator system. This also ensures to keep pipe dimensions as reduced as possible.

In the Demo Site tests, some consumers have been engaged for the demonstration, and the already installed Danfoss ECL computer has been upgraded with remote controls, using the Neogrid IoT devices to provide access for demand-response, for balancing heat input from solar PV via electric boilers. Two large consumers are already engaged: the public indoor swimming pool in Gudhjem and the local schools in Østerlars.

The biggest obstacle in the Demo Site of Bornholm is the limited capacity of the sea cable which connects Bornholm to the mainland. The future development of new solar PV and offshore wind capacity in the island can lead to a reduction of the firm power capacity, so it is key to develop robust, local sources of flexibility. This can lead to problems when the electricity production is lower, or, alternatively, if the renewable generation is too high, the surpluses could not be exported to Sweden.

It can be also mentioned that there are plans to develop, by 2030, an Energy Island in Bornholm. This island will take the electricity output of 3 GW of offshore wind farms located in the Baltic Sea, at 15 kilometres approximately south-southwest of the Bornholm Island. The electrical current will be transformed into direct current, and transported over long distances in sea and land cables, to Zealand and Germany.

The onshore substation will be located approximately one kilometre south of Nylars, Lodbæk and Aakirkeby, in the Bornholm Island. Bornholm Energy Island will be one of the largest construction projects in the history of Denmark, and will be used to test the idea of energy islands in the North Sea. The final objective of these projects is to transform the power generated in offshore wind farms into other energy sources (Power-to-X).

Other important issue is the ability of consumers to participate in flexible demand management systems. Consumers can decide to participate in such systems, and to adapt their consumption patterns to the availability of electricity generation by renewable energy sources.

Key partners which should be taken into account in the business model

The following is a list of the main stakeholders in Bornholm which have a role in the defined business model:

- Bornholm Varme A/S, owner of the district heating plant.
- Energy companies (European Energy A/S).
- Technology providers and contractors, such as Neogrid A/S and Verdo.
- Consultants.
- Press.
- District heating consumers: Citizens who can be offered to participate in a flexible market, to adapt their heat consumption to moments when the electricity generation is higher.
- Electricity consumers: Demand response mechanisms can be developed to adapt their consumption to the availability of surpluses of electricity generation.
- Consumer fora, which can coordinate the use of demand flexibility mechanisms by individual electricity consumers.
- Large heat consumers, which are more prone to participate in demand flexibility mechanisms than small consumers, for example: Gudhjem Svømmehal (Gudhjem swimming pools), Østerlars Rundkirke (church), Friskolen i Østerlars (school).
- Owners of the solar PV plants, which can sign power purchase agreements with large consumers, and with Bornholm Varme A/S, and use power surpluses in electric boilers.
- Transmission System Operators, Distribution System Operators, and demand aggregators, responsible for keeping the energy balance.
- Regulatory authorities, including the municipality, and the local authority.
- Research and development partners, including Danmarks Tekniske Universitet, one of the partners of the RE-EMPOWERED project.

Key activities which can be developed in the business model

To make the proposed business model successful, it is necessary to develop the following activities:

- Design accurate tools for renewable and heat demand forecasting, and real time monitoring.
- Control coordination between the electric and heat sectors.

- Preparation of a showcase of the portfolio of services offered to district heating systems to local and external grids.
- Communication with stakeholders.
- Identification and removal of technical and regulatory barriers.

Based on these activities, it has been foreseen that the district heating network, along with the electric boilers and the solar PV plants, will be able to optimize the production of electricity and heat, as well as to offer the following services to the power grid:

- Power flow management.
- Power quality.
- TSO and DSO services, including flexibility services for reactive and active power.
- Avoiding curtailment of peak production from the solar PV plants, using the surpluses of generation to be sold to the grid, or to heat water in the electric boilers.
- Optimization of the renewable energy production.

3.1.5. Economic sustainability analysis for Bornholm

Economic and financial model for Bornholm

According to the information about investment costs, operation and maintenance costs of the Demo Site, and expected incomes, provided by the Demo Site leader, Bornholms Varme A/S, it has been possible to build an economic model to evaluate the profitability and sustainability of the business model.

To design this economic model, the following information has been used:

- Investment cost: The installation of the ecoTools related to the RE-EMPOWERED project has a negligible cost, and only minor additional equipment is expected to be installed. The RE-EMPOWERED project is based on existing infrastructure which was already on site before the beginning of the project.

  The most relevant investment costs in the Demo Site are:

  - Existing Aakirkeby solar PV plant: The Aakirkeby solar PV plant is owned and operated by European Energy. This solar PV plant has a total peak power of 20 MWp, and an estimated total investment cost of €9.0 million.

    This plant is not considered as part of the investment cost.

  - Østerlars district heating plant (straw boiler, etc., excluding electric boilers): 27.4 DKK[12] million, equivalent to €3,671,600.

[12] An exchange rate of 1 DKK=0.134 € has been used to transform values in DKK into €.

- 4 x 0.6 MW electric boilers at Østerlars district heating plant: 1.52 DKK million, equivalent to €203,680.
- Østerlars-Østermarie-Gudhjem district heating system: 66.7 DKK million, equivalent to €8,937,800.

On the other hand, the development of the RE-EMPOWERED project will involve the following additional investment costs:

- A small electric heater, with less than 3 kW. This electric heater will be used along with the ecoDR tool. The cost of the electric heater is around €150.
- Neogrid IoT devices: Approximately 7 x 5,000 DKK=35,000 DKK, this is €4,690.

The total investment cost amounts to €12,817,920.

Moreover, it is foreseen to install a new solar PV plant in Østerlars. This cost will be covered by the company European Energy A/S, not by Bornholms Varme A/S. It is estimated that this plant will have a total investment cost of €6.2 million but is not included in the total Demo Site cost.

- Investment cost of developing and installing the ecoToolset:
  - ecoDR and ecoMonitor will only involve purchasing some minor hardware. There will be a minor time and material cost needed to install it, but this cost will be negligible (around 1 day).
  - ecoEMS, ecoCommunity and ecoPlatform will be all digital and online, and it is not expected that these tools will involve any development or installation cost.
- Estimated operation and maintenance costs: This includes the cost of fuel and maintenance cost (corrective, preventive and predictive) of the existing equipment:
  - Cost of the fuel needed in the district heating plant: straw. The cost of the straw is around €75/ton, and the total consumption is 4,500 tons/year.

    The total cost of the straw amounts to €337,500/year.
  - Electricity consumption for the district heating network: Around 350 MWh/year. Estimating an electricity price of €0.12/kWh, the total electricity cost is around €42,000/year.
  - Labour cost for maintenance actions: Approximately it is necessary to hire 0.5 person-year. Taking an average salary of €50,000 in Denmark, then the total cost of labour cost for maintenance is €25,000/year.
  - Operation and maintenance cost of the ecoToolset: Some operation and maintenance costs are expected for the Neogrid IoT device, around 200-500 DKK/month.

    Taking the maximum value of 500 DKK/month, this is 6,000 DKK/year, or €804/year.

- Cost of the electricity needed to run the 4 x 0.6 MW electric boilers. There is not currently reliable information about the cost of the electricity. However, and given that the use of the electric boilers will lead to expenses in electricity, it has been considered that this cost will amount to €250,000/year.

- Estimated revenue from the project to the project developer (Bornholm Varme A/S):
  - Fees for the heat supply from the clients: Østerlars district heating plant produces around 17,000 MWh per year of heat. These fees consist of three terms:
    - Up-front fee for customers to be integrated in the Bornholm district heating plant: 22,400 DKK per household or consumer + 5,600 DKK for each installation. This revenue is not considered, as it is not easy to calculate how many additional clients will be connected per year to the district heating network.
    - Yearly fixed tariff: 2,140 DKK per household or consumer + 23 DKK per m^2 of the household or building (with a limit of 175 m^2 for households, and no limit for commercial customers).

      Only the initial 2,140 DKK per household or consumer will be considered.
    - Variable cost: 570 DKK per MWh.

    Considering that there are 600 consumers, then the yearly fixed tariff will amount to a minimum of 1,284,000 DKK/year (€172,056/year), without considering the part of the tariff which depends on the surface.

    Since the total heat production amounts to 17,000 MWh/year, at a price of 570 DKK per MWh, then the yearly incomes from the heat sale amount to 9,690,000 DKK per year (€1,298,460/year).

    Thus, the total incomes for the district heating from the heat sale amount to €1,470,516/year.
  - Revenue from the participation of the district heating and the electric boilers in the electric flexibility market. As mentioned before, one of the parts of the proposed business model is to use the electric boilers for frequency down-regulations services, especially the FCR-D (frequency containment reserve for disturbances) market in the East Denmark grid (DK2).

    To participate in the FCR-D market, the participant has to bid at increments of 0.3 MWp. This means that not all the power capacity of the electric boilers (2.4 MWp) can be used, but only 2.1 MWp. The average price of the FCR-D market, which was opened in September 2022, has been 440 DKK/MWp/hour of availability on average.

    As the electric boilers can offer 2.1 MWp, then the estimated incomes for Bornholm Varme A/S from participating in this market amount to 8,094,240 DKK/year, this is, €1,084,628.16/year.

- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €12,817,920, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €640,896/year.
- The corporate taxes in Denmark are around 22%.
- In the economic model, no financial costs are considered.

Using the information provided below, and using a discount rate of 10%, the following cash flows are obtained during the 20-years lifetime of the Bornholm district heating:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the demo site (€)	-12,817,920 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Østerlars heat plant (4 MW straw boiler)	-3,671,600 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
4 x 0.6 MW of electric boilers	-203,680 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Østerlars district heating system	-8,937,800 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Small electric heater	-150 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Neogrid IoT devices	-4,690 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€) from clients (purchase of heat)- Variable income	- €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €
Incomes (€) from clients (purchase of heat)- Fixed income	- €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €
Incomes from flexibility services provided to the frequency market	- €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €
Operation and maintenance costs (€)	- €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €
Fuel for straw boiler	- €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €
Electricity consumption of the district heating	- €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €
Maintenance labour costs	- €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €
Maintenance of the Neogrid IoT devices	- €	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €
Electricity consumption of the electric boilers	- €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €
Depreciation and amortization (€)	- €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €
Profit before taxes (€)	- €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €
Deferred corporate taxes (€)	- €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €
Net cash flow (€)	-12,817,920 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €
Accumulated net cash flows (€)	-12,817,920 €	-11,195,048 €	-9,572,175 €	-7,949,303 €	-6,326,430 €	-4,703,558 €	-3,080,685 €	-1,457,813 €	165,060 €	1,787,932 €	3,410,804 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the demo site (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Østerlars heat plant (4 MW straw boiler)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
4 x 0.6 MW of electric boilers	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Østerlars district heating system	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Small electric heater	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Neogrid IoT devices	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€) from clients (purchase of heat)- Variable income	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €	1,298,460 €
Incomes (€) from clients (purchase of heat)- Fixed income	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €	172,056 €
Incomes from flexibility services provided to the frequency market	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €	1,084,628 €
Operation and maintenance costs (€)	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €	-655,304 €
Fuel for straw boiler	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €	-337,500 €
Electricity consumption of the district heating	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €	-42,000 €
Maintenance labour costs	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €	-25,000 €
Maintenance of the Neogrid IoT devices	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €	-804 €
Electricity consumption of the electric boilers	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €	-250,000 €
Depreciation and amortization (€)	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €	-640,896 €
Profit before taxes (€)	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €	1,258,944 €
Deferred corporate taxes (€)	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €	-276,968 €
Net cash flow (€)	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €	1,622,872 €
Accumulated net cash flows (€)	5,033,677 €	6,656,549 €	8,279,422 €	9,902,294 €	11,525,167 €	13,148,039 €	14,770,912 €	16,393,784 €	18,016,656 €	19,639,529 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	998,508
IRR (%)	11.126%
First positive accumulated cash flow	165,060
Payback (years)	Year 8

Table 22. Economic model for the Bornholm Demo Site, including the cash flow model and a profitability analysis.

According to the model provided before, the business model proposed for Bornholm has positive results: the net present value of the project (with a discount rate of 10%) amounts to €998,508 along 20 years, and the IRR is 11.1%.

On the other hand, the payback period is 8 years.

The following figure shows the Cash Flow Diagram of the Bornholm Demo Site:

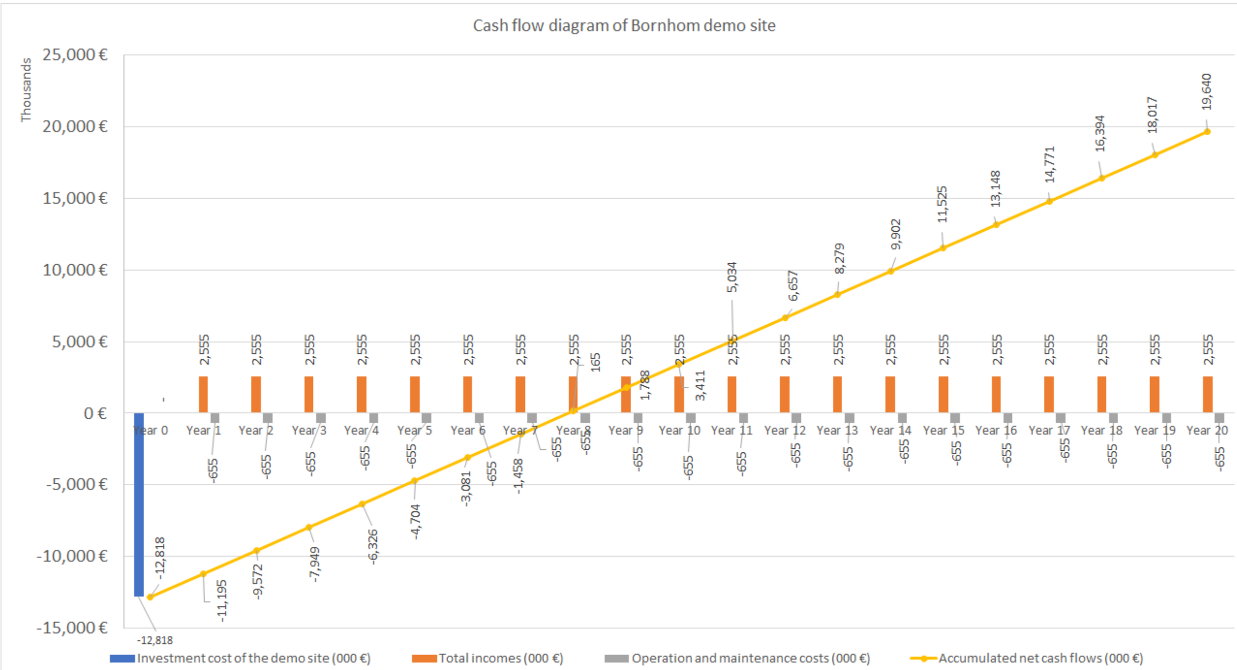

Figure 25. Cash flow diagram of Bornholm Demo Site

3.1.6. Financing tools applicable to the Demo Site

As for financing tools, the cost of the investments made to install the ecoTools (small electric heater and Neogrid IoT devices) is negligible, and will be funded by the RE-EMPOWERED project.

On the other hand, the investment cost of the Bornholm district heating network, amounting to €12,813,000, for the construction and development, has been already incurred.

It has been financed with a 30-years, municipality guaranteed loan. The yearly payments of the loan are covered with the yearly payments from the clients, which are much higher than the operation and maintenance costs.

Other alternative financing instruments could have been considered. Among them, the most important are the following:

- Leasing: This instrument can be used when there is a specific asset, for instance, the district heating network. A leasing contract usually has a duration dependent on the lifetime of the asset, usually between 5 and 12 years. Leasing can cover between 50% and 70% of the cost of the equipment, and similarly to loans, corporate and personal guarantees are required.

  It is important to mention that leasing is considered as debt in the company's annual statements.

  On the other hand, the interest rate of a leasing contract is usually higher than in the case of loans. In the leasing contract, the lessor is a financial company which is the owner of the good. Indeed, the user or lessee pays a periodic fee for the use of the good. At the end of the leasing contract, the user would purchase the good.

- Renting: It can be considered to be similar in some respects to leasing. Similar to it, there exists a specific good which can be used as the main guarantee for the operation, although personal and corporate guarantees can be also required. However, the duration of the renting contract usually is between 2 and 10 years, and covers between 50% and 100% of the cost of the project (not only the equipment, as in leasing, but also other costs such as services, project design, civil works, licenses and so on).

  The client is required to present some corporate and personal financial guarantees, but renting is not considered as debt in the company's annual statements.

  The interest rates are similar to that of leasing: the user pays a periodic fee for the use of the good.

- Project finance: Project finance is a financial instrument very suitable for the Bornholm district heating network. In a project finance, a specific, individual project is financed based on the expected cash flows. A special purpose entity is created for each project, with the participation of the project sponsor and the financing entity.

  As mentioned, the special purpose entity is a new company, with no other assets than the project. The project developer and the financing entity (typically an investment fund) share the ownership of the project, as well as the investment and the risk of the project, and the decisions made on its management.

The financing term is usually between 5 and 15 years. The cost of the financing instrument is higher than an ordinary loan, since the risk for the financing entity is higher, and it is necessary to fund the special purpose entity.

On the other hand, there are fewer financial guarantees for the financing entity: the project itself, and its future cashflows, are the sole needed guarantee.

In general, the financing entity can provide funding for up to 80% of the investment cost, although the project sponsor is expected to cover at least 20%, to ensure its commitment to the success of the project. Project finance is a good instrument for projects with a budget higher than €1 million.

- Equity: The investor (in general, an investment fund), funds the project by becoming a shareholder of the client, what means that the funding becomes part of the equity capital.

  The term of the contract is usually between 3 and 10 years. Since the investor becomes part of the company, it receives a part of the returns of the investment. This means that the cost of equity is always higher than cost of loans, as risks are. Equity is not considered as debt in the company's annual statements.

  Participation in equity is a good financial instrument for projects with a budget of more than €1 million.

  In this case, Bornholms Varme A/S is a subsidiary of Bornholms Energi & Forsyning, the Bornholm public utility, and is publicly owned. Equity would be an option only if a public private partnership could be made.

- Forfaiting or sale of receivables: This is a very innovative model to finance large projects carried out by energy services companies (ESCOs) for municipalities or big clients, with a low risk of default.

  Firstly, an ESCO signs a guaranteed savings or shared savings contract with a municipality to carry out an energy efficiency project. For instance, the Bornholm Regional Municipality (BRK) could have decided to contract an ESCO to build, own and operate the biomass district heating.

  In that case, the investment would have been carried out by the ESCO, with its own funds. The ESCO would have been paid an amount by the three towns, along a period of 10-15 years, based on the obtained savings due to the replacement of the heating systems installed before for the district heating system.

  The ESCO sells the remuneration receivables (completely or partially, and only the receivables related to energy savings) to the financing entity. The purchase price is the net present value of the remuneration receivables, discounted at an agreed factor. Depending on the financial situation of the ESCO, a pledge of the operation and maintenance payments can be needed.

The ESCO and the financing entity sign a forfaiting agreement. The municipality has to be informed, accepts certain representations/undertakings in the Acknowledgement of Notice of Assignment, and provides a Waiver of Defence after the acceptance of works.

Finally, the financing entity collects partially or totally the remuneration receivables from the municipality during a period of time.

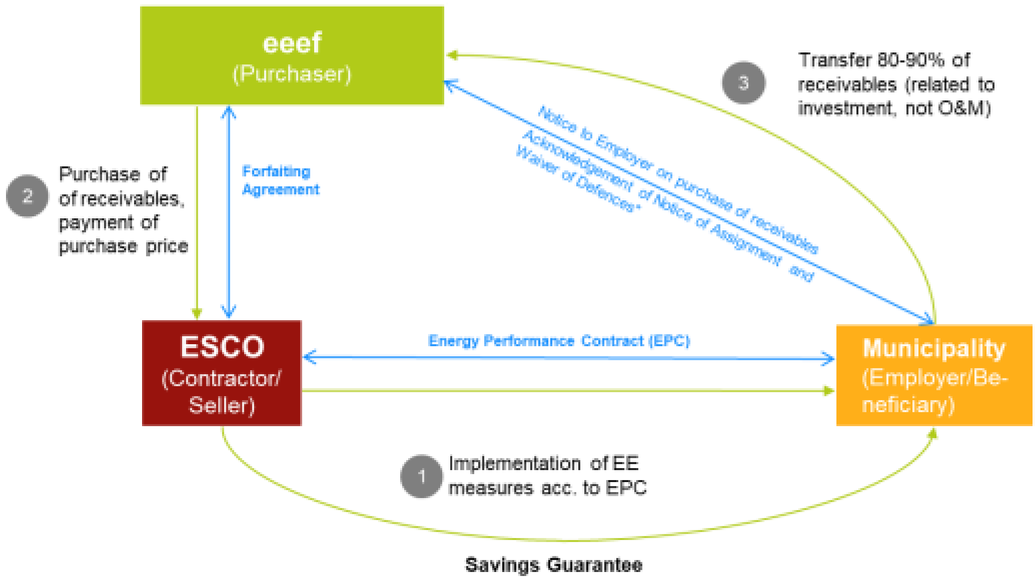

Figure 26. Structure of a forfaiting contract[13]

Crowdfunding could be a good option to ensure citizen involvement in the project. However, it is only a suitable funding option for projects with a limited budget, around €300,000.

[13] Source: European Energy Efficiency Fund.

3.2 Kythnos Island: Greece

Kythnos is a small island in Greece, located in the Western Cyclades, between Kea and Serifos. It is 104 km from the Athenian harbour of Piraeus.

Figure 27. Kythnos island

The total population of the island of Kythnos is 1,568 inhabitants[14], although the permanent population is only 1,456 inhabitants. In summer, the population peaks can be even 8-10 times bigger than the permanent population.

To compare to these data, the total population of Greece was 10.448 million people[15] in 2023.

The economy of Kythnos is mainly focused on tourism. It takes profit of 125 beaches, from which around 60 are easily accessible. Other economic sectors are agriculture, fishing, and crafting of local products.

3.2.1. Energy system and Business models in Greece and Kythnos island

Kythnos island is non-interconnected to the mainland electric grid, what has led to problems in coping with the electricity demand in the island. This situation is the same for other islands in Greece, existing 28 autonomous electric systems. However, it is planned to connect most of these systems to the main grid by 2029.

At the same time, it has been a very good test site to develop renewable energies. For example, Kythnos hosts the first wind farm in Europe, built in 1982, and the first microgrid in Europe, commissioned in 2001, in Gaidouromantra, a small valley next to the coast, in the southern part of Kythnos.

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[14] Source: 2021 Population- Housing Census, Permanent population by settlement. Hellenical Statistical Authority.
[15] Source: World Economic Outlook: April 2024. International Monetary Fund.

For these reasons, Kythnos has been used as a live testbed for different smart grid technologies and has been one of the Demo Sites in different leading European projects. Based on the experience obtained in these projects, as well as the lack of interconnections to the mainland, and constraints to increase the RES penetration, it has been selected to test the use of the ecoTool set in the RE-EMPOWERED project. In the Kythnos Island, the Gaidouromantra Microgrid is isolated from the rest of the microgrid.

Due to the lack of interconnections to the grid, all electricity has to be produced in the island. The power generation infrastructure consists of the following power plants:

- 5.2 MW of fossil fuel generation (diesel generators), in particular:
    - 4 units MWM TBD603V12: 4 x 0.3 MW.
    - 4 units MITSUBISHI S16R-PTA: 4 x 1 MW.
- 908.65 kW of renewable energy generation, including:
    - 3 solar PV power plants, totalizing 238.25 kW (1 x 98,4 kW + 1 x 69.92 kW + 1 x 69.93 kW).
    - 2 solar PV rooftop installations, with a total of 29.535 kW (1x 19.875 kW + 1 x 9.66 kW).
    - 6 wind turbines, totalizing 665 kW: 5 x 33 kW + 1 x 500 kW. However, these wind turbines are out of order, and have to be repowered.

The total electricity production in Greece reached, in 2023, 11,387.33 MWh. The yearly peak load of the island reached 4.05 MW in 2022.

On the other hand, there are 3,353 electricity customers at the low voltage side, including both end consumers and producers. There are around 630 households and 425 businesses.

The split of the electricity production between the plants is as follows (information for 2023):

- Diesel generators: 10,989.93 MWh/year (96.5%).
- Solar PV power plants: 372.64 MWh/year (3.3%).
- Solar PV rooftop installations: 24.76 MWh/year (0.2%).

As can be seen, the penetration of renewable energy in the Kythnos Island is reduced to 3-4% of the electricity consumption. Although there are plenty of renewable energy resources in the island, especially wind and solar irradiation, the installation of new renewable energy systems is reduced due to the demand seasonality, the lack of energy systems and technical restrictions, due to the variability of wind and solar plants.

Additionally, Kythnos counts on with the following energy related infrastructure:

- A desalination plant of 1 x 75 kW.
- 7 electric vehicles have been currently put into operation in the island.

- 9 three phase, AC, dual socket electric vehicle chargers have been installed in the island. Each electric vehicle charger has 11 kW, which makes a total power of 99 kW.
- Heat pump in the municipal school: Recently, the heating system of the Kythnos school has been restored, installing a new heat pump. This heat pump has a total power of 30 kW, and operates in school days, approximately, 2,500 hours per year.
- Large scale energy storage systems are not available in the Kythnos Island. A hotel in Loutra has an 18-kWh battery storage system.

As can be seen, the most relevant energy consumptions in Kythnos are cooling during summertime, and water treatment in the desalination plant. Thus, there are three energy vectors: cooling, water, and electricity.

It is necessary to ensure the optimized and efficient operation of the three energy vectors, to manage the energy demand and be able to increase the installed renewable energy capacity.

The most relevant stakeholders of the energy sector in Kythnos are the following:

- DSO: HEDNO S.A. (Hellenic Electricity Distribution Network Operator), in Greek “Διαχειριστής Ελληνικού Δικτύου Διανομής Ηλεκτρικής Ενέργειας”, or ΔΕΔΔΗΕ.
- TSO: There is not a TSO active on the island since there is no transmission system. However, it is foreseen to interconnect the Kythnos Island to the mainland in the future, according to the IPTO’s ten-year development plan. IPTO is the Independent Power Transmission Operator, the TSO for the Greek mainland.
- Energy supplier: There are different energy suppliers: Watt and Volt, NRG, Elpedison, Mytilineos, Public Power Corporation (PPC), ELTA, KEN, Zenith and Elinoil.
- Energy producer: PPC (diesel generators), and different private owners, which have invested in the renewable energy plants (among them, PPC Renewables).
- Electric Mobility Manager: The existing electric vehicle charging infrastructure is currently operated by the Municipality of Kythnos.
- Heat Storage Manager: It does not exist.

HEDNO S.A is the responsible for the operation of the electricity distribution system in the Kythnos Island, as well as the electricity market.

Regarding the availability of renewable energy sources, in Kythnos Island there are not relevant biomass and water resources. It is possible to use wind and solar PV energy.

3.2.2. Access and cost of energy supply in Kythnos island

The electricity supply in the Kythnos Island is offered to 100% of the population, and there are 3,353 low-voltage customers. However, although electricity is supplied to all inhabitants, there are some problems with the stability of the energy supply. During peak hours, the -power demand can be higher than the generation capacity of the island. This leads to voltage and frequency variations, which rarely have caused blackouts, and damage the electrical devices.

Currently, there are not load controllers. The main economic activity of the island is tourism, which makes that the number of inhabitants in summer is 8-10 times the existing in winter. This negatively affects the grid stability and the supply security in Kythnos Island. The extra power which is needed in summer is covered with diesel generators, which are transported from an island to another.

Kythnos Island has issues related to power outages and voltage drops, especially in the edges of the electricity network, which have weaker connections to the grid (for example, Loutra in the North and Aghios Dimitrios in the South). For this reason, one of the main objectives related to energy in the island is to improve the SAIDI (System Average Interruption Duration Index) and the SAIFI (System Average Interruption Frequency Index), as well as the amount of electricity not delivered. Additionally, it is necessary to develop protection systems against extreme weather conditions and better load and weather forecasts.

As for energy prices, as happens in other European islands, all customers pay the same electricity price, regardless where they live or the cost of producing electricity. As electricity production in Kythnos relies mostly on diesel generators, the electricity cost is much higher than in mainland Greece.

This means that in Greece, the energy cost of all non-interconnected islands is subsidized, and consumers only pay a part of this cost. This is due to the fact that island systems are not interconnected to other systems, and this makes it more difficult to increase the production of renewable energies, as a low generation cannot be balanced with higher productions in other zones. Due to this, most electricity is produced with thermal power plants. The extra cost of the island electricity is paid by all Greek consumers, with the Public Service Obligation. The costs incurred by HEDNO, the distribution system operator, have to be approved by the Regulatory Authority of Energy (RAE), and are covered by the Network Charges in the electricity bills. The electricity supply in Greece is totally liberalized.

The following figure shows the evolution of the electricity prices for Greece, the European Union as a whole, and some countries which are comparable to Greece, or are its neighbours: Spain, Albania, Bulgaria, and Italy. The comparison has been carried out for consumers with a band of consumption between 2,500 and 5,000 kWh per year, considered as domestic consumers.

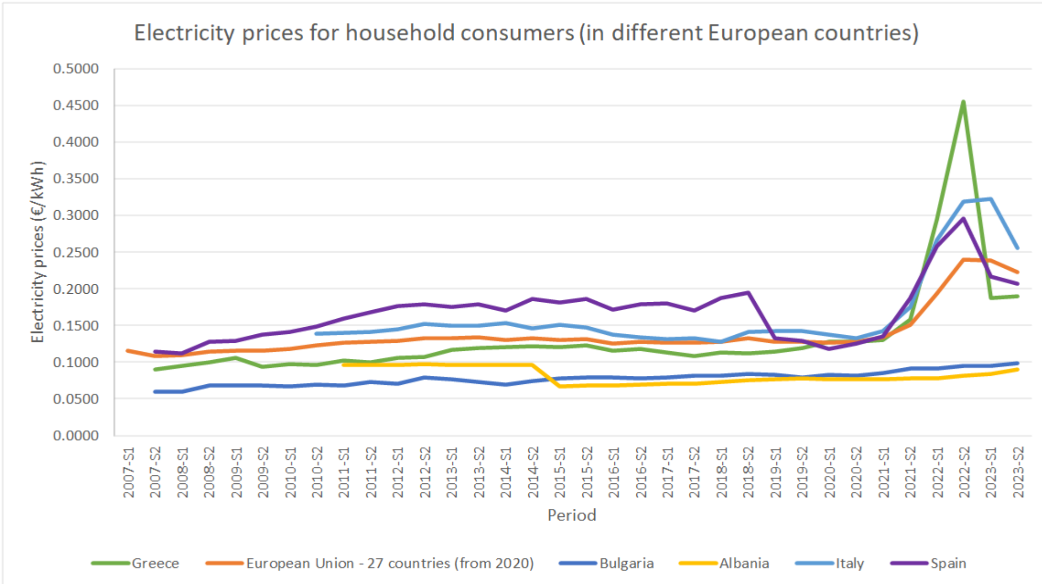

Figure 28. Evolution of the electricity prices for household consumers in Greece and other European countries (Eurostat, 2024).

From the previous figure, it can be seen that, historically, prices in Greece have been lower than that of the European Union, at least until 2020. During the years 2020 and 2021, prices in Greece and the average price of the European Union have been similar. However, in 2022, Greece had the highest prices of all the European Union, 53% higher in the first semester (€0.2950/kWh in Greece, and €0.1934/kWh in the European Union), and 90% higher in the second semester, reaching €0.4556/kWh. Prices went down again in 2023, when they have been, on average, 18% lower than the average in the European Union.

Greece has electricity prices considerably higher than that of the neighbouring countries. Besides, prices vary much more. In Bulgaria and Albania, prices have only increased by 16% and 18%, respectively, between 2021 and 2023. In Greece, the increase has been 46%. Moreover, prices in Bulgaria and Albania did not peak in 2022.

The following analysis considers the evolution of the electricity prices for household consumers, considering different consumption bands:

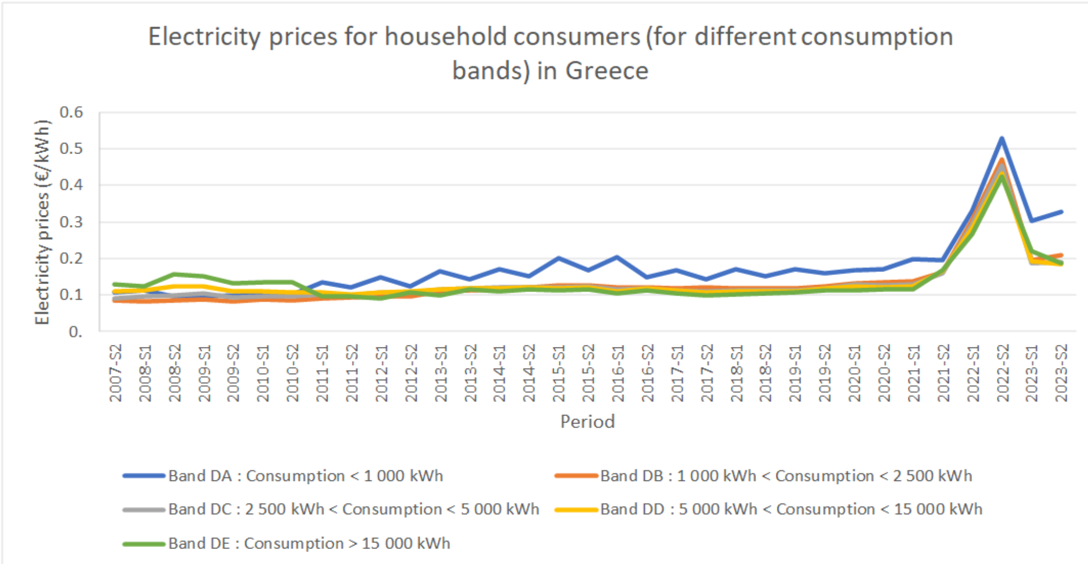

Figure 29. Evolution of the electricity prices for different consumption bands of household consumers in Greece (Eurostat, 2024).

According to the graph, until 2011, the band with the highest prices was consumers which demanded for more electricity, namely, above 15,000 kWh/year. This changed in 2011, when prices for the consumption band below 1,000 kWh/year went up by 35%, this, is, €0.035/kWh.

During the period 2011-2021, prices for the consumption band below 1,000 kWh/year have varied much more than other consumption bands, ranging between €0.15/kWh and €0.20/kWh. Prices peaked in 2022, reaching a maximum of €0.5294/kWh for clients with a consumption below 1,000 kWh/year, the maximum record during the time series. For other consumption bands, the price increase was very important, too, with €0.425/kWh for the clients with the largest demand. Tariffs in the second semester of 2022 were between 2.5 and 3 times higher than that of the second semester of 2021.

In 2023, all tariff levels went down, keeping lightly above €0.30/kWh for consumers with a consumption lower than 1,000 kWh/year, and around €0.20/kWh for consumers with a consumption above 15,000 kWh/year. For the other consumption bands, prices were between €0.18/kWh and 0.20/kWh during 2023.

The following figure includes the comparison of the prices for industrial consumers, in a consumption band between 20,000 and 70,000 kWh/year.

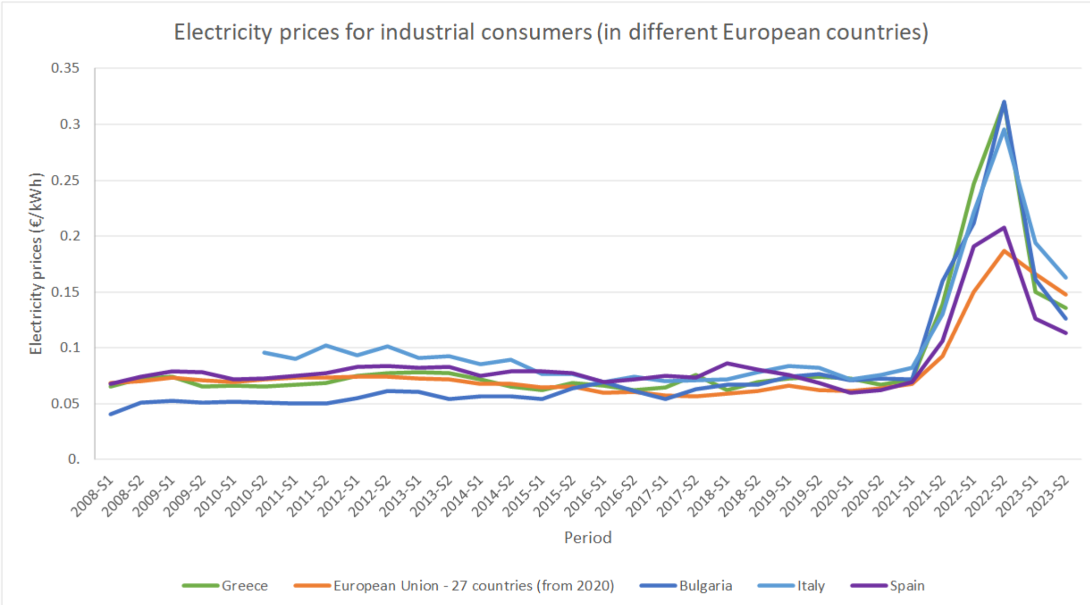

Figure 30. Evolution of the electricity prices for industrial consumers in Greece and other European countries (Eurostat, 2024).

As can be seen, prices during the period 2008-2021 in Greece kept in a band between €0.06/kWh and €0.08/kWh, with small variations. However, in the second semester of 2021, the price began to rise, reaching €0.1386/kWh in this semester, with an increase of 94% in a period of 6 months. This increase continued in 2022, with a record of €0.3192/kWh in the second semester of 2022, what means a price more than 4 times higher than the average during the period 2008-2021.

In 2023, the electricity price for industrial consumers in Greece, during the first semester of the year, was less than a half of that of the second semester of 2022, and continued going down during the second semester of 2023. However, it still was twice the normal price in the period 2008-2021.

Compared to other European countries, electricity prices for industrial consumers have evolved similarly in all countries. However, Greece is one of the countries which had highest prices in 2022. Only Bulgaria, with €0.3200/kWh in the second semester of 2022 had a higher price.

Finally, the following graph shows the evolution of the electricity prices for industrial consumers in Greece, comparing different consumption bands. Not surprisingly, consumers with the largest consumption, this is, band IG (150,000 MWh or more per year) have the lowest prices during all the period. All consumption bands had very high prices during the period from the first semester of 2022 to the second semester of 2023, with record prices in the second semester of 2022. In the case of the band IA, this is, the consumers which demanded less than 20,000 MWh/year, the electricity price was higher than €0.50/kWh.

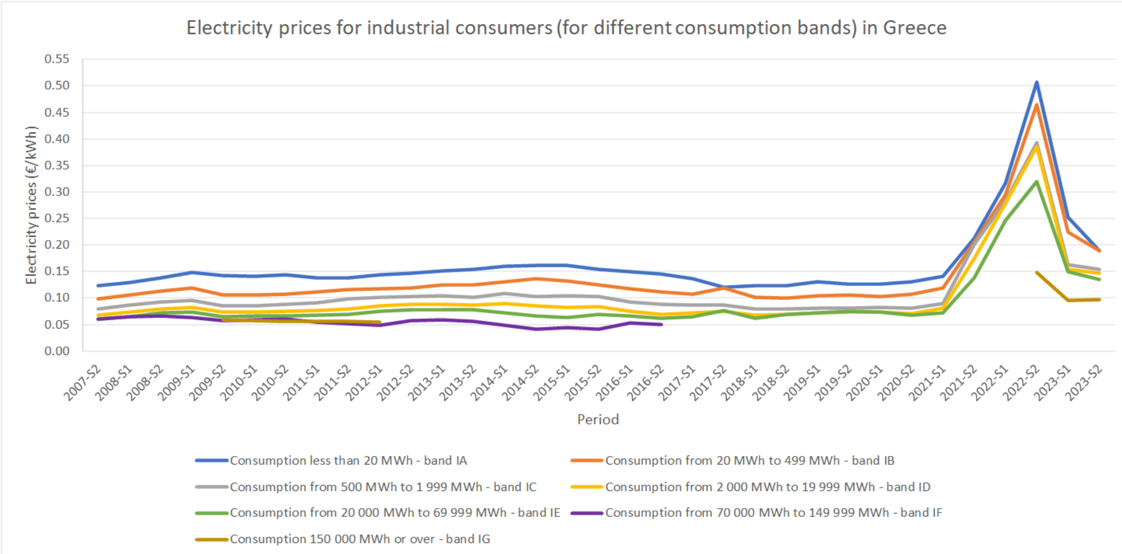

Figure 31. Evolution of the electricity prices for different consumption bands of industrial consumers in Greece (Eurostat, 2024).

Greek consumers have been among the ones, in the European Union, for which electricity prices have gone up more during the period 2021-2023. This has led to dissatisfaction between consumers. Electricity prices in Kythnos are the same that apply to the rest of Greece. It has to be noted that the Greek government opted for subsidizing the electricity price, and for this reason, the price paid by consumers has been finally lower. One of the reasons for the relevant increases in the electricity prices in Greece is the large dependency on natural gas of the power system. In 2022 natural gas made 38% of the total electricity generation, while wind was only 21.9%[16]. However, this is changing quickly: in 2023, 57% of the electricity generation in Greece was based on renewable energy[17].

3.2.3. Use of the ecoTools in Kythnos Island

The objective of RE-EMPOWERED in Kythnos island is to accelerate the digitalization and the energy transition of Kythnos' energy system. Although Kythnos has been used as pilot site to test renewable energy projects in the European Union, it still uses considerable amounts of diesel and fuel oil generators, what makes the electricity cost very high compared to that of the continental Greece.

For this reason, it is expected that the use of the ecoTool set in Kythnos will allow introducing a higher amount of renewable energy generation. The use of a combination of ecoMonitor, ecoEMS and ecoPlanning tools, as an energy management system, will allow to maximize the synergies

[16] Source: The International Energy Agency. Greece analysis.
[17] Source: ADMIE Ανεξάρτητος Διαχειριστής Μεταφοράς Ηλεκτρικής Ενέργειας (ΑΔΜΗΕ) or IPTO (Independent Power Transmission Operator).

between different energy vectors, to increase the electricity generation with renewable energies, and to reduce the costs of energy.

Besides, demand response measures will be used to improve further the energy management, engaging local energy consumers and producers, which will lead the development of new attractive business cases. The community engagement in the island is needed to maximize the local benefit, and to accelerate the clean energy transition.

Kythnos will be an example which will be replicated in other non-interconnected islands in Greece.

Mapping UCs and, ecoTools in Kythnos Island

In the following table, it is possible to find a summary of the ecoTools and Use Cases used in the Kythnos island Demo Site, developed in WP02. The selection of Use Cases for all Demo Sites is included in Deliverable 2.1: Report on requirements for each demo, use cases and KPIs definition.

In the table it is possible to identify the Use Cases and the proposed business models.

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Association with New BM
ecoEMS	EMS_1UC1	Real time monitoring and system data visualization	EMS_2UC1.1	Real time system monitoring and data acquisition and visualization	Demand response mechanisms
			EMS_2UC1.2	Module manager: intercommunications and data exchange	
	EMS_1UC2	Forecasts, Unit Commitment, Economic Dispatch, Multi-energy optimization	EMS_2UC2.1	Mid-term and short-term RES and load forecasting	
			EMS_2UC2.2	Forecasting model training	
			EMS_2UC2.3	Unit Commitment and Economic Dispatch algorithms	
			EMS_2UC2.4	Multi-energy vector management of operation	
ecoMicrogrid	MG_1UC1	Microgrid monitoring	MG_2UC1.1	Real time microgrid monitoring and data acquisition	Energy Communities
			MG_2UC1.2	RES production estimation	
			MG_2UC1.3	Data concentration, storage and management	
	MG_1UC2	Microgrid optimal management of operation	MG_2UC2.1	Effective communication with controllable assets	
			MG_2UC2.3	Multi-energy vector microgrid management of operation	
ecoPlanning	PN_1UC1	7-Year Energy Planning	PN_2UC1.1	Data collection and storage	
			PN_2UC1.2	Electrical models & demand peak models design, RES & Load estimation	
			PN_2UC1.3	Optimization algorithm for mid to long term horizon (1 to 7 years), for hourly Unit Commitment, maximizing RES penetration and securing normal operation	
	PN_1UC2	RES Hosting Capacity	PN_2UC2.1	Electrical models & demand peak models design, RES & Load estimation, RES units dimensions and thresholds	
			PN_2UC2.2	Scenario simulation through optimization for 1 year per scenario run, for hourly Unit Commitment.	
	PN_1UC3	Interconnections	PN_2UC3.1	Electrical models, demand peak models & interconnections design, RES & Load estimation	
			PN_2UC3.2	Hourly Unit Commitment, through optimization algorithm for mid to long term horizon	
	PN_1UC4	Multi-energy vectors	PN_2UC4.1	Energy carriers identification, data collection and quantification of impact on total load (hourly)	

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Association with New BM
			PN_2UC4.2	Electrical models & demand peak design, RES & Load estimation, energy carriers scenarios integration	
			PN_2UC4.3	Optimal Unit Commitment for mid to long term horizon, based on multi energy carriers	
ecoDR	DR_1UC1	Increased energy monitoring at demand side	DR_2UC1.1	Real time monitoring of energy consumption	Demand response mechanisms
ecoPlatform	PT_1UC2	Platform as a service for dependent tools integration	PT_2UC2.1	Facilitate data exchange between dependent tools	Demand response mechanisms Energy Communities
	PT_1UC3	Data storage and cloud server	PT_1UC3.1	Route the microgrid data and data from dependent tools to cloud database	
			PT_1UC3.2	Facilitate archived data access for dependent tools using API	
ecoMonitor	MON_1UC1	Drinking water quality surveillance	MON_2UC1.1	Acquisition and monitoring of water quality	Demand response mechanisms
			MON_2UC1.2	Data processing and evaluation	
ecoCommunity	CM_1UC1	Dynamic pricing of electricity*	CM_2UC1.1	Displaying the dynamic pricing based on shape of energy profile	Energy Communities
			CM_2UC1.2	Billing and payments	
			CM_2UC1.3	Data security and privacy	
	CM_1UC2	Scheduling and Coordination	CM_2UC2.1	Facilitating(display) of the scheduling and shifting of non-critical and flexible loads	
			CM_2UC2.2	Coordination of communal/shared loads	
	CM_1UC3	Outreach forum	CM_2UC3.1	Feedback and suggestions from users about the tools	
			CM_2UC3.2	Reporting of problems	
			CM_2UC3.3	Forum to share experiences	
	CM_1UC4	Guidance and Training	CM_2UC4.1	Training material (troubleshooting)	
			CM_2UC4.2	Easy-to-use multimedia material and step-by-step guides (walkthroughs)	
ecoResilience	RS_1UC3	WT Local Manufacturing and Testing	RS_2UC3.1	Testing of Small Wind Turbines using Standards	

Table 23. Association of ecoTools and UCs in the Kythnos Island Demo Site: RE-EMPOWERED

3.2.4. Business Canvas and proposed business models

The business model in Kythnos should consider some particularities of the island:

- Although the Kythnos Island is not connected to the rest of the Greek power system, HEDNO S.A. is in charge of the electricity supply, and there are different energy suppliers and producers.
- The energy consumption is covered with diesel generators and solar PV plants, although fossil fuel production amounts to 96%-97%.
- Although there are not energy scarcity problems, power outages and energy drops are not uncommon. There are also problems with extreme weather situations.

The main issue in Kythnos is to find alternatives to increase the penetration of solar PV plants without compromising the stability of the grid. Today, no more solar PV plants are allowed to ensure that there are not instability problems.

The following business canvas has been defined for Kythnos Demo Site.

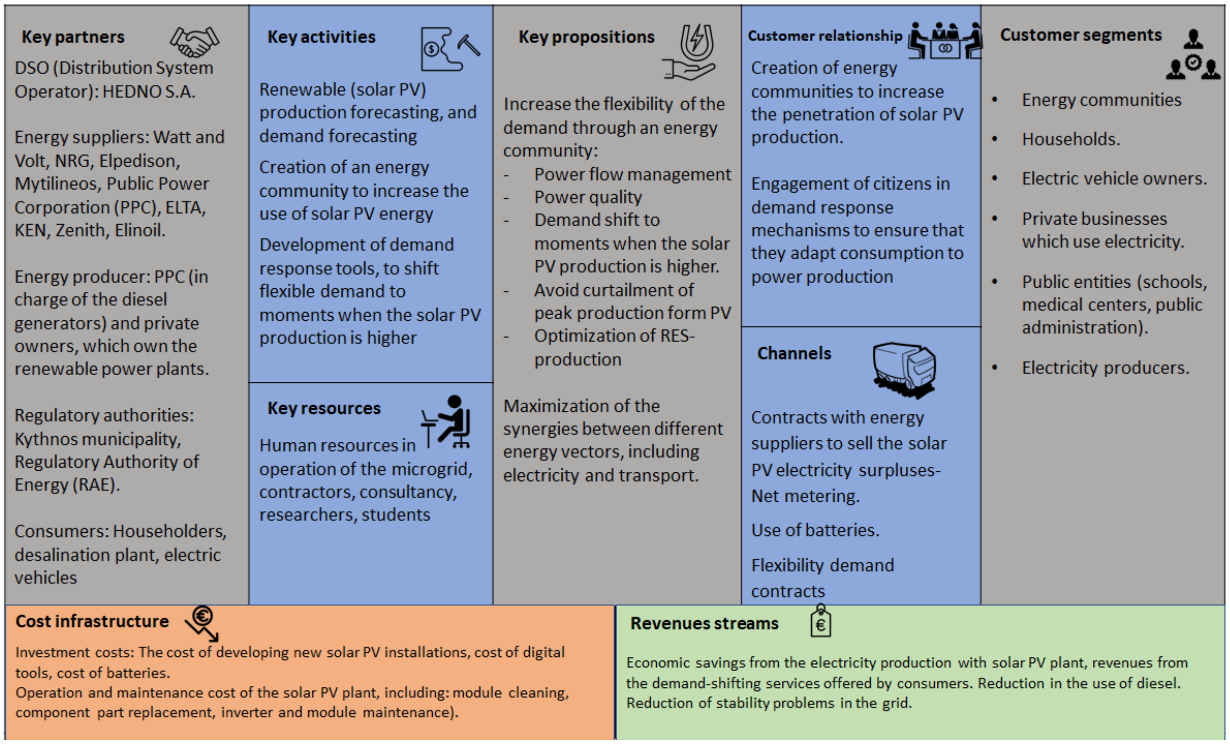

Figure 32. Proposed business canvas to Kythnos Demo Site

Proposed business model

Two are the main business models which can be proposed for Kythnos island: the creation of energy communities, and demand response mechanisms.

Energy communities can be considered as an appropriate option to increase the use of solar PV plants. An energy community is a citizen association which joins together to produce and use renewable energy. An energy community is made of different consumers in a zone, which share the investment cost in a renewable energy plant (typically, a solar PV plant), and also share the operation and maintenance costs. In turn, they can share the free renewable energy produced, as well as any potential income from the sale of electricity surpluses and the provision of ancillary services.

To become a part of the energy community, all members have to purchase at least one cooperative share. The cost of the share will be used to cover the investment cost of the solar PV plant. Then, the electricity production is shared between the members of the energy community, according to their consumption patterns. Each member will pay for the electricity received depending on the consumption. However, the price of the electricity is the needed to cover the cost of the operation of the solar PV plant, and the operating cost of the energy community, so it is considerably lower to the retail electricity price.

The decision-making process of the energy community is shared by all the members.

In general, the energy community is managed by a professional or a volunteer member of the community. This energy community manager will oversee the operation of the solar PV plant, ensuring that it is properly maintained, and solving any issue. The local energy community is a legal entity, for instance an association, a cooperative, a partnership, a non-profit organization or a small or medium-sized enterprise.

There are different ownership models for energy communities, which can be summarized as follows: cooperative (social SME owned by the energy community), hybrid model community-local government, hybrid model community-private, segregated ownership.

They are described in the following table:

Business model	Strengths	Weaknesses
Cooperative (Social SME owned by the energy community)	• Becoming a part of the cooperative is volunteer, and the cooperative is very democratic: each member has 1 vote. • Cooperative energy communities share common cultural, economic, and social objectives	• Lack of equity to develop the project: it is not enough with the fee paid by each member. • Lack of technical and economic knowledge by the owners to manage the solar PV project.
Hybrid model community-local government	• The involvement of local public authorities can subsidize part of the investment cost, offer loans, and support in the search for private financing. • Local authorities can support in the planning of the energy community, and can offer public lands for the installation of the plant.	• Not all local authorities support energy communities actively. • Decision processes by local authorities can hinder the development of the energy community.
Hybrid model community-private	• The support of a private stakeholder can enable the energy community to develop bigger projects, which are more economically profitable. • Private stakeholders can help with their experience and knowledge to develop the solar PV project and to obtain all the needed licences.	• Differences in the organization of the private stakeholder and the energy community. • Lack of understanding and transparency between the private stakeholder and the energy community. • Economic benefits have to be shared with the private stakeholder, making the project be less profitable.
Segregated ownership	• The solar PV project is owned by different owners, which only share the site and the project. • Some parts of the project can be owned by a commercial project developer, a public services company, an independent power producer, or an investment fund.	• The energy community has to obtain financing to purchase a part of the solar PV project. • It can be difficult to coordinate all owners in the operation, monitoring, and maintenance of the solar PV plant.

Table 24. Proposed business models for a solar PV energy community.

The other relevant business model which can be applied in Kythnos is the demand response model.

In this model, customers are encouraged to shift their electricity consumption to moments when the electricity production by solar PV plants is higher. Demand response is based on the use of smart meters, which can measure the consumption of the users, and when it is produced. The changes in the electricity consumption patterns rely on changes in electricity prices over the time, or incentive payments to encourage the use of electricity at times when the electricity demand is lower, or when electricity production with solar PV plants is higher.

The following figure includes a summary of the different demand response mechanisms.

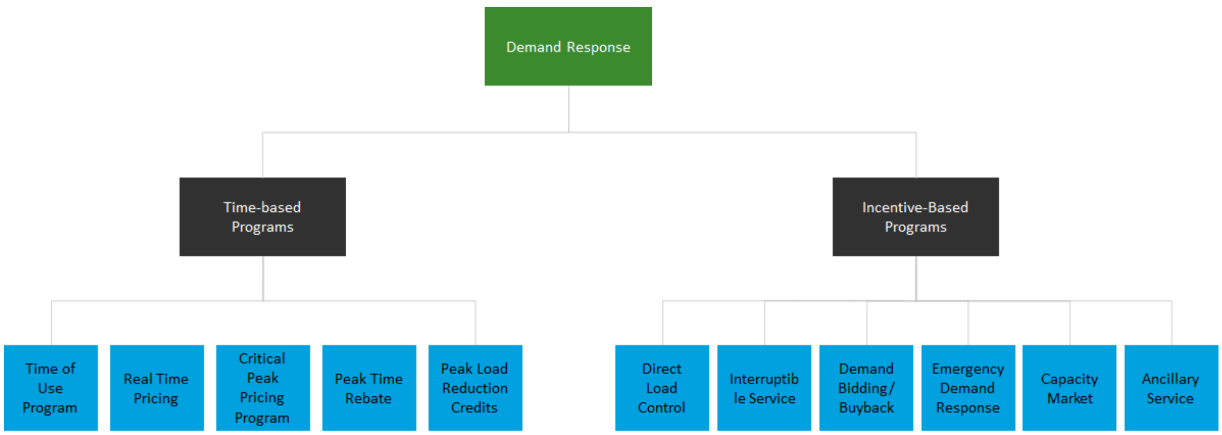

Figure 33. Different categories of demand response [7], [8].

The figure before includes two different types of incentives. Firstly, incentive-based programs are methods which are based on reducing the load of the system by offering payments to the customers. There are six different types of incentives which can be used, depending on the way they operate.

The following incentive-based programs exist [7],[8]:

- Direct load control program: These programs allow the company to remotely shut down the electric devices of the consumers, for instance, water heaters or air conditioners, to reduce the power demand in peak hours. In exchange, consumers are compensated with lower electricity prices and other incentives. This program can reduce the power consumption in peak hours. Consumers can choose if they participate in these programs and are not penalized if they do not want to.
- Interruptible service program: These programs include an agreement between the grid operator and the customer, which involve that customers can be asked to reduce their power demand to a pre-specified level in hours when the demand is very high. They decide to participate in the programs voluntarily, and in exchange they receive incentive payments or lower electricity prices. If a consumer participating in the program is asked to reduce its consumption and it does not, it can face penalties. The company cannot reduce the power consumption of a client.

- Demand bidding/buyback programs: This system has been recently developed. Consumers are encouraged to offer a price for reducing their load, or to give information about the amount of load that they can reduce being offered different payments.
- Emergency demand response program: Incentive payments are offered to customers who reduce their power demand during reliability triggered events. Customers are not penalized if they do not reduce their consumption, since the program is voluntary.
- Capacity market program: In these programs, customers can offer to commit to reducing their load at a predefined amount during system contingencies, being paid for it. These programs are offered by wholesale market providers, and are called on a one-day notice. If the customer does not reduce its consumption when required, it is penalized. Normally, the ability of a consumer to reduce the load is analysed before it is included in the program.
- Ancillary service program: Customers can bid load curtailment as operating reserve in the spot market. Customers are paid market price if their bids are accepted, and are paid spot market energy price if the load curtailment is needed. However, customers must be able to adjust their load quickly to any requirement.

The second option are time-based programs. This demand response mechanism is based on dynamic pricing rates and time-based rates. The electricity price varies depending on the demand, so in peak hours the price is much higher than in off-peak times. There are five different programs:

- Time of Use Program (TOU). The system changes the price of electricity depending on the hour block. There are two-hour blocks: peak hours and off-peak hours. In peak hours, demand is higher, and for this reason the electricity price is higher, while in off-peak hours, the electricity price is lower. The periods when there are peak and off-peak hours are fixed, and do not depend on the actual power generation or demand.
- Real time pricing (RTP). The price of electricity varies hourly, depending on the real cost of the power generation. The main RTP programs are day of versus day-ahead pricing, mandatory versus voluntary, and one-part versus two-part pricing. In these programs, customers can save more money if they are able to adapt their consumption to the previously known price, but can pay much more if they are not able to do so.
- Critical peak pricing (CPP). This program is a variant of the Time of Use Program and is designed to reduce demand at critical times for the network. Since the objective of the program is to reduce the load at critical moments, it usually only operates for a few hours throughout the year. The electricity price is the actual cost of power generation in peak demand hours, which can make prices very high. In exchange of paying very high prices at these hours, the remaining hours of the year the consumer can benefit from a subsidized electricity price.
- Peak Time Rebate (PTR): Instead of paying more for the electricity, as happens in the critical peak pricing method, customers can be paid for reducing their electricity demand in peak hours. In the Peak Time Rebate, the client can have a flat rate in non-peak hours and receive a cash rebate for each kWh it does not use in peak hours.

- Peak Load Reduction Credits. These credits can be offered to consumers with large loads. These consumers can participate in pre-established peak load reduction agreements, reducing the commitment of a utility to have an installed power capacity.

In the Kythnos Island, smart meters are generally available nationally. However, only a small percentage of households have installed them, what makes difficult to develop these business models. Thus, it is essential to make sure that smart meters are widely used.

<u>Community engagement</u>

According to the European, international, and national rules for public participation in the development of renewable energy projects, the civil society is involved in the development of renewable energy projects, and individuals can give their opinions on the environmental impacts of such projects.

In Greece, according to Law 4513/2018 and Law 5037/2023, natural persons can directly participate in energy communities. Local actors, including citizens, municipalities, local businesses, or universities are allowed to take an active role in the clean energy transition with some special provisions for islands.

Besides, the Hellenic Republic develops different incentive programs, to offer subsidies for the renovation of equipment by households, to reduce the energy consumption or to use renewable energies. For instance, there are subsidies related to the installation of rooftop solar PV systems, or to replace the heating systems.

On the other hand, until now, there is not a specific regulation for microgrids. For this reason, only small-scale microgrids in pilot and research phases can be installed in Greece.

As for the moment, in Kythnos island there is not any citizen-led energy community. This is changing thanks to the RE-EMPOWERED project, as the establishment of a new energy community in the Kythnos Island is being promoted by the project, along with the Municipality of Kythnos and different commercial associations.

Many of the power suppliers have developed payment through mobile apps, which offers information to electricity consumers.

<u>Key partners which should be taken into account in the business model</u>

The following is a list of the main stakeholders which are involved in the business model for Kythnos island:

- Distribution system operator (DSO): HEDNO, S.A.
- Energy suppliers: Watt and Volt, NRG, Elpedison, Mytilineos, Public Power Corporation (PPC), ELTA, KEN, Zenith, Elinoil.
- Energy producers: Public Power Corporation (PPC), in charge of the diesel generators, and different private owners which operate the renewable power plants.
- Regulatory authorities: Municipality of Kythnos, Regulatory Authority of Energy (RAE), Municipal Technical Service, Municipal Public Benefit Corporation of Kythnos.

- Consumers: Householders, desalination plant, electric vehicles, businesses.
- Research and development partners, including ICCS-NTUA, one of the partners of the RE-EMPOWERED project.

Key activities which can be developed in the business model

The following activities are needed to make the business model successful:

- Renewable (solar PV) production forecasting, and demand forecasting.
- Creation of an energy community to increase the use of the solar PV energy.
- Development of demand response tools, to shift flexible demand to moments when the solar PV production is higher.

3.2.5. Financing tools applicable to the Demo Site.

In principle, the RE-EMPOWERED project does not foresee to carry out any specific investment in the Demo Site of Kythnos.

Since the development of energy communities based on solar PV plants is forecast, there will be a need for financing these solar PV plants. Considering the reduced size of solar PV plants, the following financing instruments can be considered:

- Loan: This is the most common financing instrument. In a loan, a bank or other financial institution lends money during a term (in general, 3-10 year), to the borrower to invest in the project. Loans in general cover only between 50% and 70% of the cost of the project. The bank requires from the client the existence of corporate and personal guarantees.

  The interest rate of loans is lower than other alternatives since there is a guarantee. Loans are appropriate for any size of projects and investments.

- Leasing: This instrument is very suitable for projects where there is a specific asset, for example, solar PV panels. A leasing contract funds between 50% and 70% of the cost of the asset, and its duration depends on the lifetime of the asset, generally, between 5 and 12 years.

  Similarly to loans, personal and corporate guarantees can be required. The difference with the loan is that, in this case, the owner of the asset is the financing company, called the lessor. The user or lessee pays a periodic fee for the use of the good. At the end of the leasing contract, the user can purchase the good, in general, paying the last fee, or for free.

  Leasing contracts do not include the maintenance and insurance of the asset. The interest rate of leasing contracts is higher than the interest rate of loans.

  Another important point is that leasing is considered as debt in the financial statements of the company.

- Renting: Renting is similar to leasing, but there are some differences. In both, there is a specific equipment (the solar PV panels) which are the main guarantee of the operation.

The typical duration of a renting contract is between 2 and 10 years, and can cover between 50% and 100% of the cost of the project, including not only the equipment, as in leasing, but also other costs, such as services, project design, civil works, licenses, and others. Maintenance and insurance of the asset is also included.

Since the asset is not owned by the user, renting contracts are not considered as debt, but they are an expense. The renting company is paid not only for the use of the equipment, but also for the maintenance. In a renting contract, the purchase of the asset by the user is not considered, as in leasing.

The client is required to present some corporate and personal financial guarantees, but renting is not considered as debt in the company's annual statements.

- Crowdfunding: This is a good option for solar PV projects developed by energy communities. Crowdfunding is based on online platforms, which allow individuals to support a project investing a small amount of money.

  In general, a specialized online crowdfunding platform publishes each project, after the presentation of the project by the project developer. The crowdfunding platform is also responsible for an analysis of the risk and financial and technical viability of the project.

  The main advantage of the crowdfunding is that it is an excellent way for citizen engagement. It allows citizens to invest, and become owners, of a renewable energy project from which they will benefit directly. In some cases, the investment can be limited to citizens which live near to the project.

  Crowdfunding is usually used for projects considered as "sustainable", such as energy efficiency, renewable energy, water treatment, health (such as gym), electric mobility, development of Internet networks in a village, circular economy and so on.

  Crowdfunding loans have a typical term among 1 and 8 years, and the interest rate is higher than a typical loan, due to the higher complexity. However, they have some advantages, such as the possibility of funding projects which are not so attractive for a bank.

  Crowdfunding has a limit in the amount which can be funded, usually around €300,000.

- Power Purchase Agreement (PPA): It is an innovative financing instrument, very appropriate for solar PV projects. In these contracts, a company specialized in solar PV projects funds a solar PV project, to provide electricity to the final client. The company funds the project with a loan, or another financial instruments, and owns the plant and maintains it.

  The owner can sell the electricity to the client at an agreed price. This allows the owner to recover the investment, while the client has the electricity supply guaranteed, at a lower price than electricity bought in the grid. The electricity which is not used by the client can be sold to the grid as surpluses, which will increase the incomes of the project developer.

These contracts are very suitable for electricity consumers, which want to benefit from electricity produced with solar PV energy, but do not want to invest in a new solar PV plant, or cannot operate or maintain it.

Finally, forfaiting or sale of receivables, which was proposed for Bornholm Island, is not easy to apply in Kythnos Island, due to the reduced size of the Demo Site. Forfaiting is usually used for projects which require a large investment amount, at least, €1 million, and when the receivables (payment from the final clients) can be easily determined and recovered in case of defaulf of the project developer.

3.3 Gaidouromantra Microgrid: Kythnos island, Greece

Gaidouromantra is a small settlement of 14 vacation houses located in a small valley next to the coast, in the southern part of Kythnos island.

Figure 34. Location of the Gaidouromantra microgrid in the Kythnos island

Figure 35. View of the Gaidouromantra microgrid[18]

[18] Source: *12 years operation of the Gaidouromantra Microgrid in Kythnos island*, COI-3869. Conference paper. December 2012. Author: Stathis Tselepis. ResearchGate.

Gaidouromantra is isolated from the rest of the Kythnos grid, and for this reason, the electricity supply of the Demo Site is provided by a permanently islanded microgrid, which operates based on 100% renewables. Gaidouromantra has been the first microgrid developed in Europe, has received the support from different European projects, and has been operational since 2001.

Gaidouromandra has been the pilot test for advanced technologies based on renewable energies, batteries and decentralized technologies for demand-side management (DSM).

The Demo Site has a surface of 0.56 km^2. As mentioned, there are 14 vacation houses, and no businesses. The houses are only used during holidays, and the number of inhabitants in Gaidouromantra ranges from zero, in low season, to twenty-five in high season. All inhabitants have access to electricity and to the Internet.

3.3.1. Energy system and Business models in Gaidouromantra Microgrid

As described before, the power supply in Gaidouromandra comes from a microgrid operating since 2001. The system consists of a 3-phase microgrid, composed of the overhead power lines and a communication cable running in parallel. The power generation comes from distributed energy resources (DER), which will be described in detail in the following paragraphs.

The microgrid provides electricity to 14 houses with a 1-phase electrical service. The project begun in early 2001, with the support of European projects.

Some of the most relevant features of the Gaidouromandra microgrid are as follows:

- The microgrid is permanently isolated from the rest of the Kythnos grid.
- The consumption profile is typical for holiday homes: consumption is very high in summer, while in non-holidays period it is very low, since the homes are not used.

The Gaidouromandra microgrid has the following topology:

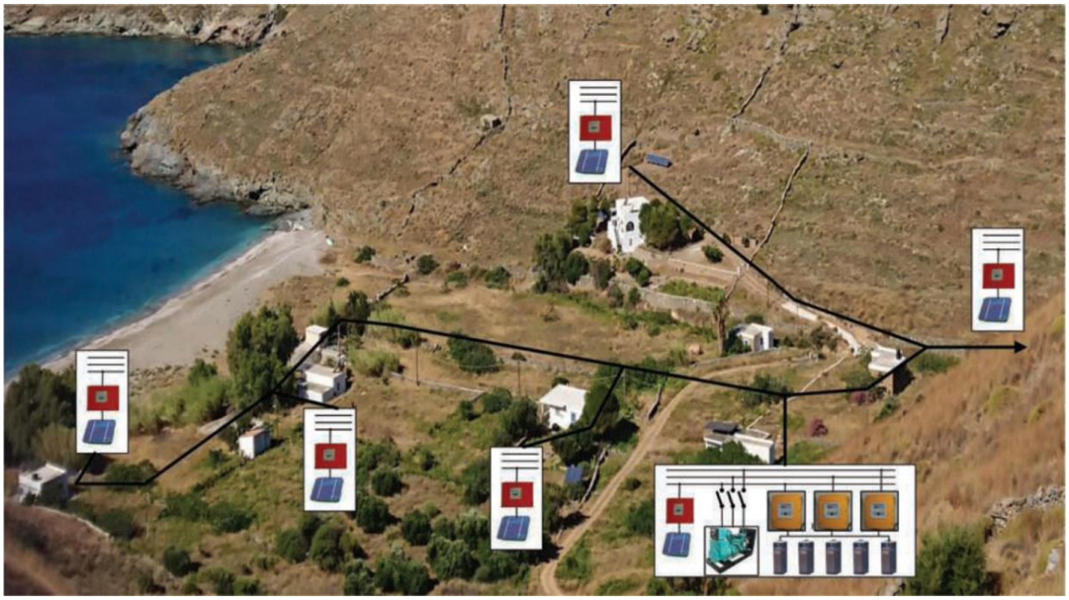

Figure 36. Overview of the Gaidouromantra microgrid

The electric infrastructure of the Gaidouromandra microgrid includes the following components:

- 14 vacation houses as consumers.
- 11.145 kW of solar PV panels: 6 distributed solar PV plants (rooftop and ground mounted).

  The solar PV plants are distributed as follows:

  - System house: 1.920 kWp (2x16 Solarex MSX60) connected to 3 inverters (3x SMA SB 1100).

    The System house is the centre of the microgrid, and it houses the energy storage battery, the diesel generator, the grid inverters and all the computer and communication equipment used to monitor the grid.
  - House 4: 1.920 kWp (2x16 Solarex MSX60) connected to 2 inverters (2x SMA SB 1100).
  - House 5: 1.200 kWp (2x10 Solarex MSX60) connected to 1 inverter (SMA SB 1100).
  - House 7: 2.025 kWp (9 Suntech STP225-20/Wd 225 Wp) connected to 1 inverter (SMA SB 1700).
  - House 8: 1.920 kWp (2x18 Solarex MSX60) connected to 1 inverter (SMA SB 2500).
  - House 10: 2.160 kWp (2x18 Solarex MSX60) connected to 1 inverter (SMA SB 2500).
  - A total of 16 kW was installed in the houses, divided as follows: System house: 6 kW, House 10: 6 kW and House 8: 4 kW. The model of the panels was Suntech STP225-20/Wd 225 Wp.
- A Lead-Acid battery bank OPzV (VRLA GEL) with nominal capacity of 1,000 Ah/11,900 Wh/48V, connected through 3 single phase battery inverters (SMA SI5048). During the day, the battery bank is connected to the AC, while at the night, it is disconnected, and the secondary system covers the control and monitoring equipment needs.
- 1 new battery system, model SunLight RES SOPzV 1190Ah (C120), with a capacity storage of 96 kWh. It uses the technology Valve Regulated Tubular Plate GEL battery.
- A 3-phase diesel generator of 22 kVA: PETROGEN P22E, with STAMFORD generator and PERKINS 404A-22G engine.

The total electricity production of the solar PV panels and the diesel generator is around 6.3 MWh/year. The share of electricity production per month is as follows (taking as example the year 2022):

Parameter	January	February	March	April	May	June	July	August	September	October	November	December	Total
Diesel generator electricity production (kWh)	24.3	19.8	-	-	0.2	-	1.1	156.5	0.5	-	-	10.4	212.8
Solar PV panels electricity production (kWh)	366.0	227.5	513.1	404.9	445.4	553.8	646.5	1,031.3	752.2	556.8	423.6	153.9	6,075.0
Total electricity production	390.3	247.3	513.1	404.9	445.6	553.8	647.6	1,187.8	752.7	556.8	423.6	164.3	6,287.8
RES Percentage	94%	92%	100%	100%	100%	100%	100%	87%	100%	100%	100%	94%	97%

Table 25. Share of electricity production with diesel generator and solar PV panels by month, for year 2022

The battery bank is installed in the system house. Its main objective is to maintain the continuous power supply, reducing as much as possible the participation of the diesel generator in the system (only when there is not solar PV production, and the batteries are deeply discharged).

Battery inverters play the role of energy management, regulating frequency either for load shedding or for solar PV derating. Besides, they manage the diesel generator start-up. In the system, the frequency is used as a communication signal between the power units, to manage the generated and consumed energy, and make the most of the battery lifetime.

This means that there are three states of operation according to the battery state of charge:

- When the charge of the batteries is below 30%, the diesel generator is put into operation to charge the batteries. In this case, the battery inverters use the generator frequency.
- When the charge of the batteries is below 15%, the frequency becomes 47 Hz to trigger the load controller and shut down the loads.
- If the charge of the batteries is above 30%, then the battery voltage increases, and the frequency changes from 50 Hz to 51 Hz and from 51 to 52 Hz.

The consumption of the island is made by the electric appliances of the houses (e.g., lamps, refrigerators, and dwelling pumps), which can be considered as ohmic and inductive constant. Most of this consumption can be shifted to moments when the solar PV generation is higher, for example, the water pumping. These water pumps are used to fill a water tank, which supplies water to the house. The water can be used in some small-scale agricultural activities and gardening.

It has to be remarked that in the Gaidouromandra microgrid, there is no need for energy for heating, since the houses are only used in summer holidays. In some cases, wood collected from the near zones can be used for small fireplaces. Cooking is covered with natural gas.

3.3.2. Access and cost of energy supply in Gaidouromantra Microgrid

In the Gaidouromantra microgrid, the main problem is the overloading of the batteries when many houses reach at the same time their maximum demand. This makes that the users of the microgrid have a grid-oriented energy culture, instead of a culture of autonomous energy supply.

For this reason, it is important to reach a combination of technical and behavioural demand response, to ensure that the energy management is optimized.

In Gaidouromantra, the number of devices which can be used in each household is limited to some lamps, refrigerators and dwelling pumps. Other big appliances, such as air conditioners, cannot be used. Besides, outages are common in peak hours, when the electricity demand is high, and the batteries are discharged.

As for the electricity price in Gaidouromantra, the local consumers have to pay a low price based on their consumption, in order to cover the operation and maintenance costs of the microgrid, as well as the purchase of fuel for the diesel generator. However, as the microgrid is not connected to the rest of the Greece power system, the tariff does not include the power term.

In general terms, the satisfaction of the Gaidouromantra electricity consumers is high, considering that the electricity cost is subsidized. During the peak season, some of them can be upset when they are required to reduce their consumption, or when there is an outage.

In the past, CRES (Centre for Renewable Energy Sources and Saving), a public company, was in charge of the operation and maintenance of the Gaidouromantra microgrid. However, the maintenance actions were funded with EU projects, so after the funding from EU projects stopped, this maintenance was neglected, and electricity bills were no longer issued. In 2019, the project Kythnos Smart Island, by DAFNI and ICCS-NTUA, gave the opportunity to renovate the microgrid and to create a new business model to guarantee the long-term sustainability of the microgrid.

3.3.3. Use of the ecoTools in Gaidouromantra Microgrid

In Gaidouromantra microgrid, there will be five different ecoTools: ecoMicrogrid, ecoDR, ecoCommunity, ecoPlatform and ecoResilience. The objective of these ecoTools is to maximize the use of the solar PV projects, while minimizing the diesel consumption, and to ensure that the microgrid is able to provide consumers with electricity when they demand for it.

The ecoTools will allow to introduce demand response in the 14 vacation houses of Gaidouromantra. Among other functionalities, ecoTools are expected to adapt the consumption of the houses to the availability of electricity produced with the solar PV panels, or when the battery is charged.

<u>Mapping UCs and, ecoTools in Gaidouromantra microgrid</u>

In the following table, it is possible to find a summary of the ecoTools and Use Cases used in the Gaidouromantra microgrid, developed in WP02. A higher detail on the Use Cases analyzed for the Gaidouromantra microgrid can be found in Deliverable 2.1: Report on requirements for each demo, use cases and KPIs definition.

In the table it is possible to identify the Use Cases and the proposed business models.

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Association with New BM
ecoMicrogrid	MG_1UC1	Microgrid monitoring	MG_2UC1.1	Real time microgrid monitoring and data acquisition	Smart Sustainable Energy Community
			MG_2UC1.2	RES production estimation	
			MG_2UC1.3	Data concentration, storage and management	

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Association with New BM
	MG_1UC2	Microgrid optimal management of operation	MG_2UC2.1	Effective communication with controllable assets	Energy Communities
			MG_2UC2.3	Multi-energy vector microgrid management of operation	
ecoDR	DR_1UC1	Increased energy monitoring at demand side	DR_2UC1.1	Real time monitoring of energy consumption	Demand response mechanisms
			DR_2UC1.2	Dynamic pricing-based energy cost computation	
	DR_UC2	Integration Interfaces for Load Management	DR_2UC2.1	Scheduling of loads	Pay-as-you-go
ecoPlatform	PT_1UC2	Platform as a service for dependent tools integration	PT_2UC2.1	Facilitate data exchange between dependent tools	Demand response mechanisms Energy Communities
	PT_1UC3	Data storage and cloud server	PT_1UC3.1	Route the microgrid data and data from dependent tools to cloud database	
			PT_1UC3.2	Facilitate archived data access for dependent tools using API	
ecoCommunity	CM_1UC1	Dynamic pricing of electricity*	CM_2UC1.1	Displaying the dynamic pricing based on shape of energy profile	Energy Communities
			CM_2UC1.2	Billing and payments	
			CM_2UC1.3	Data security and privacy	
	CM_1UC2	Scheduling and Coordination	CM_2UC2.1	Facilitating(display) of the scheduling and shifting of non-critical and flexible loads	
			CM_2UC2.2	Coordination of communal/shared loads	
	CM_1UC3	Outreach forum	CM_2UC3.1	Feedback and suggestions from users about the tools	
			CM_2UC3.2	Reporting of problems	
			CM_2UC3.3	Forum to share experiences	
	CM_1UC4	Guidance and Training	CM_2UC4.1	Training material (troubleshooting)	
			CM_2UC4.2	Easy-to-use multimedia material and step-by-step guides (walkthroughs)	
ecoResilience	RS_1UC3	WT Local Manufacturing and Testing	RS_2UC3.1	Testing of Small Wind Turbines using Standards	

Table 26. Association of ecoTools and UCs in the Gaidouromantra Microgrid: RE-EMPOWERED

3.3.4. Business Canvas and proposed business models

The Gaidouromantra microgrid is a very particular project, with some specific characteristics which are not common to other projects.

These particularities include the following:

- Limited number of consumers or clients: 14 vacation houses.
- The microgrid is not operated by any specialized entity or private or public body. Although its components are owned by the Centre for Renewable Energy Sources (CRES), the entity which developed the microgrid with the support of EU projects, since these EU projects came to an end, the components have been replaced by DAFNI.
- The investment cost is not covered by the users or "owners" of the local community, but has been paid by different European projects. This reduces the need for future incomes. If the cost of the project was not covered by these European projects, the project would not be economically feasible.

- The microgrid is totally disconnected from the Greece or Kythnos power grid. This involves that there are neither balance services, nor the security of supply is guaranteed. In turn, the cost of electricity is only the fuel cost and the operation and maintenance cost of the microgrid.

Thus, the proposed business model has to deal with these particularities, especially the lack of a connection to a big support grid.

The following business canvas has been defined for Gaidouromantra microgrid.

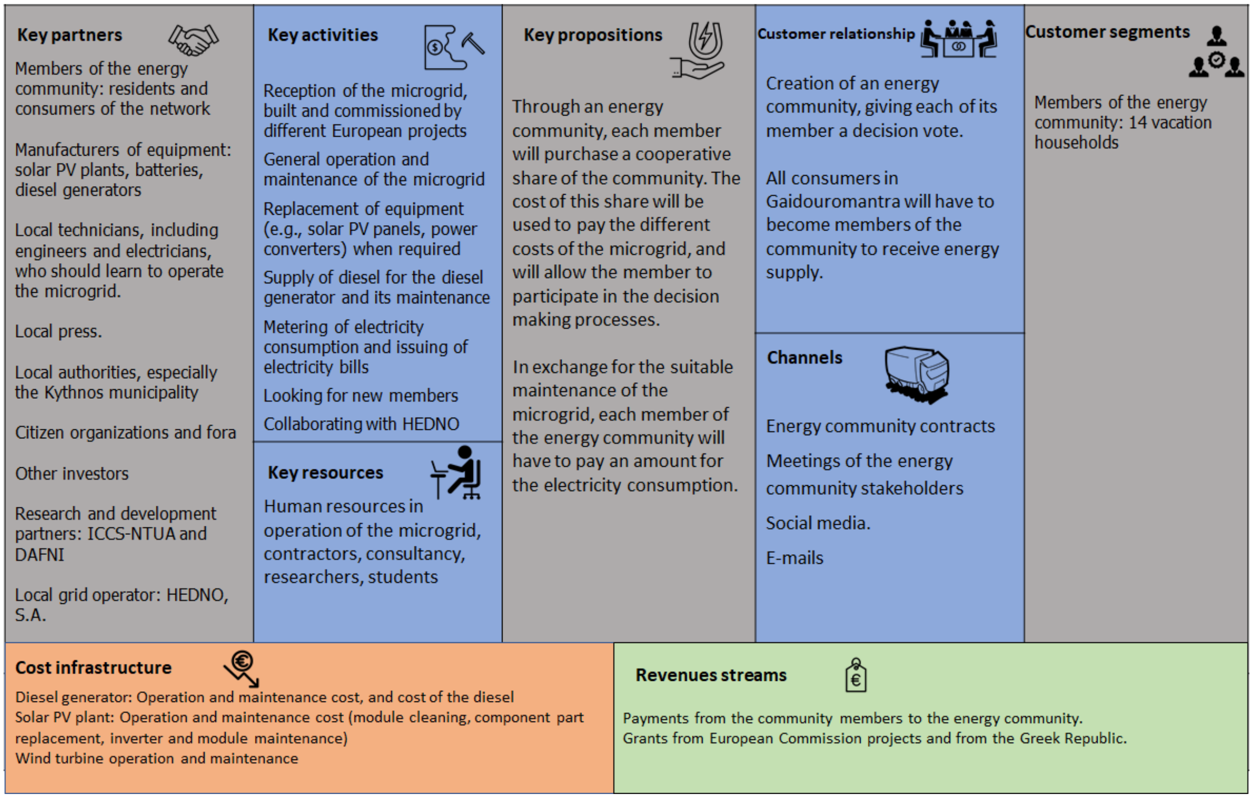

Figure 37. Proposed business canvas to Gaidouromantra microgrid

<u>Proposed business model</u>

As mentioned above, the creation of an energy community is considered to be the best business model for the Gaidouromantra microgrid.

The citizen energy community model is very appropriate for the Gaidouromantra microgrid, due to its reduced size, local character, basic principles of operation and organization, and the received support from different European Commission projects.

The energy community will be made up by all the residents of Gaidouromantra, in particular, 14 vacation house owners. Other stakeholders can be manufacturers of equipment, such as solar PV modules, batteries or diesel generators, other technical experts (including engineers and electricians), local authorities (such as the Kythnos municipality), citizen organizations and fora. In particular, it would be very recommendable that the Kythnos municipality become a member of the energy community, and supported the residents in the management of such energy community.

Local energy communities consist of all the consumers who contribute to the investment, participate in the decision-making processes, share the costs of the project, and benefit from the renewable energy produced.

In this case, the investment cost of the project is covered by different European Commission projects. This means that the new energy community of Gaidouromantra will only charge its members with the operation and maintenance costs of the microgrid. The members of the energy community will benefit from cheaper electricity, as well as a larger and more stable electricity supply.

Each member of the energy community has to hold at least one cooperative share. At least 50% plus one of the members must be resident of the Gaidouromantra microgrid. Additionally to the minimum cooperative share, each member can decide to purchase more shares, with a maximum limit of 20% of the cooperative capital. There is an exception for second-tier local authorities, which can participate in energy communities with a limit of 40% and first-tier local authorities, which can participate with a limit of 50%.

To cover the costs of the energy community, it is necessary that each member of the community makes some payments for the electricity which they receive. In the case of Gaidouromantra, this can be difficult since the inhabitants are used to be only charged for the fuel used.

Different business models have been considered to obtain these funds from the energy community members. The pay-as-you-go model has been selected, to complement the grants received from the European Commission to test different projects in the microgrid.

The objective of the business model is to bill the electricity consumption of each energy community member, to create a communal fund for the operation and maintenance of the microgrid.

The “pay-as-you-go” business model is based on that each resident or consumer of the Gaidouromantra microgrid purchases, in advance, the estimated energy which they foresee they will use.

In this model, each kWh of electricity is given a price, which is estimated to be appropriate to cover the operation and maintenance costs of the microgrid. This allows to obtain stable incomes for the operation of the microgrid. Besides, this business model allows to match better the electricity consumption with the production, using a pricing policy which offers discounts to these consumers which are able to modify their consumption patterns. This encourages consumers to adapt, even more than before, their electricity consumption to moments when there are solar PV production surpluses. This will minimize the use of diesel generators, as well as operation costs.

Other potential business models would not be appropriate for the Gaidouromantra microgrid, including the following ones:

- Funding and maintenance of the microgrid by its owner: As mentioned, the microgrid is not operated by a power company, which could invest in improvements, or in its maintenance.
- Application of fixed charges for electricity services: Inhabitants are not used to pay for these services, and probably they would be very dissatisfied to do so.
- Government energy services contracts: It is difficult to find an energy services company interested in managing the microgrid, which is very isolated, and generates low incomes, due to the reduced number of inhabitants.
- Power purchase agreements: Similar to the energy services contracts, the reduced energy consumption is a disadvantage for this model.
- Operation and maintenance contracts: This was the model used before and was quite satisfactory. The main problem was the lack of funds to pay for the maintenance actions.

Community engagement

As mentioned before, the users of the Gaidouromantra microgrid have been used to adapt their consumption to the availability of energy, and the possible overloads of the microgrid if the energy consumption was too high.

For this reason, it is not difficult to involve citizens in the use of advanced demand response tools, and to adapt their consumption to the availability of energy.

It is necessary to promote a behavioural change, from adapting consumption to avoid overloads, to adapt it to the availability of electricity produced with the solar PV plant, to try to minimize the use of diesel generator.

On the other hand, to create an energy community based on the pay-as-you-go model, citizens should be used to pay for the electricity they use, and not for the diesel use. The cost of this electricity should cover the whole cost of the energy community, but it is necessary to make users aware of the benefits stemming from the energy community, to make them accept the probable increase in the electricity price.

It can be also mentioned that in the last years, payments with bank transfers or credit card are becoming more common, but most of elderly people still use cash for the payments, what makes difficult the automatization of payments.

ICCS-NTUA and DAFNI will be in charge of the training and engagement of the energy community members. They will provide support in the establishment, operation and maintenance of the microgrid and the energy community.

Key partners which should be taken into account in the business model

In this chapter, a list of the main stakeholders which are involved in the Gaidouromantra microgrid business model is included:

- Residents and owners of the vacation houses, as well as other consumers of the network (if any).

- Manufacturers of equipment: solar PV panels, batteries, diesel generator.
- Local technicians, including engineers and electricians who should learn to operate the microgrid.
- Local press, in charge of the promotion and dissemination of the project.
- Local public authorities, especially the Kythnos municipality. ICCS-NTUA and DAFNI will collaborate with the Kythnos municipality to develop commitment to the decarbonization of the island.
- Citizen organizations and fora.
- Other investors.
- Research and development partners, including ICCS-NTUA, one of the partners of the RE-EMPOWERED project. ICCS-NTUA and DAFNI would be in charge of providing support to the Gaidouromantra community for the local engagement, and they are in charge of the operation of the Gaidouromantra microgrid.
- Local grid operator for the Kythnos Island, HEDNO, S.A. Although the Gaidouromantra microgrid is totally disconnected from the rest of the Kythnos grid, communication channels will be developed with HEDNO, to support the energy community with grid issues.

Key activities which can be developed in the business model

To make the proposed business model successful, it is necessary to develop the following activities:

- Reception of the microgrid, built and commissioned by different European projects.
- General operation and maintenance activities in the microgrid.
- Replacement of equipment (solar PV panels, inverters) when needed.
- Supply of diesel for the diesel generator, and maintenance of the diesel generator.
- Metering of electricity consumption, and issuing of electricity bill.
- Identification of potential new members of the energy community.
- Develop collaboration agreements with HEDNO, S.A., to ensure that the microgrid is correctly operated and maintained.

In the Gaidouromantra microgrid, clients can obtain information about their consumption and energy uses from SMS or phone calls. This information is related to the consumption patterns or consumption in previous months. However, there is not information about measures to reduce or shift power demand.

3.3.5. Economic sustainability analysis for Gaidouromantra microgrid

The Demo Site leader of Gaidouromantra microgrid has been asked to provide some information about the investment cost, the operation and maintenance costs of the Demo Site, and expected incomes. Using this information, an economic model has been prepared to evaluate the profitability of the Gaidouromantra microgrid.

To design this model, the following information has been used:

- Investment cost: The total cost of the infrastructure and equipment to be installed in the Gaidouromantra microgrid will amount to €147,656.22, which is divided as follows:
  - Generator: €11,110.40.
  - Electrical equipment and installation services: €3,718.45.
  - 1 fire extinguishing system: €2,318.80.
  - Batteries: €14,808.97.
  - Microgrid control system: €35,669.60.
  - Wind turbine: €25,000.
  - Solar PV plants and inverters: €30,000.
  - Landscaping: €10,000.
  - Other equipment, material and work: €15,000
- Investment cost of developing and installing the ecoToolset: In Gaidouromantra Demo Site, the ecoToolset includes the ecoDR, ecoMicrogrid, ecoResilience, ecoPlatform and ecoCommunity.

  The development and design cost of these ecoTools is independent from its use in each Demo Site. On the other hand, the need for hardware and installation costs will be negligible.
- Estimated operation and maintenance costs: This includes the cost of fuel, cost of maintenance (corrective, preventive and predictive) of the existing equipment:
  - Cost of the diesel for the diesel generator: It is estimated that the diesel fuel costs around €2.1/litre.

    In a normal year, the microgrid uses an average of 155 litres, with a total cost of €325.50/year, running the generator 42 hours per year.

    The development of the RE-EMPOWERED project will allow to reduce the consumption of fuel to 40 litres per year (among 30 and 50 litres per year), with a cost of €84/year.
  - Operation and maintenance of the diesel generator: This cost has been estimated to be around €3.5/operation hour, considering that each maintenance actions

requires that experienced professionals travel to the remote location of the microgrid, the replacement of oil and parts, and so on.

Between 1 and 2 visits per year are common to carry out the maintenance of the diesel generator, with a total cost of €147/year.

The use of the ecoToolset will allow to reduce the maintenance hours by 70-80%, this is, the costs once the ecoToolset is working will be around €36.75/year.

- Operation and maintenance cost of solar PV panels: It is estimated that a solar PV project has a total operation and maintenance cost of €30/year/kW, including module cleaning, components replacement, inverter and module maintenance, and monitoring and inspection costs.

  Since the total installed capacity of solar PV panels is 11.145 kW, then the total operation and maintenance cost is €334.35/year

- Operation and maintenance of the wind turbine: A cost of €213.33/kW is expected from the wind turbine which will be installed in the Gaidouromandra microgrid. This cost includes €80/year for material and transport, and €133.33/kW for a working day of 1 person.

- Estimated revenue from the project:

  The project developer will not receive direct revenues, since one of the conditions of the microgrid is that no costs are passed to the residents. They are considered as users of a pilot and test model, and in exchange for their availability to test different European projects in the microgrid, they are not charged any cost.

  It will be supposed that the final users have to pay for the used diesel for the generator.

  - Payments for the diesel: The final clients have to pay for the used diesel, this is, €84/year.
  - Saved diesel and reduction in the cost of operation and maintenance: As described before, the installation of the microgrid will reduce the cost of fuel from €325.50/year to €84/year (a saving of €241.50/year), and operation and maintenance costs will be reduced by €110.25/year.

    This means that the savings of diesel and the reduction of the operation and maintenance costs will amount to €351.75/year.

- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is €147,656.22/year, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €7,382.81/year.

- The corporate taxes are around 22%.
- In the economic model, no financial costs are considered.

Using the information provided below, and using a discount rate of 10%, the following cash flows are obtained during the 20-years lifetime of the Gaidouromantra microgrid:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the demo site (€)	- 147,656 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Generator	- 11,110 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electrical equipment and installation services	- 3,718 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
1 Fire-extinguishing system	- 2,319 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Batteries	- 14,809 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Microgrid control system	- 35,700 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Wind turbine	- 25,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Solar PV plant and inverters	- 30,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Landscaping	- 10,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Other equipment/materials/work	- 15,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€) from clients (payment for the diesel)	- €	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €
Incomes from diesel savings	- €	352 €	352 €	352 €	352 €	352 €	352 €	352 €	352 €	352 €	352 €
Operation and maintenance costs (€)	- €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €
Operation of the diesel generator (€)	- €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €
Cost of diesel (€)	- €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €
Maintenance of the solar PV plant	- €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €
Maintenance of the wind turbine	- €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €
Depreciation and amortization (€)	- €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €
Profit before taxes (€)	- €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €
Deferred corporate taxes (€)	- €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €
Net cash flow (€)	- 147,656 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €
Accumulated net cash flows (€)	- 147,656 €	-146,213 €	-144,771 €	-143,328 €	-141,885 €	-140,443 €	-139,000 €	-137,557 €	-136,114 €	-134,672 €	-133,229 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the demo site (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Generator	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electrical equipment and installation services	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
1 Fire-extinguishing system	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Batteries	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Microgrid control system	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Wind turbine	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Solar PV plant and inverters	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Landscaping	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Other equipment/materials/work	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€) from clients (payment for the diesel)	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €
Incomes from diesel savings	352 €	352 €	352 €	352 €	352 €	352 €	352 €	352 €	352 €	352 €
Operation and maintenance costs (€)	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €
Operation of the diesel generator (€)	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €
Cost of diesel (€)	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €
Maintenance of the solar PV plant	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €
Maintenance of the wind turbine	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €
Depreciation and amortization (€)	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €	- 7,383 €
Profit before taxes (€)	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €	- 7,615 €
Deferred corporate taxes (€)	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €	1,675 €
Net cash flow (€)	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €	1,443 €
Accumulated net cash flows (€)	- 131,786 €	-130,344 €	-128,901 €	-127,458 €	-126,015 €	-124,573 €	-123,130 €	-121,687 €	-120,244 €	-118,802 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	- 135,373
IRR (%)	-12.197%

Table 27. Economic model for the Gaidouromantra microgrid, including the cash flow model and a profitability analysis.

The results of the economic model for Gaidouromantra are negative. Since no payments are made by the residents of the microgrid, the only incomes for the operator are the savings in diesel and operation and maintenance, which are too low to allow to recover the investment.

The following figure shows the cash flow diagram for the Gaidouromantra microgrid.

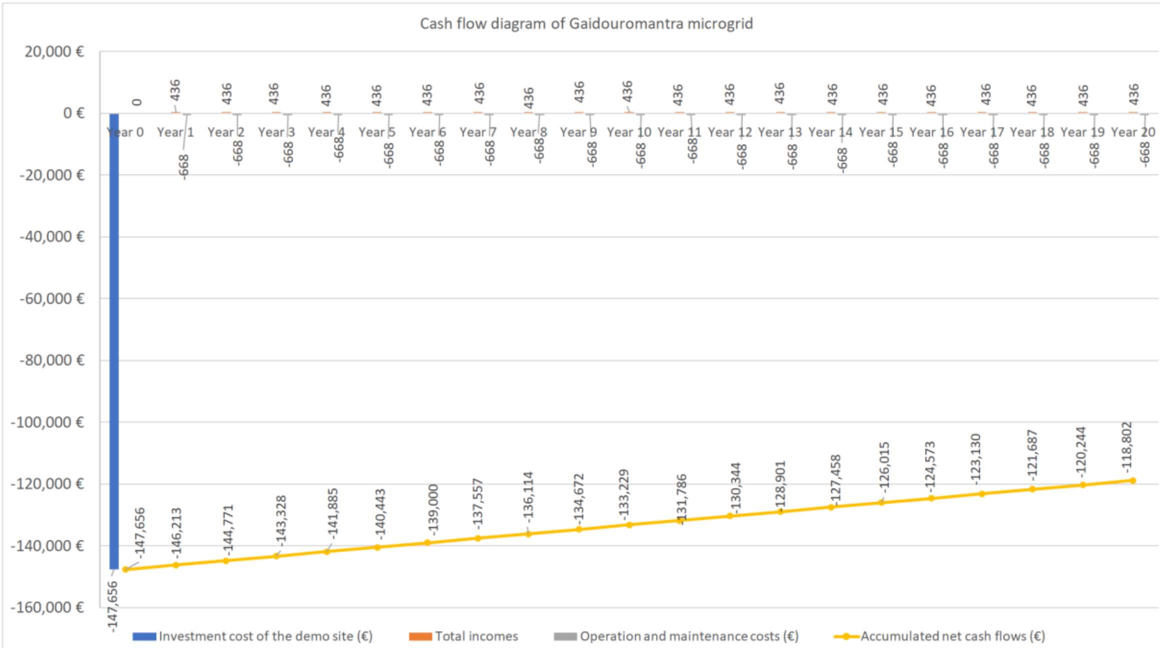

Figure 38. Cash flow diagram of the Gaidouromantra microgrid

This analysis has considered the total investment cost of the microgrid, and also takes into account that the clients are only charged the real use of diesel. As can be seen, the model has negative results.

It would be possible to make the same analysis, considering that the total investment cost of the microgrid is covered by the European Commission, through different projects.

In that case, the users of the microgrid would have to be charged the total operation and maintenance cost of the microgrid. This is, instead of only paying the cost of diesel, users should be charged a fee for the operation of the diesel generator, the maintenance of the solar PV plant, and the maintenance of the wind turbine.

The analysis of the minimum fee to be charged to the clients, to make that costs are recovered with incomes, is carried out in the following cash flow model:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the demo site (€)											
Incomes (€) from clients (payment for the diesel)		84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €
Additional payment from clients		584 €	584 €	584 €	584 €	584 €	584 €	584 €	584 €	584 €	584 €
Operation and maintenance costs (€)		- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €
Operation of the diesel generator (€)		- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €
Cost of diesel (€)		- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €
Maintenance of the solar PV plant		- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €
Maintenance of the wind turbine		- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €
Depreciation and amortization (€)		- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Profit before taxes (€)		- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Deferred corporate taxes (€)		- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Net cash flow (€)		- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Accumulated net cash flows (€)		- €	- €	- €	- €	- €	- €	- €	- €	- €	- €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the demo site (€)										
Incomes (€) from clients (payment for the diesel)	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €	84 €
Additional payment from clients	584 €	584 €	584 €	584 €	584 €	584 €	584 €	584 €	584 €	584 €
Operation and maintenance costs (€)	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €	- 668 €
Operation of the diesel generator (€)	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €	- 37 €
Cost of diesel (€)	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €	- 84 €
Maintenance of the solar PV plant	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €	- 334 €
Maintenance of the wind turbine	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €	- 213 €
Depreciation and amortization (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Profit before taxes (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Deferred corporate taxes (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Net cash flow (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Accumulated net cash flows (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €

Corporate taxes	22%
Discount rate (%)	10%
NPV	-
IRR (%)	
First positive accumulated cash flow	
Payback (years)	

Table 28. Economic model for the Gaidouromantra microgrid, to recover the made expenses

The conclusion of this analysis is that it would be necessary to charge, at least, €668.43 per year to the microgrid users, to recover the expenses made in the microgrid (not the investment cost).

This would allow the project to cover its costs, but not obtaining an economic profit.

Another interesting analysis is the creation of an energy community in Gaidouromantra.

In this assessment, only the cost derived from the creation of the energy community, and the yearly operation and maintenance costs are considered. The investment cost of the microgrid would be covered by the European Commission.

The following incomes and expenses are considered for the economic sustainability analysis of the Gaidouromantra microgrid:

- Incomes for the energy community:
    - Registration of clients in the energy community: All members of the energy community would have to pay a registration fee in the first year. The total income would amount to €1,000, and would be paid only once.

- Cooperative rations of the energy community: This would involve incomes of €2,000, during the first year.
    - Annual electricity fee: All members of the energy community will be charged €960 per year, for the electricity supply.
    - Revenues from electricity: Additionally, the energy community will obtain €1,645 per year, for the electricity.
    - Reserve for equipment replacement and upgrade: Another income would be the reserve for equipment replacement and upgrade, worth €600 per year.
- Expenses for the energy community:
    - Establishment and registration of the energy community: To set the energy community, it will be necessary to pay a registration fee of €500 during the first year.
    - Accountant: The fees for an accountant in charge of the account management of the energy community are estimated to be €200 per year.
    - Annual diesel cost: The diesel consumption of the energy community will be around €1,500 per year.
    - Operation and maintenance cost: Local technicians which will be in charge of the maintenance of the microgrid will be paid €1,000 per year. This also includes the cost of spare parts, consumables and other material used in maintenance actions.
    - Internet connection cost: The management of the microgrid, and the communication with all members of the energy community, will require a strong and stable internet connection, whose cost will be around €300.
- Legal reserve: Law 4513/2018 on Energy Communities and Other Provisions establishes that each energy community has to allocate at least 10% of the surplus to a legal reserve, regardless the energy community is for-profit or non-for profit.

  This legal reserve is subtracted from the profit, but is not considered in the cash flows.
- The corporate taxes are around 22%.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Incomes of the energy community		6,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €
Registration of clients in the energy community		1,000 €									
Cooperative rations of the energy community		2,000 €									
Annual electricity fee		960 €	960 €	960 €	960 €	960 €	960 €	960 €	960 €	960 €	960 €
Revenues from electricity		1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €
Reserve for equipment replacement and upgrade		600 €	600 €	600 €	600 €	600 €	600 €	600 €	600 €	600 €	600 €
Expenses of the energy community		- 3,500 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €
Establishment and registration of the energy community		- 500 €									
Accountant		- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €
Annual diesel cost		- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €
Operation and maintenance service costs		- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Internet connection cost		- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €
Surplus		2,705 €	205 €	205 €	205 €	205 €	205 €	205 €	205 €	205 €	205 €
Legal reserve (10%)		- 271 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €
Profit before taxes (€)		2,435 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €
Deferred corporate taxes (€)		- 536 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €
Net cash flow (€)		2,440 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €
Accumulated net cash flows (€)		2,440 €	2,625 €	2,810 €	2,995 €	3,180 €	3,364 €	3,549 €	3,734 €	3,919 €	4,104 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Incomes of the energy community	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €	3,205 €
Registration of clients in the energy community										
Cooperative rations of the energy community										
Annual electricity fee	960 €	960 €	960 €	960 €	960 €	960 €	960 €	960 €	960 €	960 €
Revenues from electricity	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €	1,645 €
Reserve for equipment replacement and upgrade	600 €	600 €	600 €	600 €	600 €	600 €	600 €	600 €	600 €	600 €
Expenses of the energy community	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €	- 3,000 €
Establishment and registration of the energy community										
Accountant	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €	- 200 €
Annual diesel cost	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €
Operation and maintenance service costs	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Internet connection cost	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €	- 300 €
Surplus	205 €	205 €	205 €	205 €	205 €	205 €	205 €	205 €	205 €	205 €
Legal reserve (10%)	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €	- 21 €
Profit before taxes (€)	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €
Deferred corporate taxes (€)	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €	- 41 €
Net cash flow (€)	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €	185 €
Accumulated net cash flows (€)	4,289 €	4,474 €	4,659 €	4,844 €	5,029 €	5,214 €	5,398 €	5,583 €	5,768 €	5,953 €

Corporate taxes	22%
Discount rate (%)	10%
NPV	3,624 €

Table 29. Economic model for the Gaidouromantra energy community

According to the previously described economic model, the Gaidouromantra energy community which could be created to manage the microgrid would have low positive incomes, reduced to €185 each year. These benefits could be allocated to improvements in the energy community or could be saved along with the legal reserve to carry out unexpected maintenance actions.

The net present value of the energy community is positive, and reaches €3,624, what shows that the business model, defined for the Gaidouromantra microgrid is appropriate.

Additionally, the cash flows have been represented in a cash flow diagram:

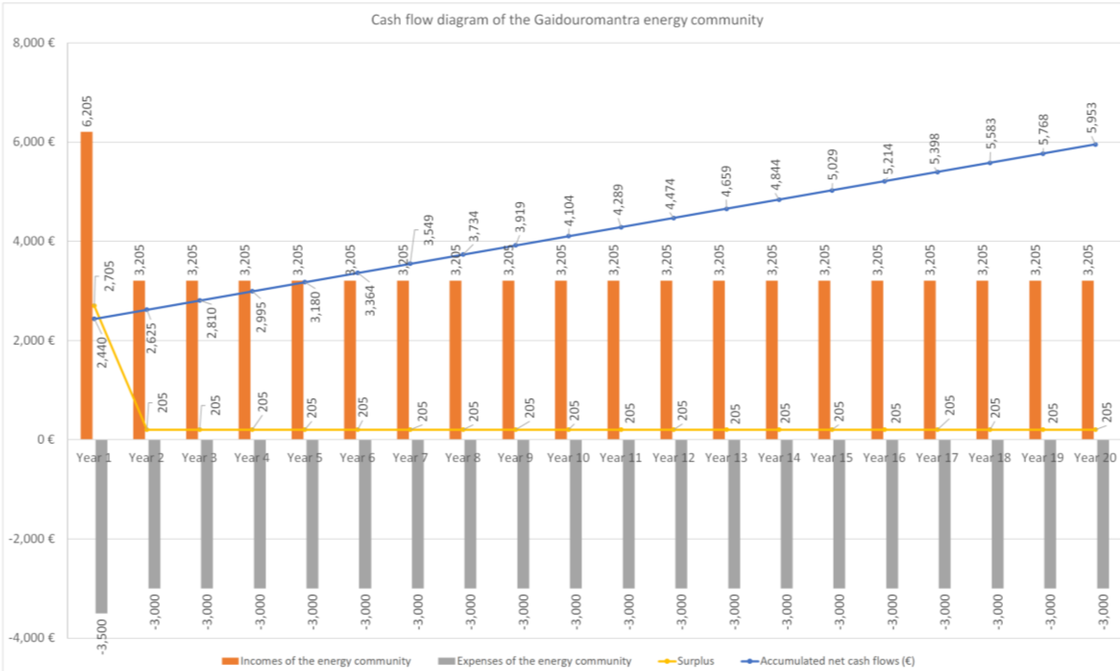

Figure 39. Cash flow diagram of the Gaidouromantra energy community

3.3.6. Financing tools applicable to the Demo Site. Availability of subsidies.

The following is an analysis of the alternative financing tools which are available for the total investment expected for the Gaidouromantra microgrid.

First of all, it is necessary to consider that the total investment cost will amount to €147,656.22, for the construction and development. Actually, the total investment for the development and technical support of the Gaidouromantra microgrid has been covered with funds from different European Programmes, such as PV-MODE, MORE and MORE MICROGRIDS. This means that the assessment of the potential financing tools is theoretical, and will only consider the new devices.

Considering the cost of the investments, there are the following alternatives:

- Loan: A loan is offered by banks and other financial institutions. It can last, in general, for 3-10 years, although it can be longer depending on the expected useful lifetime of the project. Loans, in general, cover only between 50% and 70% of the cost of the project, and a corporate guarantee is required from the borrower.

  The interest rate of a loan is lower than other alternatives, since there exists a guarantee.

- Leasing: This instrument is appropriate when there is a specific asset, such a solar PV plant, a generator or a wind turbine. The duration of the leasing contract depends on the expected lifetime of the asset, but it is usually between 5 and 12 years.

  A leasing contract can cover between 50% and 70% of the cost of the equipment, and corporate and personal guarantees are required.

Leasing is considered as debt in the annual statements.

The interest rate of leasing contracts is higher than the interest rate of loans.

- Renting: This instrument is quite similar to leasing. As in this case, there exists a specific asset which can be used as the main guarantee for the operation, although personal and corporate guarantees can be also required.

  The duration of the renting contract is usually between 2 and 10 years, and can cover between 50% and 100% of the cost of the project. In this case, the renting contract does not only cover the cost of the equipment, but also other costs, such as services, project design, civil works, licenses and so on.

  The client is required to present some corporate and personal financial guarantees, but renting is not considered as debt in the company's annual statements.

  The interest rates are similar to that of leasing: the user pays a periodic fee for the use of the good.

- Crowdfunding: Due to the amount of the project, lower than €300,000, this financial instrument can be an option for Gaidouromantra.

  Crowdfunding is based on online platforms, where many people can participate investing a small amount of money. The project is proposed by the project developer to an online crowdfunding platform. This platform analyses the risk and financial and technical viability of the project.

  If the project is considered to be fundable, then the crowdfunding platform publishes the project on its website and any citizen can support it.

  Crowdfunding is a loan, but has some advantages. It is a very suitable tool for citizen engagement, since it is necessary that many citizens participate in the financing with a limited amount of money. For this reason, crowdfunding is usually a good instrument for projects socially and environmentally sustainable, such as projects related to renewable energy, energy efficiency, water treatment, health, electric mobility, development of Internet networks in a village, and so on.

  Crowdfunding loans usually have a term among 1 and 8 years, and the interest rate is higher than a typical loan. Their main advantages are that some projects which are not very economically attractive can be supported if they are socially and environmentally sustainable. A crowdfunding loan can cover up to 100% of the investment.

The use of other innovative financing tools, such as forfaiting, project finance or equity is limited due to the limited size of the investment, as well as the reduced incomes expected from the project.

4. Energy system and Business models applied in India

4.1 Ghoramara Island Microgrid: West Bengal, India

The Ghoramara Island is located approximately 92 km south of Kolkata, in the Sundarban Delta complex of the Bay of Bengal in India. The following images show the location of the island in the Bay of Bengal, as well as the structure of the village.

The island has different villages. The nearest mainland is Kakdwip, located 5 km away. It takes around 1 hour to reach this city, using diesel operated boats and paddle boats. Ghoramara Island has roughly 5 km^2 in area, and a population of 3,000 residents, in 1,100 houses (data from 2016). Out of the population, 50% of them belong to scheduled caste (SC) category, while 20-30% belong to a minority group.

The houses are mainly single-family dwellings and are mud houses or huts.

There are four primary schools (around 500 students), one higher secondary school (420 students) and a primary health care centre in the island. The island also has around 30 shops in the central area, near the schools, including grocery shops, tea stalls, photocopiers, toys and electronic shops. The administration of the island is controlled by an elected Gram-panchayat system.

Residents live in poor conditions, and are affected by severe cyclonic storms, which happen every 5-10 years. With each cyclone, the electricity supply is disturbed, due to damages in solar PV panels, and the supply of livelihood items is stopped, what makes it difficult to restore normality.

The economy of the island is based on agriculture, mainly betel leaves and rice crops. This activity employs 85%-90% of the working people. The remaining inhabitants work in fishing.

There are two rice-cum-hauler mills in the island, run by diesel engine. To move in the island, people use four e-rickshaws, which are charged with a diesel generator, which is neither economical, nor environmentally suitable. Pedal rickshaws are used to carry loads.

4.2.1 Energy system and Business models in Ghoramara island microgrid

The Ghoramara Island energy system has the following infrastructures:

- The island is isolated from connection to the utility grid, so the main energy supply are kerosene lamps for lighting. A reduced number of solar PV panels is installed in the rooftop of individual houses and shops, which are mostly used for mobile charging and glowing of LED lamps (there are one or two lamps in each home). These solar PV panels cannot cover the whole power demand. Around 60-70% of the households have these systems, and around 20% of the households own a TV.
- Around 100 streetlights, which use solar panels are installed in streets, but are now inoperative.

The following table includes a summary of the energy equipment which was installed before the development of the RE-EMPOWERED project:

Energy vectors	Type of installation	Capacity
Solar	A few solar PV panels are mounted on the roof-top of some individual houses to provide power to one/two LED lamp and mobile charging. In some cases, battery is damaged, and replacement is not yet done. Around 100 solar powered streetlights were installed across the island, but most of them are presently non-functional due to non-replacement of battery.	Power rating is corresponding to one PV module (30-70 W). These solar PV modules are mounted in only a few houses.
Wind	A 3-kW wind turbine is mounted at the vicinity of school which is not operational after the cyclonic storm "AMPHAN".	3 kW

Table 30 Existing energy infrastructure in Ghoramara

It can be mentioned that the average wind speed in the island is 4.6-5.6 m/s, which can generate around 6,200-7,200 kWh of wind energy per year, from a 5-kW wind turbine (this is, 19-20 kWh/day).

The objective of the RE-EMPOWERED project is to develop a local microgrid system, to provide the Ghoramara Island with a secure and sustainable electricity supply, and to improve the economy and quality of life of inhabitants:

	Proposed hardware facilities	Capacity
1.	A 160 kW off-grid system	150 kW solar PV + 10 kW wind + 720 kWh BESS, with distribution line to 650 houses It also includes a 160-kW inverter.
2.	2 wind turbines	2 5-kW wind turbines and their interfacing with the microgrid
3.	A 10-kW advanced microgrid, developed by the RE-EMPOWERED project	7.5 kW solar PV + 2.5 kW wind + 50 kWh BESS, with RE-EMPOWERED developed technologies. Partial Power Converters (PPC) for higher capture of solar energy. SiC based DC-DC converters for BESS and wind power integration. Modula configuration and in-built communication.
4.	A Load flow controller	5 kW
5.	Load limiters	They limit the power to a preset limit, avoiding power overconsumption. Maximum load capacity of 300 W and adjustable load range of 5 W.

	Proposed hardware facilities	Capacity
		Automatic reconnection after overload in cleared. Located in each house. More than 100 units have been installed.
6.	A Power Quality Conditioner (STATCOM)	10 kVA
7.	Deployment of electric three wheelers	2 Pay-load: 800 kg. Motor rating: 1.2 kW BLDC 48 V, 100 Ah Lithium-Ion battery Millage: 60 – 70 km per charge Speed: 25 km/hour
8.	A charging station	A 15-kW charging station, with 15 kW solar PV panels and 72 kWh BESS, and three ports with 3.3 kW each.
9.	Dimmable Street light	80 streetlights will be deployed out of which 20 are energy efficient dimmable
10.	Smart meters with advanced features	50 smart meters with remote monitoring and management facilities Additionally, 5 advanced smart meters with features such as management of non-critical loads, and real time dynamic pricing. Each smart meter has a capacity of 2 kW.
11.	Wind resilient structures	Wind resilient structure has been considered for 20 kW PV and 5 kW wind installation. The commercially available conventional structures will be used for rest of the installations.
12.	Electric boat	An electric boat has been deployed which can carry 15 persons with a speed of 6 knots. The boat has 3 kW on-board solar panel, 2x6 kW electric outboard motor and 2x12 kWh Li-Ion battery.
13.	Solar Powered high-mast system	A high mast light has been installed in the market area of the Ghoramara Island. It has 4 LED lamps of 40 W each. Additionally, it has 4 solar PV panels with 200 Wp capacity, and a battery with 12.8 V and 120 Ah. It provides electricity for a maximum of 3 days.

Table 31 Planned installations in Ghoramara island

4.2.2 Access and cost of energy supply in the Ghoramara island

As commented in the chapter before, Ghoramara Island is not connected to the utility grid, and is only communicated with the mainland through boats. Besides, it has difficult weather conditions, with periodic severe cyclones, which can affect the installed 250 kW proposed microgrid (230 kW with conventional technology, and 20 kW with technology developed during RE-EMPOWERED).

Residents have no access to the electricity grid, and their supply relies on the production from solar PV panels, which are available only in some households. This involves that inhabitants do not pay for the electricity, as there is not a regular supply.

There is neither a normal access to the Internet. Besides, it is difficult for inhabitants to obtain solar PV panels. It is not possible to install large scale solar PV plants, due to the topography of the zone.

4.2.3 Use of ecoTools in Ghoramara Island Microgrid

In Ghoramara Island, eight different ecoTools will be tested, specifically: ecoConverter, ecoDR, ecoResilience, ecoMicrogrid, ecoVehicle, ecoPlatform, ecoMonitor and ecoCommunity. This is based on the analysis carried out in WP02, where innovative solutions were identified for each Demo Site.

Mapping UCs and, ecoTools in Ghoramara Island Microgrid

The following table shows the use of ecoTools and use cases in the Ghoramara Island Microgrid. This is based on the ecoTool assessment carried out in Deliverable 2.1: Report on requirements for each demo, use cases and KPIs definition:

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Association with new business model
ecoMicrogrid	MG_1UC1	Microgrid monitoring	MG_2UC1.1	Real time microgrid monitoring and data acquisition	Use of innovative algorithms to monitor power flows
			MG_2UC1.3	Data concentration, storage and management	
	MG_1UC2	Microgrid optimal management of operation	MG_2UC2.1	Effective communication with controllable assets	
			MG_2UC2.2	Multi objective microgrid management: Energy Production Optimization, Storage & Purchase	
			MG_2UC2.3	Multi-energy vector microgrid management of operation	
ecoDR	DR_1UC1	Increased energy monitoring at demand side	DR_2UC1.1	Real time monitoring of energy consumption	Use of smart devices Use of innovative algorithms to monitor power flows Development of a pricing algorithm
			DR_2UC1.2	Dynamic pricing-based energy cost computation	
	DR_1UC2	Integration Interfaces for Load Management	DR_2UC2.1	Scheduling of loads	
			DR_2UC2.2	Programmable Load shedding controller	
ecoPlatform	PT_1UC2	Platform as a service for dependent tools integration	PT_2UC2.1	Facilitate data exchange between dependent tools	
	PT_1UC3	Data storage and cloud server	PT_2UC3.1	Data cloud storage	
			PT_2UC3.2	Facilitate archived data access for dependent tools using API	
ecoMonitor	MN_1UC1	Air quality surveillance	MN_2UC1.1	Acquisition and transmission of air quality parameters data	

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Association with new business model
	MN_1UC2	Drinking water quality surveillance	MN_2UC1.2	Acquisition and monitoring of water quality	
ecoCommunity	CM_1UC1	Dynamic pricing of electricity*	CM_2UC1.1	Displaying the dynamic pricing based on shape of energy profile	Energy cooperative/community
			CM_2UC1.2	Billing and payments	
	CM_1UC2	Scheduling and Coordination	CM_2UC2.1	Facilitating(display) of the scheduling and shifting of non-critical and flexible loads	
			CM_2UC2.2	Coordination of communal/shared loads	
	CM_1UC3	Outreach forum	CM_2UC3.1	Feedback and suggestions from users about the tools	
			CM_2UC3.2	Reporting of problems	
			CM_2UC3.3	Forum to share experiences	
	CM_1UC4	Guidance and Training	CM_2UC4.1	Training material (troubleshooting)	
			CM_2UC4.2	Easy-to-use multimedia material and step-by-step guides (walkthroughs)	
ecoResilience	RS_1UC1	Optimal passive resilient support structure for solar photovoltaic system	RS_2UC1.1	Optimal selection of parameters	Development of cyclone resilience structures
			RS_2UC1.2	Computational fluid dynamics (CFD) and structural analysis (CSA) of support structures	
			RS_2UC1.3	Experimental validation of the designed structure through wind tunnel testing	
			RS_2UC1.4	Design of resilient foundation for solar photovoltaic system	
	RS_1UC2	Improved resilient tower and passive mechanism for wind turbine blades	RS_2UC2.1	Preliminary design of a tower truss structure and its optimization	
			RS_2UC2.2	Design of a resilient mechanism to reduce wind loads on blades and its optimization	
			RS_2UC2.3	Laboratory and field testing of the mechanism	
			RS_2UC2.4	Resilient foundation for wind turbine tower structure	
	RS_1UC3	WT Local Manufacturing and Testing	RS_2UC3.1	Small Wind Turbine Manufacturing and installation	
ecoVehicle	VH_1UC1	Tailor-made Electric Vehicle (EV) charging facility	VH_2UC1.1	Effective control strategies for dc-bus voltage regulation	Renting of electric vehicles
			VH_2UC1.2	State of charge and temperature estimation	
			VH_2UC1.3	Temperature regulated charging strategies	
	VH_1UC2	Selection and customization of rickshaw	VH_2UC2.2	Customization of the vehicle to the Demo Site requirements	
	VH_1UC3	Onboard energy management for e-Boat	VH_2UC3.1	PV Integration with e-Boat	
ecoConverter	C_UC1	Control of power electronics	C_UC1.1	Development and control of power electronic converters	
			C_UC1.2	Testing and on-filed demonstration of the power electronic converters satisfying various standards	
			C_UC1.3	Exchange, replicability and scalability in EU and India	

Table 32. Association of ecoTools and UCs in the Ghoramara Island Microgrid: RE-EMPOWERED

4.2.4 Business Canvas and proposed Business models

The objective of the project is to provide a safe electricity supply to both households and businesses, improving their welfare and quality of life.

However, the inhabitants have limited economic capacity, and for this reason, it is essential to develop a complex business model, where there are different income sources. This ensures that the offered services are affordable for the potential users, and that they can make use of them.

The Demo Site combines different ecoTools, to demonstrate state-of-the art technologies, which can solve the specific problems of the Ghoramara Island microgrid. Among them, it is possible to mention:

- Use of smart devices and solutions for automation and remote monitoring of the system.
- Improvement of voltage profile and other power quality issues of the micro grid.
- Use of innovative algorithms and control simulations and various components for power flow management.
- Integration of multiple renewable energy vectors with fewer elements, higher efficiency at low cost.
- ecoVehicle demonstration to facilitate transportation at low running cost.
- A novel privacy pricing algorithm is developed to determine the price of privacy of consumers' smart meter energy data for usability.
- Development of a cyclone resilient support structure for micro grid system due to severe cyclonic storms phenomenon for reliable power generation and asset protection.
- Use of a dimmable LED street lighting system with advanced motion sensors offers on demand dynamic lightning for energy savings and reduction of light pollution.

The proposed business model will consider the changes in load and demand, and will try to adapt it to the power generation, using the ecoDR ecoTool. The load shedding controller feature enables operator (energy supplier) to create a local load shedding once the energy consumption/load connection goes beyond the threshold value. This important feature may also be used by the committee members to address the free rider problem and reduce risk of defaulter. Furthermore, the ICT based remote monitoring system may create a system of checks and balances to service provider to exercise some control to resolve social conflict, if any.

The business model for Ghoramara Island includes a variety of income sources:

- Sale of electricity to domestic users (households), at a reduced price. It is important to consider that consumers are used not to pay for the electricity, so the price has to be reduced, and they have to be informed of the advantages of having a reliable electricity supply.
- Sale of electricity for house lighting systems (HLS), charging a limited fee to households.
- Investment and management of a e-boat, which will transport passengers from the Ghoramara Island to the mainland.

- Investment and loan of electric 3-wheelers, which will be made available for the Ghoramara Island citizens.

- Investment of two electric loaders, which can be used by citizens, for a limited fee.

The microgrid will be managed by an energy services company (ESCO) or, alternatively, a company in charge of the management of all the assets, and charging the fees to all users. In the following chapter, the economic feasibility of the business model for an ESCO is evaluated, considering the total investment cost in the Ghoramara Island Microgrid, the operation and maintenance costs, and the expected incomes.

The value proposition is clear i.e., installation of a unique reliable and efficient 'product' solar and wind micro grid for the community comprising 1,100 households which is grid-less with no access to electricity bridging the accessibility gap for the vulnerable residents. It will provide six to eight hours of clean energy at affordable price to households, businesses, and community institutions like school, relief centre, etc. The customers served are the residents with access to lightning, mobile charging at household level as well as shops, enterprises, etc. at commercial level. It incorporates an inclusive approach with the local manpower engagement, creating a support and maintenance network, local skill building (trainings) and local capacity building (groups, networks, and entrepreneurs).

Additionally, the project is expected to create value for the whole community of the Ghoramara Island Microgrid, including domestic and commercial users. It will generate economic activity during the installation of the microgrid, bringing companies and professionals from out of the island to install, and to operate and maintain the microgrid. The increase in the economic activity, the new availability of electricity, as well as the use of an e-boat, e-3 wheelers and electric loaders can lead to the creation of new businesses, such as rice hullers. The use of the electric boat will allow to improve the transport between Ghoramara and the mainland. Besides, new business such as rice hullers will be created, and existing ones will be able to increase their incomes (for example, shops can extend their operating hours). Incomes for the island can come from new different sources, such as charging stations, logistics and transportation to and from nearby islands and mainland, ecotourism, or poultry farming.

As commented, it is expected that an ESCO or maintenance company will be in charge of the operation and maintenance of the microgrid. However, two professionals have to be employed to be in charge of these activities. It is highly advisable that these professionals are inhabitants in the island. For this reason, training will be necessary for these employees. They will be in charge of the technical support and customer service agents.

This project can be a guideline for project developers and energy service providers in rural areas, with a high scalability and replicability potential. Business model will be tested and benchmarked over time leading to standardisation of processes and protocols.

Alternatively to the ESCO model, it is possible to develop a user cooperative. The cooperative is a non-profit community organization, owned and managed by its members. These members are the electricity consumers of the Ghoramara Island. Each member has to pay a fee for the electricity consumed and for the batteries, and the user cooperative owns and maintains the system. Community members, needs to be involved early in the planning process. Past experience has shown that when there is no personal sense of ownership, projects are not sustainable.

On account of the range of stakeholders involved and services provided, business models suitable for decentralized applications differ greatly. Application of business models to renewable energy projects depends highly on the roles of the five primary project stakeholders: financier, owner, operator, maintenance entity and consumer. The business environment for decentralized rural electrification projects is different as the operating environment is often not defined, therefore local conditions have been taken into account during business modelling of Ghoramara Island. Business model for hybrid micro grid projects can provide economic profitability to investors from the consumers having per capita income above poverty line. Hence, for Ghoramara community, income generating activities are most critical which are enabled by access to reliable clean electricity. The most appropriate business model therefore depends on the state of the infrastructure, the local energy resource, and the geographic setup of the remote rural area.

The following business canvas has been defined for the Ghoramara Island Microgrid, including the basic information about the key partners, activities, resources, value propositions, customer relationship, customer segments and channels.

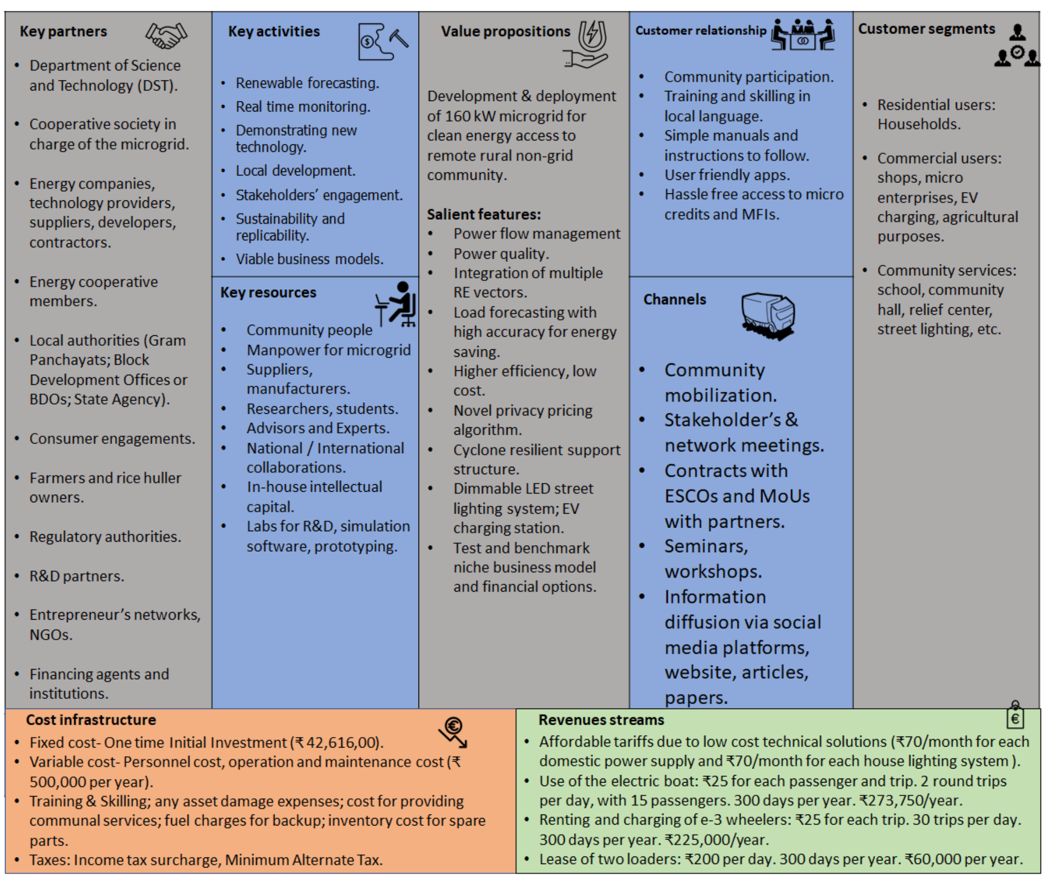

Figure 40. Business Canvas Model for Ghoramara Island Microgrid, India

Key partners which should be taken into account in the business model

The following is a list of the main stakeholders in the Ghoramara Island Microgrid which have a role in the defined business model:

- Department of Science and Technology (DST)- Ministry of Science and Technology- Government of India. It has funded the project, and covered the total investment cost in the development of the 160 kW microgrid system.
- Cooperative society which will be in charge of the microgrid. The members of the cooperative have received trained during the installation of the microgrid, and about the handling of the same.
- Energy companies.
- Technology providers and suppliers, promoters and contractors.
- Energy cooperative members.
- Local authorities, such as the Gram Panchayats, Block Development Offices (BDOs), and the State Agency.
- Consumer engagements.
- Regulatory authorities.
- R&D partners.
- Entrepreneur's networks, NGOs.
- Financing agents and institutions.

Key activities which can be developed in the business model

To make the proposed business model successful, it is necessary to develop the following activities:

- Renewable energy forecasting.
- Real time monitoring.
- Demonstration of new technology.
- Local development.
- Stakeholders' engagement.
- Sustainability and replicability.
- Development of viable business models.

4.2.5 Economic sustainability analysis for Ghoramara Island Microgrid

In order to develop an economic sustainability analysis for the Ghoramara Island Microgrid, the Demo Site leader, IIT Kharagpur, has been asked to provide basic information about the investment cost, the operation and maintenance cost of the microgrid, as well as the expected incomes per year. Although this analysis had been already carried out in 2022, by September 2024, more updated and accurate information has been made available.

To develop this economic model, the following information has been considered:

- Previous hypotheses about the Demo Site: The following basic information about the Demo Site has been considered:
  - Number of households: 650 households.
  - Number of house lighting systems (HLS): 490 house lighting systems.
  - Number of travels in the e-boat: 2 round trips/day.
  - Number of passengers traveling by e-boat: 15 passengers per trip.
  - Number of electric three wheelers: 6 electric three wheelers.
  - Number of travels in the electric three wheelers: 30 travels per day.
  - Number of charging facilities: Two charging points for the electric three wheelers.
- Investment cost: The total investment cost is ₹42,616,000, which is equivalent to €473,037.60.

  The most relevant investment costs in the Demo Site are:
  - Microgrid installation: ₹33,598,000 (which is equivalent to €372,937.80).
  - E-boat: ₹3,500,000 (which is equivalent to €38,850.00).
  - Charging facilities: ₹400,000 (which is equivalent to €4,440.00).
  - Electrical vehicle charging station: ₹1,400,000 (which is equivalent to €15,540.00).
  - Solar powered dimmable street light: ₹400,000 (which is equivalent to €4,440.00).
  - IoT based remote measuring system: ₹1,068,000 (which is equivalent to €11,854.80).
  - Cyclone resilient structure, for a 5 kWp solar PV facility and 10 kW of wind: ₹1,150,000 (which is equivalent to €12,765.00).
  - Wind turbines: 2 5-kW wind turbines: ₹1,100,000 (which is equivalent to €12,210.00).
- Estimated operation and maintenance cost: This cost includes the maintenance cost of equipment (corrective and preventive), as well as the cost of the personnel who works in the microgrid.
  - Personnel cost: It has been estimated that two professionals will be hired to work in the Ghoramara microgrid. A technical supervisor, with a salary of ₹200,000 per year, and a non-technical person for tariff collection, with a salary of ₹100,000 per year. The total cost will be ₹300,000 per year, or €3,330.00

- Operation and maintenance cost of the equipment: The cost of maintaining the equipment has been estimated to be ₹200,000 per year, equivalent to €2,200.00 per year.

The total operation and maintenance cost reaches ₹500,000, or €5,550.00. Maintenance actions are free during the first three years, because all equipment is covered by a 3-year guarantee. This does not apply to the personnel cost.

On the other hand, batteries should be replaced after 20 years of use, with a total cost of ₹8,000,000, or €88,800. However, this cost is not included in the economic model.

- Incomes for the microgrid: The incomes for the microgrid are obtained from the sale of electricity to domestic consumers, both for domestic use and for lighting systems. Besides, there will be incomes from the loan of the electric three-wheelers, the lease of the two charging facilities, and the use of the electric boat.
  - Incomes from domestic power supply: In the hypotheses, 650 households have been considered. Each one is charged ₹70/month (€0.777) for the use of electricity.

    With these hypotheses, the total incomes from domestic power supply will amount to ₹45,500 per month (€505.05), and ₹546,000 per year (€6,060.60).

    Besides, the fee is expected to increase by 10% each year.
  - Incomes from house lighting systems: 490 of the households will also have a house lighting system (HLS).

    The tariff charged for each house lighting system will be ₹70/house and month (€0.777). Considering the number of households, the total incomes will be ₹411,600 per year, and €4,568.76.

    Besides, the fee is expected to increase by 10% each year.
  - Incomes from the use of the electric boat: It has been supposed that the electric boat will make 2 round trips per day. In each travel, there will be an average of 15 passengers.

    The tariff for using the electric boat will be ₹25 (€0.278) for each passenger. Then, the total incomes per day will be ₹750 (€8,33). Considering that the boat is used 300 days per year, the total incomes would be ₹273,750/year (€3,038.63/year).

    Besides, the fee is expected to increase by 10% each year.
  - Renting and charging of e-3 wheelers: It has been considered that the e-3 wheelers will be used 30 times per day. The tariff to be paid by users will be ₹25/trip (€0.278). Finally, each e-3 wheeler will be used 300 days per year.

    This means that the total incomes from the e-3 wheelers will amount to ₹225,000/year, or €2,497.50/year.

    Besides, the fee is expected to increase by 10% each year.

- Lease of the two loaders: Each loader will produce incomes or ₹100 per day (€1.11/day). As there are 2 loaders, the total incomes will be ₹200 per day (€2.22/day).

  As the use of the loaders will not be constant, an average of 300 days per year of use has been considered. This leads to incomes of ₹60,000 per year, or €666.00/year.

  The fee is expected to increase by 10% each year.

- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is ₹42,616,000 (€473,037.60), and a lifetime of 20 years is considered, then the depreciation and amortization will amount to ₹2,130,880/year (or €23,651.88/year).

- The income tax surcharge is estimated to be 7% of the profit before taxes.
- The Minimum Alternate Tax (MAT) is estimated to be 15% of the profit before taxes.
- Lifetime of Microgrid is 20 years.
- Discount rate considered is 10%.

According to the previously explained hypotheses and information, the following economic model, based on cash flows, has been prepared for the Gaidouromantra microgrid. The model has been calculated in rupees and euros, and different financial ratios have been estimated, like Net Present Value (NPV), Internal Rate of Return (IRR) and payback period, to evaluate the economic and financial sustainability of the microgrid and the solutions. The model has been calculated in rupees and in euros.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the demo site	-₹ 42,616,000										
Microgrid installation	-₹ 33,598,000										
e-boat	-₹ 3,500,000										
e-loader	-₹ 400,000										
EV charging station	-₹ 1,400,000										
Solar powered dimmable street light	-₹ 400,000										
IoT based remote measuring system	-₹ 1,068,000										
Cyclone resilient structure	-₹ 1,150,000										
Wind turbines	-₹ 1,100,000										
Total incomes		₹ 1,516,350	₹ 1,667,985	₹ 1,834,784	₹ 2,018,262	₹ 2,220,088	₹ 2,442,097	₹ 2,686,307	₹ 2,954,937	₹ 3,250,431	₹ 3,575,474
Earning from domestic power supply		₹ 546,000	₹ 600,600	₹ 660,660	₹ 726,726	₹ 799,399	₹ 879,338	₹ 967,272	₹ 1,064,000	₹ 1,170,399	₹ 1,287,439
Earning from HLS		₹ 411,600	₹ 452,760	₹ 498,036	₹ 547,840	₹ 602,624	₹ 662,886	₹ 729,175	₹ 802,092	₹ 882,301	₹ 970,531
Earnings from e-boat		₹ 273,750	₹ 301,125	₹ 331,238	₹ 364,361	₹ 400,797	₹ 440,877	₹ 484,965	₹ 533,461	₹ 586,807	₹ 645,488
Electric 3-wheeler charging		₹ 225,000	₹ 247,500	₹ 272,250	₹ 299,475	₹ 329,423	₹ 362,365	₹ 398,601	₹ 438,461	₹ 482,307	₹ 530,538
Lease to two loaders		₹ 60,000	₹ 66,000	₹ 72,600	₹ 79,860	₹ 87,846	₹ 96,631	₹ 106,294	₹ 116,923	₹ 128,615	₹ 141,477
Operation and maintenance costs		-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000
Personnel costs (2 people per year)		-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000
Operation and maintenance costs					-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000
Depreciation and amortization		-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800
Profit before taxes		-₹ 914,450	-₹ 762,815	-₹ 596,017	-₹ 612,538	-₹ 410,712	-₹ 188,703	₹ 55,507	₹ 324,137	₹ 619,631	₹ 944,674
Income Tax Surcharge											
Minimum Alternate Tax (MAT)											
Net cash flow	-₹ 42,616,000	₹ 1,216,350	₹ 1,367,985	₹ 1,534,784	₹ 1,518,262	₹ 1,720,088	₹ 1,942,097	₹ 2,174,095	₹ 2,383,627	₹ 2,614,112	₹ 2,867,646
Accumulated net cash flows	-₹ 42,616,000	-₹ 41,399,650	-₹ 40,031,665	-₹ 38,496,882	-₹ 36,978,620	-₹ 35,258,532	-₹ 33,316,435	-₹ 31,142,340	-₹ 28,758,713	-₹ 26,144,601	-₹ 23,276,955

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the demo site										
Microgrid installation										
e-boat										
e-loader										
EV charging station										
Solar powered dimmable street light										
IoT based remote measuring system										
Cyclone resilient structure										
Wind turbines										
Total incomes	₹ 3,933,021	₹ 4,326,324	₹ 4,758,956	₹ 5,234,851	₹ 5,758,337	₹ 6,334,170	₹ 6,967,587	₹ 7,664,346	₹ 8,430,781	₹ 9,273,859
Earning from domestic power supply	₹ 1,416,183	₹ 1,557,802	₹ 1,713,582	₹ 1,884,940	₹ 2,073,434	₹ 2,280,778	₹ 2,508,855	₹ 2,759,741	₹ 3,035,715	₹ 3,339,286
Earning from HLS	₹ 1,067,584	₹ 1,174,343	₹ 1,291,777	₹ 1,420,955	₹ 1,563,050	₹ 1,719,355	₹ 1,891,291	₹ 2,080,420	₹ 2,288,462	₹ 2,517,308
Earnings from e-boat	₹ 710,037	₹ 781,041	₹ 859,145	₹ 945,059	₹ 1,039,565	₹ 1,143,522	₹ 1,257,874	₹ 1,383,661	₹ 1,522,027	₹ 1,674,230
Electric 3-wheeler charging	₹ 583,592	₹ 641,951	₹ 706,146	₹ 776,761	₹ 854,437	₹ 939,881	₹ 1,033,869	₹ 1,137,256	₹ 1,250,981	₹ 1,376,080
Lease to two loaders	₹ 155,625	₹ 171,187	₹ 188,306	₹ 207,136	₹ 227,850	₹ 250,635	₹ 275,698	₹ 303,268	₹ 333,595	₹ 366,955
Operation and maintenance costs	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000
Personnel costs (2 people per year)	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000
Operation and maintenance costs	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000
Depreciation and amortization	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800	-₹ 2,130,800
Profit before taxes	₹ 1,302,221	₹ 1,695,524	₹ 2,128,156	₹ 2,604,051	₹ 3,127,537	₹ 3,703,370	₹ 4,336,787	₹ 5,033,546	₹ 5,799,981	₹ 6,643,059
Income Tax Surcharge										
Minimum Alternate Tax (MAT)										
Net cash flow	₹ 3,146,533	₹ 3,453,308	₹ 3,790,762	₹ 4,161,960	₹ 4,570,279	₹ 5,019,429	₹ 5,513,494	₹ 6,056,966	₹ 6,654,785	₹ 7,312,386
Accumulated net cash flows	-₹ 20,130,422	-₹ 16,677,114	-₹ 12,886,352	-₹ 8,724,392	-₹ 4,154,114	₹ 865,315	₹ 6,378,809	₹ 12,435,775	₹ 19,090,560	₹ 26,402,946

Income Tax Surcharge	7%
Minimum Alternate tax (MAT)	15%

Discount rate (%)	10%

NPV	-₹ 20,644,465
IRR (%)	3.80%
First positive accumulated cash flow	₹ 865,315
Payback (years)	Year 16

Table 33. Economic model for the Ghoramara Island Microgrid, including the cash flow model and a profitability analysis, in rupees.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the demo site	-473,037.60 €										
Microgrid installation	-372,937.80 €										
e-boat	-38,850.00 €										
e-loader	-4,440.00 €										
EV charging station	-15,540.00 €										
Solar powered dimmable street light	-4,440.00 €										
IoT based remote measuring system	-11,854.80 €										
Cyclone resilient structure	-12,765.00 €										
Wind turbines	-12,210.00 €										
Total incomes		16,831.49 €	18,514.63 €	20,366.10 €	22,402.71 €	24,642.98 €	27,107.27 €	29,818.00 €	32,799.80 €	36,079.78 €	39,687.76 €
Earning from domestic power supply		6,060.60 €	6,666.66 €	7,333.33 €	8,066.66 €	8,873.32 €	9,760.66 €	10,736.72 €	11,810.39 €	12,991.43 €	14,290.58 €
Earning from HLS		4,568.76 €	5,025.64 €	5,528.20 €	6,081.02 €	6,689.12 €	7,358.03 €	8,093.84 €	8,903.22 €	9,793.54 €	10,772.90 €
Earnings from e-boat		3,038.63 €	3,342.49 €	3,676.74 €	4,044.41 €	4,448.85 €	4,893.74 €	5,383.11 €	5,921.42 €	6,513.56 €	7,164.92 €
Electric 3-wheeler charging		2,497.50 €	2,747.25 €	3,021.98 €	3,324.17 €	3,656.59 €	4,022.25 €	4,424.47 €	4,866.92 €	5,353.61 €	5,888.97 €
Lease to two loaders		666.00 €	732.60 €	805.86 €	886.45 €	975.09 €	1,072.60 €	1,179.86 €	1,297.85 €	1,427.63 €	1,570.39 €
Operation and maintenance costs		-3,330.00 €	-3,330.00 €	-3,330.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €
Personnel costs (2 people per year)		-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €
Operation and maintenance costs		0.00 €	0.00 €	0.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €
Depreciation and amortization		-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €
Profit before taxes		-10,150.40 €	-8,467.25 €	-6,615.78 €	-6,799.17 €	-4,558.90 €	-2,094.61 €	616.12 €	3,597.92 €	6,877.90 €	10,485.88 €
Income Tax Surcharge		0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
Minimum Alternate Tax (MAT)		0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
Net cash flow	-473,037.60 €	13,501.49 €	15,184.63 €	17,036.10 €	16,852.71 €	19,092.98 €	21,557.27 €	24,132.46 €	26,458.26 €	29,016.64 €	31,830.87 €
Accumulated net cash flows	-473,037.60 €	-459,536.12 €	-444,351.48 €	-427,315.38 €	-410,462.68 €	-391,369.70 €	-369,812.43 €	-345,679.97 €	-319,221.71 €	-290,205.07 €	-258,374.20 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the demo site										
Microgrid installation										
e-boat										
e-loader										
EV charging station										
Solar powered dimmable street light										
IoT based remote measuring system										
Cyclone resilient structure										
Wind turbines										
Total incomes	43,656.54 €	48,022.19 €	52,824.41 €	58,106.85 €	63,917.54 €	70,309.29 €	77,340.22 €	85,074.24 €	93,581.66 €	102,939.83 €
Earning from domestic power supply	15,719.64 €	17,291.60 €	19,020.76 €	20,922.83 €	23,015.12 €	25,316.63 €	27,848.29 €	30,633.12 €	33,696.43 €	37,066.08 €
Earning from HLS	11,850.19 €	13,035.21 €	14,338.73 €	15,772.60 €	17,349.86 €	19,084.84 €	20,993.33 €	23,092.66 €	25,401.93 €	27,942.12 €
Earnings from e-boat	7,881.41 €	8,669.55 €	9,536.51 €	10,490.16 €	11,539.17 €	12,693.09 €	13,962.40 €	15,358.64 €	16,894.50 €	18,583.95 €
Electric 3-wheeler charging	6,477.87 €	7,125.66 €	7,838.22 €	8,622.05 €	9,484.25 €	10,432.68 €	11,475.95 €	12,623.54 €	13,885.89 €	15,274.48 €
Lease to two loaders	1,727.43 €	1,900.18 €	2,090.19 €	2,299.21 €	2,529.13 €	2,782.05 €	3,060.25 €	3,366.28 €	3,702.90 €	4,073.20 €
Operation and maintenance costs	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €
Personnel costs (2 people per year)	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €
Operation and maintenance costs	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €
Depreciation and amortization	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €	-23,651.88 €
Profit before taxes	14,454.66 €	18,820.31 €	23,622.53 €	28,904.97 €	34,715.66 €	41,107.41 €	48,138.34 €	55,872.36 €	64,379.78 €	73,737.95 €
Income Tax Surcharge	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
Minimum Alternate Tax (MAT)	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
Net cash flow	34,926.51 €	38,331.72 €	42,077.45 €	46,197.76 €	50,730.09 €	55,715.66 €	61,199.78 €	67,232.32 €	73,868.11 €	81,167.48 €
Accumulated net cash flows	-223,447.69 €	-185,115.96 €	-143,038.51 €	-96,840.75 €	-46,110.66 €	9,605.00 €	70,804.78 €	138,037.10 €	211,905.22 €	293,072.70 €

Income Tax Surcharge	7%
Minimum Alternate tax (MAT)	15%

Discount rate (%)	10%

NPV	-229,153.57 €
IRR (%)	3.80%
First positive accumulated cash flow	9,605.00 €
Payback (years)	Year 16

Table 34. Economic model for the Ghoramara Island Microgrid, including the cash flow model and a profitability analysis, in euros.

As can be seen in the cash flow model, the results for the Ghoramara Island Microgrid are negative. Although the accumulated cash flow becomes positive in year 16, the internal rate of return is only 3.80%. This means that, considering a discount rate of 10%, the net present value of the project along 20 years is negative, €-229,153.57.

The following figure shows the Cash Flow Diagram of the Ghoramara Island Microgrid Demo Site:

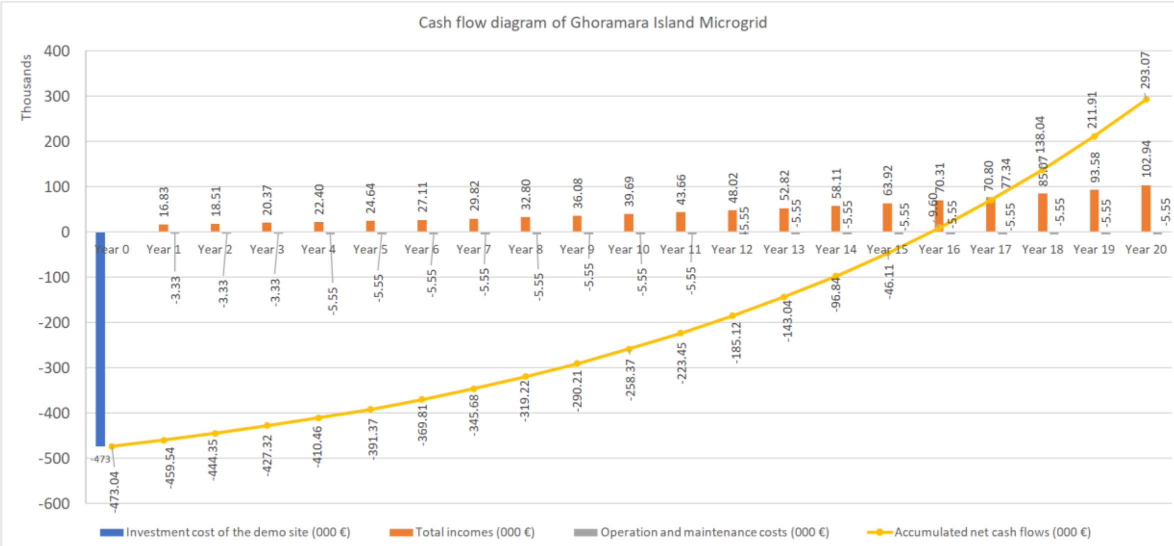

Figure 41. Cash flow diagram of Keonjhar Demo Site

As can be seen, the microgrid business model is not profitable, so it will be developed only if it receives any economic support from the government, in form of subsidized access to finance, or covering a part of the investment cost. There are three main reasons for this: firstly, the high cost of the investment in the microgrid. Secondly, the low tariff which can be paid by households and users of the electric boat and e-3 wheelers. Finally, the reduced number of households, compared to the high amount which has to be invested.

However, if the investment cost of the microgrid is covered by the RE-EMPOWERED project, then the result of the project is much more beneficial.

The following table shows the cash flow model for the Demo Site, considering that the investment cost in the microgrid is paid with a subsidy:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the demo site	-₹ 9,018,000										
Microgrid installation	₹ 0										
e-boat	-₹ 3,500,000										
e-loader	-₹ 400,000										
EV charging station	-₹ 1,400,000										
Solar powered dimmable street light	-₹ 400,000										
IoT based remote measuring system	-₹ 1,068,000										
Cyclone resilient structure	-₹ 1,150,000										
Wind turbines	-₹ 1,100,000										
Total incomes		₹ 1,516,350	₹ 1,667,985	₹ 1,834,784	₹ 2,018,262	₹ 2,220,088	₹ 2,442,097	₹ 2,686,307	₹ 2,954,937	₹ 3,250,431	₹ 3,575,474
Earning from domestic power supply		₹ 546,000	₹ 600,600	₹ 660,660	₹ 726,726	₹ 799,399	₹ 879,338	₹ 967,272	₹ 1,064,000	₹ 1,170,399	₹ 1,287,439
Earning from HLS		₹ 411,600	₹ 452,760	₹ 498,036	₹ 547,840	₹ 602,624	₹ 662,886	₹ 729,175	₹ 802,092	₹ 882,301	₹ 970,531
Earnings from e-boat		₹ 273,750	₹ 301,125	₹ 331,238	₹ 364,361	₹ 400,797	₹ 440,877	₹ 484,965	₹ 533,461	₹ 586,807	₹ 645,488
Electric 3-wheeler charging		₹ 225,000	₹ 247,500	₹ 272,250	₹ 299,475	₹ 329,423	₹ 362,365	₹ 398,601	₹ 438,461	₹ 482,307	₹ 530,538
Lease to two loaders		₹ 60,000	₹ 66,000	₹ 72,600	₹ 79,860	₹ 87,846	₹ 96,631	₹ 106,294	₹ 116,923	₹ 128,615	₹ 141,477
Operation and maintenance costs		-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000
Personnel costs (2 people per year)		-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000
Operation and maintenance costs					-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000
Depreciation and amortization		-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900
Profit before taxes		₹ 765,450	₹ 917,085	₹ 1,083,884	₹ 1,067,362	₹ 1,269,188	₹ 1,491,197	₹ 1,735,407	₹ 2,004,037	₹ 2,299,531	₹ 2,624,574
Income Tax Surcharge		-₹ 53,582	-₹ 64,196	-₹ 75,872	-₹ 74,715	-₹ 88,843	-₹ 104,384	-₹ 121,478	-₹ 140,283	-₹ 160,967	-₹ 183,720
Minimum Alternate Tax (MAT)		-₹ 114,818	-₹ 137,563	-₹ 162,583	-₹ 160,104	-₹ 190,378	-₹ 223,680	-₹ 260,311	-₹ 300,606	-₹ 344,930	-₹ 393,686
Net cash flow	-₹ 9,018,000	₹ 1,047,951	₹ 1,166,226	₹ 1,296,329	₹ 1,283,442	₹ 1,440,867	₹ 1,614,034	₹ 1,804,517	₹ 2,014,049	₹ 2,244,534	₹ 2,498,068
Accumulated net cash flows	-₹ 9,018,000	-₹ 7,970,049	-₹ 6,803,823	-₹ 5,507,494	-₹ 4,224,051	-₹ 2,783,185	-₹ 1,169,151	₹ 635,366	₹ 2,649,415	₹ 4,893,949	₹ 7,392,017

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the demo site										
Microgrid installation										
e-boat										
e-loader										
EV charging station										
Solar powered dimmable street light										
IoT based remote measuring system										
Cyclone resilient structure										
Wind turbines										
Total incomes	₹ 3,933,021	₹ 4,326,324	₹ 4,758,956	₹ 5,234,851	₹ 5,758,337	₹ 6,334,170	₹ 6,967,587	₹ 7,664,346	₹ 8,430,781	₹ 9,273,859
Earning from domestic power supply	₹ 1,416,183	₹ 1,557,802	₹ 1,713,582	₹ 1,884,940	₹ 2,073,434	₹ 2,280,778	₹ 2,508,855	₹ 2,759,741	₹ 3,035,715	₹ 3,339,286
Earning from HLS	₹ 1,067,584	₹ 1,174,343	₹ 1,291,777	₹ 1,420,955	₹ 1,563,050	₹ 1,719,355	₹ 1,891,291	₹ 2,080,420	₹ 2,288,462	₹ 2,517,308
Earnings from e-boat	₹ 710,037	₹ 781,041	₹ 859,145	₹ 945,059	₹ 1,039,565	₹ 1,143,522	₹ 1,257,874	₹ 1,383,661	₹ 1,522,027	₹ 1,674,230
Electric 3-wheeler charging	₹ 583,592	₹ 641,951	₹ 706,146	₹ 776,761	₹ 854,437	₹ 939,881	₹ 1,033,869	₹ 1,137,256	₹ 1,250,981	₹ 1,376,080
Lease to two loaders	₹ 155,625	₹ 171,187	₹ 188,306	₹ 207,136	₹ 227,850	₹ 250,635	₹ 275,698	₹ 303,268	₹ 333,595	₹ 366,955
Operation and maintenance costs	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000	-₹ 500,000
Personnel costs (2 people per year)	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000	-₹ 300,000
Operation and maintenance costs	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000	-₹ 200,000
Depreciation and amortization	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900	-₹ 450,900
Profit before taxes	₹ 2,982,121	₹ 3,375,424	₹ 3,808,056	₹ 4,283,951	₹ 4,807,437	₹ 5,383,270	₹ 6,016,687	₹ 6,713,446	₹ 7,479,881	₹ 8,322,959
Income Tax Surcharge	-₹ 208,748	-₹ 236,280	-₹ 266,564	-₹ 299,877	-₹ 336,521	-₹ 376,829	-₹ 421,168	-₹ 469,941	-₹ 523,592	-₹ 582,607
Minimum Alternate Tax (MAT)	-₹ 447,318	-₹ 506,314	-₹ 571,208	-₹ 642,593	-₹ 721,115	-₹ 807,491	-₹ 902,503	-₹ 1,007,017	-₹ 1,121,982	-₹ 1,248,444
Net cash flow	₹ 2,776,955	₹ 3,083,730	₹ 3,421,184	₹ 3,792,382	₹ 4,200,701	₹ 4,649,851	₹ 5,143,916	₹ 5,687,388	₹ 6,285,207	₹ 6,942,808
Accumulated net cash flows	₹ 10,168,971	₹ 13,252,702	₹ 16,673,885	₹ 20,466,267	₹ 24,666,968	₹ 29,316,819	₹ 34,460,735	₹ 40,148,123	₹ 46,433,330	₹ 53,376,137

Income Tax Surcharge	7%
Minimum Alternate tax (MAT)	15%

Discount rate (%)	10%

NPV	₹ 10,398,788
IRR (%)	19.40%
First positive accumulated cash flow	₹ 10,168,971
Payback (years)	Year 11

Table 35. Economic model for the Ghoramara Island Microgrid, including the cash flow model and a profitability analysis, considering a subsidy for the microgrid in rupees.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the demo site	-100,099.80 €										
Microgrid installation	0.00 €										
e-boat	-38,850.00 €										
e-loader	-4,440.00 €										
EV charging station	-15,540.00 €										
Solar powered dimmable street light	-4,440.00 €										
IoT based remote measuring system	-11,854.80 €										
Cyclone resilient structure	-12,765.00 €										
Wind turbines	-12,210.00 €										
Total incomes		16,831.49 €	18,514.63 €	20,366.10 €	22,402.71 €	24,642.98 €	27,107.27 €	29,818.00 €	32,799.80 €	36,079.78 €	39,687.76 €
Earning from domestic power supply		6,060.60 €	6,666.66 €	7,333.33 €	8,066.66 €	8,873.32 €	9,760.66 €	10,736.72 €	11,810.39 €	12,991.43 €	14,290.58 €
Earning from HLS		4,568.76 €	5,025.64 €	5,528.20 €	6,081.02 €	6,689.12 €	7,358.03 €	8,093.84 €	8,903.22 €	9,793.54 €	10,772.90 €
Earnings from e-boat		3,038.63 €	3,342.49 €	3,676.74 €	4,044.41 €	4,448.85 €	4,893.74 €	5,383.11 €	5,921.42 €	6,513.56 €	7,164.92 €
Electric 3-wheeler charging		2,497.50 €	2,747.25 €	3,021.98 €	3,324.17 €	3,656.59 €	4,022.25 €	4,424.47 €	4,866.92 €	5,353.61 €	5,888.97 €
Lease to two loaders		666.00 €	732.60 €	805.86 €	886.45 €	975.09 €	1,072.60 €	1,179.86 €	1,297.85 €	1,427.63 €	1,570.39 €
Operation and maintenance costs		-3,330.00 €	-3,330.00 €	-3,330.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €
Personnel costs (2 people per year)		-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €
Operation and maintenance costs		0.00 €	0.00 €	0.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €
Depreciation and amortization		-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €
Profit before taxes		8,496.50 €	10,179.64 €	12,031.11 €	11,847.72 €	14,087.99 €	16,552.28 €	19,263.01 €	22,244.81 €	25,524.79 €	29,132.77 €
Income Tax Surcharge		-594.75 €	-712.58 €	-842.18 €	-829.34 €	-986.16 €	-1,158.66 €	-1,348.41 €	-1,557.14 €	-1,786.74 €	-2,039.29 €
Minimum Alternate Tax (MAT)		-1,274.47 €	-1,526.95 €	-1,804.67 €	-1,777.16 €	-2,113.20 €	-2,482.84 €	-2,889.45 €	-3,336.72 €	-3,828.72 €	-4,369.92 €
Net cash flow	-100,099.80 €	11,632.26 €	12,945.11 €	14,389.25 €	14,246.21 €	15,993.62 €	17,915.77 €	20,030.14 €	22,355.94 €	24,914.33 €	27,728.55 €
Accumulated net cash flows	-100,099.80 €	-88,467.54 €	-75,522.43 €	-61,133.18 €	-46,886.97 €	-30,893.35 €	-12,977.58 €	7,052.56 €	29,408.51 €	54,322.83 €	82,051.39 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the demo site										
Microgrid installation										
e-boat										
e-loader										
EV charging station										
Solar powered dimmable street light										
IoT based remote measuring system										
Cyclone resilient structure										
Wind turbines										
Total incomes	43,656.54 €	48,022.19 €	52,824.41 €	58,106.85 €	63,917.54 €	70,309.29 €	77,340.22 €	85,074.24 €	93,581.66 €	102,939.83 €
Earning from domestic power supply	15,719.64 €	17,291.60 €	19,020.76 €	20,922.83 €	23,015.12 €	25,316.63 €	27,848.29 €	30,633.12 €	33,696.43 €	37,066.08 €
Earning from HLS	11,850.19 €	13,035.21 €	14,338.73 €	15,772.60 €	17,349.86 €	19,084.84 €	20,993.33 €	23,092.66 €	25,401.93 €	27,942.12 €
Earnings from e-boat	7,881.41 €	8,669.55 €	9,536.51 €	10,490.16 €	11,539.17 €	12,693.09 €	13,962.40 €	15,358.64 €	16,894.50 €	18,583.95 €
Electric 3-wheeler charging	6,477.87 €	7,125.66 €	7,838.22 €	8,622.05 €	9,484.25 €	10,432.68 €	11,475.95 €	12,623.54 €	13,885.89 €	15,274.48 €
Lease to two loaders	1,727.43 €	1,900.18 €	2,090.19 €	2,299.21 €	2,529.13 €	2,782.05 €	3,060.25 €	3,366.28 €	3,702.90 €	4,073.20 €
Operation and maintenance costs	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €	-5,550.00 €
Personnel costs (2 people per year)	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €	-3,330.00 €
Operation and maintenance costs	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €	-2,220.00 €
Depreciation and amortization	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €	-5,004.99 €
Profit before taxes	33,101.55 €	37,467.20 €	42,269.42 €	47,551.86 €	53,362.55 €	59,754.30 €	66,785.23 €	74,519.25 €	83,026.67 €	92,384.84 €
Income Tax Surcharge	-2,317.11 €	-2,622.70 €	-2,958.86 €	-3,328.63 €	-3,735.38 €	-4,182.80 €	-4,674.97 €	-5,216.35 €	-5,811.87 €	-6,466.94 €
Minimum Alternate Tax (MAT)	-4,965.23 €	-5,620.08 €	-6,340.41 €	-7,132.78 €	-8,004.38 €	-8,963.14 €	-10,017.78 €	-11,177.89 €	-12,454.00 €	-13,857.73 €
Net cash flow	30,824.20 €	34,229.41 €	37,975.14 €	42,095.44 €	46,627.78 €	51,613.34 €	57,097.47 €	63,130.01 €	69,765.80 €	77,065.17 €
Accumulated net cash flows	112,875.58 €	147,104.99 €	185,080.13 €	227,175.57 €	273,803.35 €	325,416.69 €	382,514.16 €	445,644.16 €	515,409.96 €	592,475.13 €

Income Tax Surcharge	7%
Minimum Alternate tax (MAT)	15%

Discount rate (%)	10%

NPV	115,426.54 €
IRR (%)	19.40%
First positive accumulated cash flow	112,875.58 €
Payback (years)	Year 11

Table 36. Economic model for the Ghoramara Island Microgrid, including the cash flow model and a profitability analysis, considering a subsidy for the microgrid in euros.

As can be seen in the tables before, if the project developer can obtain a subsidy which covers the investment cost of the microgrid, then the project has a net present value of €115,426.54 along 20 years, and an internal rate of return of 19.40%.

The project payback would be 11 years.

4.2.6 Financing tools applicable to the Demo Site

According to the total investment cost which is required to develop the Ghoramara Island Microgrid, this chapter focuses on the alternative financing tools which can be used to fund the initial investment in the project.

As has been described before, the total investment in the microgrid is ₹42,616,000, equivalent to €473,037.60. Most of this cost is due to the microgrid, which amounts to €372,937.80. Although this cost is covered by the RE-EMPOWERED project, in this analysis, the availability of financing tools to cover this investment is considered.

According to this cost, there are different financing alternatives to fund this project:

- Loan: This alternative has, as advantages, that the investor does not need to trust the success of the project, as long as the borrower has a good financial capacity to repay the loan. The duration can be adapted to the expected useful time of the project, although generally it is between 3 and 10 years.

  Loans, in general, cover only between 50% and 70% of the cost of the project, and a corporate guarantee is required from the borrower.

  The interest rate of a loan is lower than other alternatives, since there exists a guarantee.

- Leasing: In this contract, the client can use the asset, paying a periodic fee to the owner of the asset. The duration of the leasing contract depends on the expected lifetime of the asset, but it is usually between 5 and 12 years.

  Once the contract comes to an end, the client can decide to purchase the asset, continue with the leasing contract, or return the asset to the owner. The duration of the leasing contract depends on the expected lifetime of the asset, but it is usually between 5 and 12 years.

  A leasing contract can cover between 50% and 70% of the cost of the equipment, and corporate and personal guarantees are required.

  Leasing is considered as debt in the annual statements.

  The interest rate of leasing contracts is higher than the interest rate of loans.

- Renting: This instrument is quite similar to leasing. As in this case, there exists a specific asset which can be used as the main guarantee for the operation, although personal and corporate guarantees can be also required. However, in some cases the user cannot purchase the asset.

  The duration of the renting contract is usually between 2 and 10 years, and can cover between 50% and 100% of the cost of the project. In this case, the renting contract does not only cover the cost of the equipment, but also other costs, such as services, project design, civil works, licenses and so on.

The client is required to present some corporate and personal financial guarantees, but renting is not considered as debt in the company's annual statements.

The interest rates are similar to that of leasing: the user pays a periodic fee for the use of the good.

The alternative of using crowdfunding is discarded, due to the high investment cost, and the reduced population in the Demo Site. The use of other innovative financing tools, such as forfaiting, project finance or equity is limited due to the limited size of the investment, as well as the reduced incomes expected from the project.

4.2 Keonjhar Microgrid: Odisha, India

Kanheigola, Nola and Ranipada are small Villages/hamlets in Harichadanpur-Tehsil reserve forest in Keonjhar District of Odisha State, India. They are located 54 km towards South from District headquarters Keonjhar and 180 km from state capital Bhubaneswar.

The following map shows the location of the Demo Site:

Figure 42. Ghoramara island, and villages comprising the Demo Site

Currently, these villages are not connected to the main utility grid. The area of the Demo Site is 2.02 km^2.

The climate of Keonjhar District is characterized by an oppressively hot summer, with high humidity. Summer begins in the month of March, and temperature reaches its maximum in the month of May. During the summer, maximum temperature is around 38°C.

The weather is better with the beginning of the monsoon in June, and remains as such up to the end of October. The temperature in the month of December is lower, reaching up to 11°C, or even lower, to 7°C. The average annual rainfall is around 1,534.5 mm.

The main infrastructure available in the Keonjhar Microgrid is as follows:

- A high school and a primary school, which are run by Tribal/Social Welfare Department.
- A sub centre of primary health care centre, which offers medical attention to the residents.

The economy of the zone is the agriculture, mostly based on rice. This sector employs around 80-90% of the workers. Cultivation is based on water from a downstream.

The government of Odisha has built a road which connects Harichandanpur and these three villages.

4.3.1. Energy system and Business models in Keonjhar Microgrid

A total of 77 kWp (Kanheigola- 30 kWp, Nola -25 kWp and Ranipada- 22 kWp) solar PV installations are supplying approximately 1,000 villagers, living in 306 households. Every house is provided with 100 W that allows basic facilities, like 2 LED lights and a fan.

Houses have only 4 hours of light during nighttime, approximately from 18:00 to 22:00.

These solar PV installations are completely isolated, and were commissioned by the Odisha Renewable Energy Development Agency (OREDA) in 2017-2018.

The three cluster villages in Keonjhar have been powered using solar PV and battery backup while they are deprived of purified water drinking facility and proper transportation facility. Since all the villages are part of a reserve forest, solid biomass from the forest trees can be converted into energy. The optimized and efficient operation of the various energy vectors is highly recommended to reduce the high cost, to better manage the energy demand and, finally, to increase livelihood activities of the villagers. Currently, metering systems are not installed in the Demo Site.

The following figure shows a summary of the main energy infrastructure located in Keonjhar:

No.	Village/ Block/ District	Nature of microgrid: Grid connected/ Isolated	Kind of source in each microgrid	Plant capacity in kW	Load in kW	AC/ DC system	No. of household connected
1	Kanheigola, Keonjhar	Isolated	Solar	30	21	AC system	126
2	Nola, Keonjhar	Isolated	Solar	25	17.5	AC system	105
3	Ranipad, Keonjhar	Isolated	Solar	22	15.4	AC system	75

Table 37 Existing energy infrastructure in Keonjhar

Besides, the Demo Site is located in a reserve forest, so solid biomass from the forest trees can be used to produce energy. There are different energy vectors such as solar PV, biomass, energy storage, e-mobility and water purification.

There are three rice-cum-hauler meals, run by a diesel engine. The consumption is around 6-7 litres of diesel per day and machine.

The objective of RE-EMPOWERED is to design power converters with high efficiency at low power range. The project is demonstrating optimized use of solar PV and biomass, using stiff DC-link control capability in standalone mode.

The following table includes a summary of the installations which have been promoted by RE-EMPOWERED:

No.	Planned hardware facilities	Capacity
1	A 50 kW microgrid system	30 kWp PV + 10 kW Biomass+ 10 kW Biogas
2	Battery with BMS VRLA (50% DOD)	180 kWh
3	Electrical Vehicles	2
4	Smart Meters, with Fuse and MCCB/MCB	10
5	Solar Dimmable Lights	10 out of which 5 are energy efficient dimmable
6	Charging Facility, 2 Ports	1.5 kW, 48V
7	IoT based remote measuring system	1
8	Energy management system	1

Table 38 Planned installations in Keonjhar demo

The following list includes the main power generation units which are installed in the Keonjhar Microgrid Demo Site:

- 52 kWp of solar PV panels:
    - 22 kWp which were installed before the RE-EMPOWERED project.
    - 30 kWp installed during the RE-EMPOWERED project.
    - The peak operational time is around 5 hours per day, approximately from 10 am to 3 pm.
    - The total peak generation is 185 kWh/day, from which 110 kWh/day are produced by the new solar PV panels, and the remaining 75 kWh/day were generated by existing solar PV panels.
- Battery bank: 340 kWh.
    - A battery bank with an energy storage capacity of 180 kWh has been installed as a consequence of RE-EMPOWERED activities.
    - There was a battery bank with a capacity of 160 kWh before the RE-EMPOWERED project was developed.
    - Acceptable depth of discharge (DoD): 50%.
    - Energy which can be used, considering depth of discharge and losses: 72 kWh (for the 180 kWh battery) + 64 kWh (for the 160 kWh battery).
- Biomass: 10 kW.
    - Available amount of husk to be used as a fuel: 40 kg/day.

- Winter working months: From November to June, during 5 or 6 hours per day.
- Summer working months: From July to October, during 2 or 3 hours per day.
- Daily husk collection: Between 50 and 60 kg/day, considering 5 hours or work to collect husk.
- Fuel requirement of the biomass system: Between 1.5 and 2 kg/kWh.
- Energy generation by the biomass system: Around 20 kWh/day.

- Biogas: 10 kW.
    - Available cow dung to produce biogas: Around 300 kg/day (considering a herd of cows with 150 cows, which produce at least 2 kg/day of dung each).
    - Biogas generation: 40 kWh/day.

The minimum energy generation is estimated to be 150 kWh/day. From them, 75 kWh/day will be made available for domestic customers, and the remaining 75 kWh/day will be used by commercial and industrial consumers.

The consumption side includes two parts: domestic customers and commercial customers. A plant efficiency factor is used to consider energy losses and performance, between 50% and 70%:

- Domestic consumers:
    - Total power load: 6.4 kW, including 3.2 kW for the home load which existed before the RE-EMPOWERED project was developed, and 3.2 kW of power load which has been recently installed, and includes a television and a ceiling fan.
    - Total energy consumption: 52 kWh/day, including 26 kWh/day from the consumption which was carried out before the RE-EMPOWERED project was developed, and a new consumption of 26 kWh/day after the project.
- Commercial and industrial consumers:
    - Rice huller: 3 rice hullers are installed in the Demo Site, with a power load of 4 kW each (12 kW).

      The total energy consumption of rice hullers is around 50 kWh/day.
    - Electric vehicle chargers: The total power load is 1.5 kW, and the operating hours will be 6 hours per day. This means that the total energy consumption will be around 9 kWh/day.

The maximum energy demand, after the installation of the new equipment which was foreseen in RE-EMPOWERED, amounts to 120 kWh/day.

Considering the minimum energy generation of 150 kWh/day, and the efficiency factor between 50% and 70%, the total energy consumption demand which existed before the RE-EMPOWERED project would be covered. However, the energy generation efficiency should be maximized to make sure that the new energy needs are covered.

4.3.2. Access and cost of energy supply in Keonjhar microgrid

At present these villages are not connected to the main utility grid. Due to the lack of stable electric power, and the high tariffs, villagers cannot use electricity normally. Besides, the existing electricity supply is very expensive. Inhabitants also lack any purified water drinking facility, or any proper transportation facility. On the other hand, currently, electricity is provided to the clients for free.

The proposed site is ideal as a test bed and demonstration site as it already has some basic renewable energy facilities. These have been upgraded and coupled with various available energy vectors to improve the living standards of the community. The aim is to develop and demonstrate various energy vectors integration, by means of high energy efficient converters and their control. Another objective is to promote off-grid systems in selected remote villages to create support ecosystems to promote income-generating energy uses in agriculture and small businesses, as well as to increase the population awareness and customer engagement, such that rural to urban migration is minimized.

In this Demo Site, various energy vectors such as electricity from solar PV, biomass and storage are being integrated with the existing PV system. The proposed 40 kWp microgrid system will be primarily used for livelihood activities apart from household supply. The demonstrated solutions, tools, strategies, business models in Keonjhar will enable the development of a socio-economically sustainable model which can be easily replicated in other remote villages in India.

The proposed microgrid will control various energy vectors, metering, billing and differential tariffs for business, livelihood activities, and household. It schedules demands of microenterprises, irrigation pumps, street lights, etc. The anchor loads are scheduled to match the solar generation profile. A village micro enterprise zone (MEZ) will be created to develop micro-industries for livelihood activities like irrigation through “Field-Distributed-Pumps” and mobile pumps, small enterprises such as agro processing, electric four wheelers, ice factories, cold storage, workshops, water purification stations, telecom towers, petrol stations, commercial banks and community services like schools, government buildings.

4.3.3. Use of ecoTools in Keonjhar Microgrid

In Keonjhar Microgrid, six different ecoTools will be tested, specifically: ecoMicrogrid, ecoPlanning, ecoDR, ecoPlatform, ecoCommunity and ecoVehicle. This is based on the analysis carried out in WP02, where innovative solutions were identified for each Demo Site.

Mapping UCs and, ecoTools in Keonjhar Microgrid

The following table shows the use of ecoTools and use cases in the Keonjhar Microgrid. To find more detail about use cases and ecoTools, please, see Deliverable 2.1: Report on requirements for each demo, use cases and KPIs definition:

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Association with new business model
ecoMicrogrid	MG_1UC1	Microgrid monitoring	MG_2UC1.1	Real time microgrid monitoring and data acquisition	Smart Sustainable Energy Community
			MG_2UC1.3	Data concentration, storage and management	
	MG_1UC2	Microgrid optimal management of operation	MG_2UC2.1	Effective communication with controllable assets	
			MG_2UC2.2	Multi objective microgrid management: Energy Production Optimization, Storage & Purchase	
			MG_2UC2.3	Multi-energy vector microgrid management of operation	
ecoPlanning	PN_1UC1	7-Year Energy Planning	PN_2UC1.1	Data collection and storage	
			PN_2UC1.2	Electrical models & demand peak models design, RES & Load estimation	
			PN_2UC1.3	Optimization algorithm for mid to long term horizon (1 to 7 years), for hourly Unit Commitment, maximizing RES penetration and securing normal operation	
	PN_1UC2	RES Hosting Capacity	PN_2UC2.1	Electrical models & demand peak models design, RES & Load estimation, RES units dimensions and thresholds	
			PN_2UC2.2	Scenario simulation through optimization for 1 year per scenario run, for hourly Unit Commitment.	
	PN_1UC3	Multi-energy vector microgrid management of operation	PN_2UC3.1	Electrical models, demand peak models & interconnections design, RES & Load estimation	
			PN_2UC3.2	Hourly Unit Commitment, through optimization algorithm for mid to long term horizon	
	PN_1UC4	Multi-energy vectors	PN_2UC4.1	Energy carriers identification, data collection and quantification of impact on total load (hourly)	
			PN_2UC4.2	Electrical models & demand peak design, RES & Load estimation, energy carriers scenarios integration	
			PN_2UC4.3	Optimal Unit Commitment for mid to long term horizon, based on multi energy carriers	
ecoDR	DR_1UC1	Increased energy monitoring at demand side	DR_2UC1.1	Real time monitoring of energy consumption	Use of smart devices Use of innovative algorithms to monitor power flows Development of a pricing algorithm
			DR_2UC1.2	Dynamic pricing-based energy cost computation	
	DR_1UC2	Integration Interfaces for Load Management	DR_2UC2.1	Scheduling of loads	
			DR_2UC2.2	Programmable Load shedding controller	
ecoPlatform	PF_1UC2	Platform as a service for dependent tools integration	PF_2UC2.1	Facilitate data exchange between dependent tools	
	PF_1UC3	Data storage and cloud server	PF_2UC3.1	Route the microgrid data and data from dependent tools to cloud database	
			PF_2UC3.2	Facilitate archived data access for dependent tools using API	
ecoCommunity	CM_1UC1	Dynamic pricing of electricity*	CM_2UC1.1	Displaying the dynamic pricing based on shape of energy profile	Energy cooperative/community
			CM_2UC1.2	Billing and payments	
	CM_1UC2	Scheduling and Coordination	CM_2UC2.1	Facilitating (display) of the scheduling and shifting of non-critical and flexible loads	
			CM_2UC2.2	Coordination of communal/shared loads	

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Association with new business model
	CM_1UC3	Outreach forum	CM_2UC3.1	Feedback and suggestions from users about the tools	
			CM_2UC3.2	Reporting of problems	
			CM_2UC3.3	Forum to share experiences	
	CM_1UC4	Guidance and Training	CM_2UC4.1	Training material (troubleshooting)	
			CM_2UC4.2	Easy-to-use multimedia material and step-by-step guides (walkthroughs)	
ecoVehicle	VH_1UC1	Tailor-made Electric Vehicle (EV) charging facility	VH_2UC1.1	Effective control strategies for dc-bus voltage regulation	Renting of electric vehicles
			VH_2UC1.2	State of charge and temperature estimation	
			VH_2UC1.3	Temperature regulated charging strategies	
	VH_1UC2	Selection and customization of rickshaw	VH_2UC2.2	Customization of the vehicle to the Demo Site requirements	

Table 39. Association of ecoTools and UCs in the Keonjhar Microgrid: RE-EMPOWERED

4.3.4. Business Canvas and proposed Business model

In the Keonjhar District of Odisha – three villages, specifically Kanheigola, Nola and Ranipada – are supplied with clean energy of 77 kWp isolated solar micro grid to approximately 1,000 people.

Additionally, a 50 kW microgrid, including a 30 kW solar PV plant, a 10-kW biogas power plant and a 10 kW biomass power plant has been installed, to update the existing infrastructure. The use of this combination of renewable energy sources has not been tested before.

Each house in these villages is provided with 100 W for residential requirements i.e., basic lightning facilities during evening hours.

In particular, the following technologies will be tested in the Keonjhar Microgrid.

- It will be equipped with advanced energy management system and integration.
- Commercial three-wheeler will be tested and deployed with charging infrastructure, especially designed to fulfil the local needs of the community.
- Smart meters with load limiter and load management.
- IoT based remote measuring system.
- Solar dimmable street lights with configurable brightness, energy saving ensuring public safety.

The RE-EMPOWERED project has led to the development of an energy community, the Ranipada Gram Shakti Samooh.

This energy community consists of 75 members, and the management team is formed by:

- Head of the Committee: Nalini Nayak (sarpanch).
- President: Mohan Dehury.
- Secretary: Madhusudan Dehury.

The following figure shows the business canvas of the Keonjhar Microgrid:

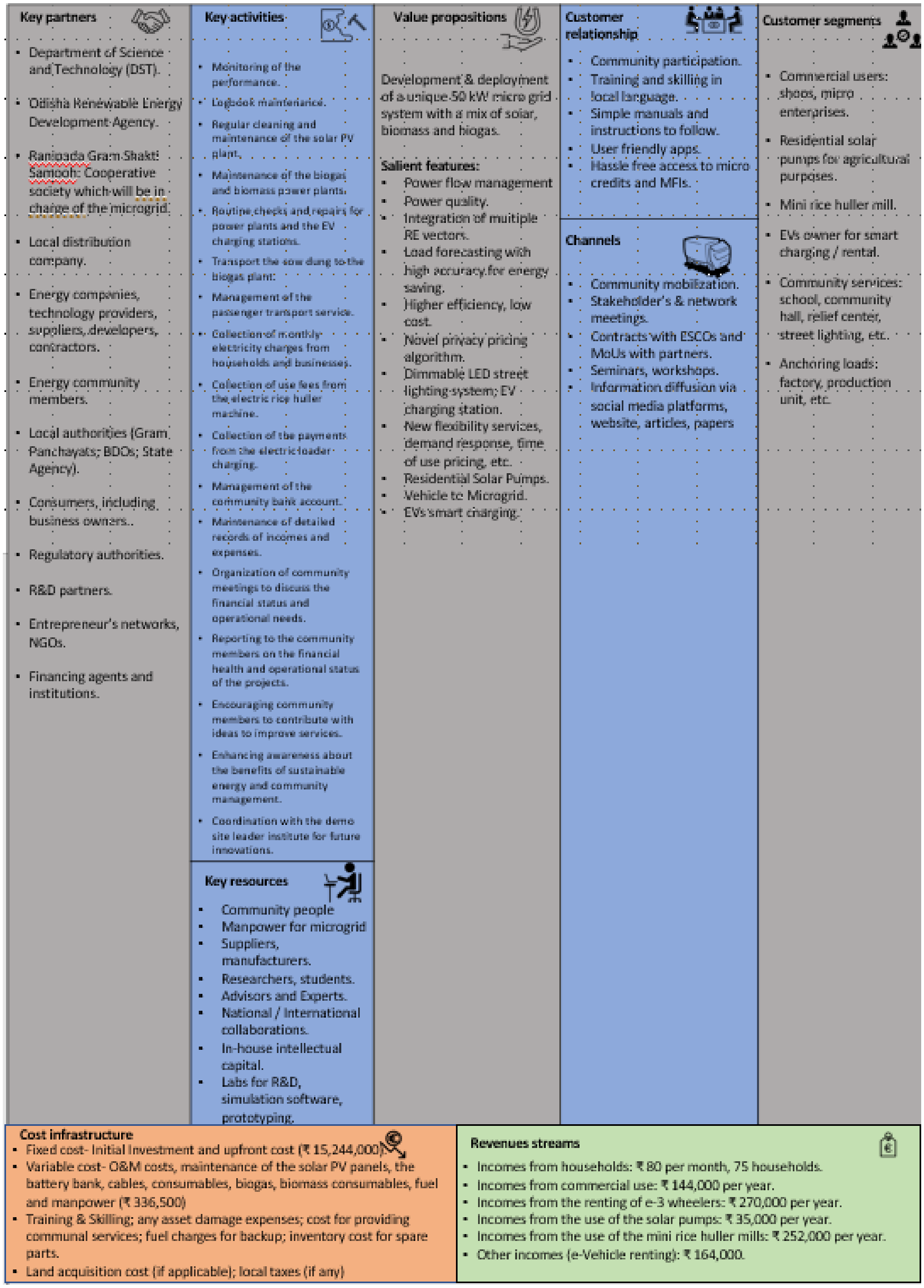

Figure 43. Business Canvas Model for Keonjhar, India

The development of the before described energy community will allow to supply electricity to the Kanheigola, Nola and Ranipada villages, which currently are not connected to the grid, and lack a stable and affordable electricity supply. Besides, the use of renewable energies will ensure that the new facilities will minimize the greenhouse gas emissions, and the environmental impact. This business model combines the improvement in the living conditions of Keonjhar inhabitants, with the use of the most advanced renewable energy technologies, and the development of an energy community which will be in charge of the management of the microgrid.

<u>Key partners which should be taken into account in the business model</u>

The following is a list of the main stakeholders in Keonjhar microgrid which have a role in the defined business model:

- Department of Science and Technology (DST)- Ministry of Science and Technology-Government of India. It has funded the project, and covered the total investment cost in the development of the 50 kWp microgrid system.
- Odisha Renewable Energy Development Agency: Owner of the existing microgrid.
- Ranipada Gram Shakti Samooh: Cooperative society which will be in charge of the microgrid. The members of the cooperative have received trained during the installation of the microgrid, and about the handling of the same.
- A local distribution company will be in charge of the maintenance tasks of the microgrid. Maintenance tasks will be carried out yearly.
- Energy companies.
- Technology providers and suppliers, promoters and contractors.
- Energy community members.
- Local authorities, such as the Gram Panchayats, Block Development Offices (BDOs), and the State Agency.
- Consumers, including business owners and local residents.
- Farmers, who will supply the needed cow dung and rice husk.
- Rice huller owners, which will supply the husk.
- Regulatory authorities: Tehsil Office, Odisha Forest Department, Department of Energy-Government of Odisha.
- R&D partners, including IIT BBS.
- Entrepreneur’s networks, NGOs.
- Financing agents and institutions.

Key activities which can be developed in the business model

To make the proposed business model successful, it is necessary to develop the following activities:

- Regularly monitoring the performance of the energy plants and EV charging stations.
- Daily wise logbook maintenance.
- Regular cleaning and maintenance of the solar power plant.
- Maintenance and operation of the biogas and biomass power plants.
- Routine checks and repairs for power plants & the EV charging stations.
- Coordinating the transportation of cow dung to the biogas plant using one electric loader and collecting husk from rice huller machine to the biomass husk storage room and if required purchasing the husk from the nearest rice mill.
- Managing the passenger transport service between Ranipada, Badapalaspal, and Harichandanpur using the second electric loader.
- Collection of monthly electricity charges from each household (₹ 80 per household).
- Collection of usage fees from the electric rice huller machine (₹ 50 per hour).
- Collection of the payments from the electric loader charging used for passenger transport.
- Management of the community bank account.
- Maintaining detailed records of income and expenses.
- Organizing community meetings to discuss the financial status and operational needs.
- Reporting to the community members on the financial health and operational status of the projects.
- Encouraging community members to contribute with ideas for improving energy and transportation services.
- Enhancing awareness about the benefits of sustainable energy and community management.
- Coordinating with the Demo site Leader Institute for future innovations.

4.3.5. Economic sustainability analysis for Keonjhar

In this chapter, an economic sustainability analysis is carried out for the Keonjhar microgrid, based on information provided by the Demo Site leader. Information about the investment cost has been mainly provided when the first analyses were carried out in 2022, and was used to carry out the Deliverable 8.1. In year 2024, the Demo Site leader has mainly provided more updated and detailed information about the operation and maintenance cost of the Demo Site, as well as the expected revenues which will be obtained.

To design this economic model, the following information has been used:

- Previous hypotheses about the Demo Site: The Demo Site has the following features:
    - Number of households: 75 households.
    - Available power per household: 100 W.
    - Number of microenterprises which are developed: 25.
    - Number of electrical 3 wheelers: At the beginning of the project, there will be 2 e-3 wheelers. Every 5 years, 3 new electrical 3 wheelers will be purchased. This means that in the fifth year, there will be 5 e-3 wheelers, in the tenth year, there will be 8, and so on.
    - 1 charging facility will be installed, with 2 ports, and 1.5 kW.
    - Number of mini rice huller mills: 3, with a power of 1 HP (0.7457 kW each).
    - Solar power dimmable lights: 10 units.
    - Smart meters with fuse and MCCB/MCB: 10 units.
    - Solar pumps: Two solar pumps will be installed.
- Investment cost: To calculate the investment cost, only the most important assets are considered.

  The most relevant investment costs in the Demo Site are:
    - 50 kW microgrid system, including 30 kWp of solar PV, 10 kW of biomass and 10 kW of biogas, with a 180 kWh battery: ₹ 11,500,000 (which is equivalent to €127,650.00).
    - Deployment of other infrastructure, and installation of ecoTools: ₹ 3,494,000 (which is equivalent to €38,783,40).
    - Electric 3-wheelers and charging station: ₹ 250,000 (which is equivalent to €2,775.00).
- Estimated operation and maintenance cost: This cost includes the maintenance cost of equipment (corrective and preventive), as well as the cost of fuel and personnel who works in the Demo Site:
    - Maintenance cost of solar PV panels: The cost of maintaining the solar PV panels is estimated to be ₹ 29/Wp. Considering that the installed power capacity is 5 kWp, the total cost is ₹ 14,500/year, this is, €160.95/year.
    - Maintenance cost of the battery bank: The cost of maintaining the battery bank is estimated to be ₹ 7,500/kWh and year. As the capacity of the battery bank is 180 kWh, then the total maintenance cost amounts to ₹ 135,000/year, equivalent to €1,498.50/year.
    - Replacement of cables (AC & DC): Each year, a maintenance action to replace some cables of the Demo Site will be needed. Its cost is estimated to be ₹ 7,000/year, equivalent to €77.70/year.

- Consumables: Maintenance actions in the Demo Site require some consumables, with a cost of ₹ 5,000/year, or €55.50/year.
- Maintenance cost of the inverter: The inverter has to be replaced each 10 years. The cost of the inverter is ₹ 900,000, or €9,990.0 each 10 years.
- Biogas consumables: The production of biogas needs some consumables. The cost of these materials is estimated to be ₹ 10,000 per year, which is equivalent to €111.00.
- Biomass consumables: To produce the biomass, the cost of the needed consumables reaches ₹ 10,000 per year, or €111.00.
- Miscellaneous: Other costs of the Demo Site have been estimated to be around ₹ 5,000 per year, or €55.50.
- Labour cost for maintenance actions, biogas and biomass fuel cost: Each year, the cost of the professionals in charge of maintaining the Demo Site, as well as the biogas and biomass, is estimated to be ₹ 150,000, equivalent to €1,665.00.

The total operation and maintenance cost reaches ₹ 336,500, or €3,735.15. Maintenance actions, including the maintenance cost of the solar PV panels, the battery bank, the replacement of cables and the consumables, are free during the first three years, because all equipment is covered by a 3-year guarantee.

- Incomes for the microgrid: The incomes for the microgrid come from the sale of electricity to domestic and industrial clients, apart from the payments for the use of the e-3 wheelers, the solar pumps, the mini rice hullers and other incomes, such as e-vehicle renting.
  - Incomes from household clients: As explained in the hypotheses, there are 75 households. Each one is charged ₹ 80/month (€0.888) for the use of electricity.

    This means that the total incomes from electricity sale to households is ₹ 6,000/month (€66.60/month), and each year, the total incomes will be ₹ 72,000 (€799.20/year).

    Besides, the fee is expected to increase by 10% each year.
  - Incomes from commercial clients: There are 25 microenterprises. The total income from these users will be ₹ 144,000 per year (€1,598.40/year), with an increase of 10% per year.
  - Incomes from the renting of e-3 wheelers: The payments received for each e-3 wheeler are estimated to be ₹ 135,000 per year, equivalent to €1,498.50/year.

    During the first 5 years, there will be only two e-3 wheelers. The incomes in the first year will be ₹ 270,000, equivalent to € 2,997.00/year.

    In the fifth year, other 3 e-wheelers will be purchased, and every five years, 3 new e-wheelers will be purchased and made available for use.

Additionally, the price for renting the e-3 wheelers will increase by 10% each year. For example, in the fifth year, the total income will be ₹ 135,000 * 5 3 e-wheelers * (1+10%)^5, this is, ₹ 988,268, or € 10,969.77.

  - Incomes from the use of the solar pumps: These incomes will amount to ₹ 35,000 per year, or €388.50/year. They will increase by 10% per year
  - Incomes from the use of the mini rice huller mills: It is expected to charge ₹ 50 per hour. Additionally, the use of the mini rice huller mills will be approximately 4 or 5 hours per day.

    This involves a total monthly use of 120 hours, and incomes amounting to ₹ 6,000 per month, and ₹ 72,000 per year.
  - Other incomes (e-Vehicle renting): Other incomes, amounting to ₹ 164,000/year will be obtained (€1,820.40/year). An increase of 10% per year is also expected.

- The depreciation and amortization cost has been supposed to be calculated linear, this is, the investment cost is amortized with the same amount yearly.

  Since the total investment cost is ₹ 15,244,000 (€ 169,244.00), and a lifetime of 20 years is considered, then the depreciation and amortization will amount to ₹ 762,200/year (or €8,460.72/year).

  The amortization cost will increase each 5 years, as new e-3 wheelers are purchases.
- The income tax surcharge is estimated to be 7% of the profit before taxes.
- The Minimum Alternate Tax (MAT) is estimated to be 15% of the profit before taxes.
- Lifetime of Microgrid is 20 years.
- Discount rate considered is 10%.

The following economic model, based on cash flows, has been prepared for the Keonjhar Demo Site, to evaluate the economic and financial sustainability of the microgrid and the solutions. The model has been calculated in rupees and in euros.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the demo site	-₹ 15,244,000					-₹ 375,000					-₹ 375,000
50 kWp solar biomass-biogas microgrid with 150 kWh battery	-₹ 11,500,000										
Deployment of other infrastructure & ecoTools	-₹ 3,494,000										
Electric 3-wheelers and charging station cost	-₹ 250,000					-₹ 375,000					-₹ 375,000
Total incomes		₹ 757,000	₹ 832,700	₹ 915,970	₹ 1,007,567	₹ 1,701,284	₹ 1,871,413	₹ 2,058,554	₹ 2,264,409	₹ 2,490,850	₹ 4,331,550
Incomes from household clients		₹ 72,000	₹ 79,200	₹ 87,120	₹ 95,832	₹ 105,415	₹ 115,957	₹ 127,552	₹ 140,308	₹ 154,338	₹ 169,772
Incomes from commercial clients		₹ 144,000	₹ 158,400	₹ 174,240	₹ 191,664	₹ 210,830	₹ 231,913	₹ 255,105	₹ 280,615	₹ 308,677	₹ 339,544
Incomes from renting the e-3 wheelers		₹ 270,000	₹ 297,000	₹ 326,700	₹ 359,370	₹ 988,268	₹ 1,087,094	₹ 1,195,804	₹ 1,315,384	₹ 1,446,922	₹ 3,183,229
Incomes from the use of the solar pumps		₹ 35,000	₹ 38,500	₹ 42,350	₹ 46,585	₹ 51,244	₹ 56,368	₹ 62,005	₹ 68,205	₹ 75,026	₹ 82,528
Incomes from the use of the mini rice huller mills		₹ 72,000	₹ 79,200	₹ 87,120	₹ 95,832	₹ 105,415	₹ 115,957	₹ 127,552	₹ 140,308	₹ 154,338	₹ 169,772
Other incomes (e-Vehicle renting)		₹ 164,000	₹ 180,400	₹ 198,440	₹ 218,284	₹ 240,112	₹ 264,124	₹ 290,536	₹ 319,590	₹ 351,549	₹ 386,703
Operation and maintenance costs		-₹ 175,000	-₹ 175,000	-₹ 175,000	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 1,236,500
Solar PV panels maintenance					-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500
Battery bank maintenance					-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000
Cable (AC & DC) maintenance					-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000
Consumables					-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000
Inverter maintenance					₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	₹ 0	-₹ 900,000
Biogas consumables		-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000
Biomass consumables		-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000
Miscellaneous		-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000
Biogas and biomass fuel cost and manpower		-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000
Depreciation and amortization		-₹ 762,200	-₹ 762,200	-₹ 762,200	-₹ 762,200	-₹ 762,200	-₹ 780,950	-₹ 780,950	-₹ 780,950	-₹ 780,950	-₹ 780,950
Profit before taxes		-₹ 180,200	-₹ 104,500	-₹ 21,230	-₹ 91,133	₹ 227,584	₹ 753,963	₹ 941,104	₹ 1,146,959	₹ 1,373,400	₹ 1,939,100
Income Tax Surcharge		₹ 0	₹ 0	₹ 0	₹ 0	-₹ 15,931	-₹ 52,777	-₹ 65,877	-₹ 80,287	-₹ 96,138	-₹ 135,737
Minimum Alternate Tax (MAT)		₹ 0	₹ 0	₹ 0	₹ 0	-₹ 34,138	-₹ 113,094	-₹ 141,166	-₹ 172,044	-₹ 206,010	-₹ 290,865
Net cash flow	-₹ 15,244,000	₹ 582,000	₹ 657,700	₹ 740,970	₹ 671,067	₹ 939,716	₹ 1,369,041	₹ 1,515,011	₹ 1,675,578	₹ 1,852,202	₹ 2,293,448
Accumulated net cash flows	-₹ 15,244,000	-₹ 14,662,000	-₹ 14,004,300	-₹ 13,263,330	-₹ 12,592,263	-₹ 11,652,547	-₹ 10,283,506	-₹ 8,768,495	-₹ 7,092,917	-₹ 5,240,715	-₹ 2,947,267

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the demo site					-₹ 375,000					-₹ 375,000
50 kWp solar biomass-biogas microgrid with 150 kWh battery										
Deployment of other infrastructure & ecoTools										
Electric 3-wheelers and charging station cost					-₹ 375,000					-₹ 375,000
Total incomes	₹ 4,764,705	₹ 5,241,175	₹ 5,765,293	₹ 6,341,822	₹ 9,539,316	₹ 10,493,247	₹ 11,542,572	₹ 12,696,829	₹ 13,966,512	₹ 19,491,402
Incomes from household clients	₹ 186,749	₹ 205,424	₹ 225,967	₹ 248,564	₹ 273,420	₹ 300,762	₹ 330,838	₹ 363,922	₹ 400,314	₹ 440,345
Incomes from commercial clients	₹ 373,499	₹ 410,849	₹ 451,934	₹ 497,127	₹ 546,840	₹ 601,524	₹ 661,676	₹ 727,844	₹ 800,628	₹ 880,691
Incomes from renting the e-3 wheelers	₹ 3,501,552	₹ 3,851,708	₹ 4,236,878	₹ 4,660,566	₹ 7,689,934	₹ 8,458,928	₹ 9,304,820	₹ 10,235,302	₹ 11,258,833	₹ 16,512,954
Incomes from the use of the solar pumps	₹ 90,781	₹ 99,859	₹ 109,845	₹ 120,829	₹ 132,912	₹ 146,204	₹ 160,824	₹ 176,906	₹ 194,597	₹ 214,057
Incomes from the use of the mini rice huller mills	₹ 186,749	₹ 205,424	₹ 225,967	₹ 248,564	₹ 273,420	₹ 300,762	₹ 330,838	₹ 363,922	₹ 400,314	₹ 440,345
Other incomes (e-Vehicle renting)	₹ 425,374	₹ 467,911	₹ 514,702	₹ 566,172	₹ 622,790	₹ 685,069	₹ 753,576	₹ 828,933	₹ 911,826	₹ 1,003,009
Operation and maintenance costs	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500	-₹ 336,500
Solar PV panels maintenance	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500	-₹ 14,500
Battery bank maintenance	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000	-₹ 135,000
Cable (AC & DC) maintenance	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000	-₹ 7,000
Consumables	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000
Inverter maintenance										
Biogas consumables	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000
Biomass consumables	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000	-₹ 10,000
Miscellaneous	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000	-₹ 5,000
Biogas and biomass fuel cost and manpower	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000	-₹ 150,000
Depreciation and amortization	-₹ 799,700	-₹ 799,700	-₹ 799,700	-₹ 799,700	-₹ 799,700	-₹ 818,450	-₹ 818,450	-₹ 818,450	-₹ 818,450	-₹ 818,450
Profit before taxes	₹ 3,628,505	₹ 4,104,975	₹ 4,629,093	₹ 5,205,622	₹ 8,028,116	₹ 9,338,297	₹ 10,387,622	₹ 11,541,879	₹ 12,811,562	₹ 17,961,452
Income Tax Surcharge	-₹ 253,995	-₹ 287,348	-₹ 324,037	-₹ 364,394	-₹ 561,968	-₹ 653,681	-₹ 727,134	-₹ 807,932	-₹ 896,809	-₹ 1,257,302
Minimum Alternate Tax (MAT)	-₹ 544,276	-₹ 615,746	-₹ 694,364	-₹ 780,843	-₹ 1,204,217	-₹ 1,400,745	-₹ 1,558,143	-₹ 1,731,282	-₹ 1,921,734	-₹ 2,694,218
Net cash flow	₹ 3,629,934	₹ 4,001,581	₹ 4,410,392	₹ 4,860,085	₹ 7,061,630	₹ 8,102,322	₹ 8,920,795	₹ 9,821,116	₹ 10,811,469	₹ 14,828,383
Accumulated net cash flows	₹ 682,667	₹ 4,684,247	₹ 9,094,640	₹ 13,954,725	₹ 21,016,356	₹ 29,118,678	₹ 38,039,473	₹ 47,860,589	₹ 58,672,057	₹ 73,500,440

Income Tax Surcharge	7%
Minimum Alternate tax (MAT)	15%

Discount rate (%)	10%

NPV	₹ 7,490,513
IRR (%)	13.545%
First positive accumulated cash flow	₹ 682,667
Payback (years)	Year 11

Table 40. Economic model for the Keonjhar Demo Site, including the cash flow model and a profitability analysis, in rupees.

Besides, the same economic cash flow model has been developed in euros:

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Investment cost of the demo site (€)	-169,208.40 €					-4,162.50 €					-4,162.50 €
50 kWp solar biomass-biogas microgrid with 150 kWh battery	-127,650.00 €										
Deployment of other infrastructure & ecoTools	-38,783.40 €										
Electric 3-wheelers and charging station cost	-2,775.00 €					-4,162.50 €					-4,162.50 €
Total incomes		8,402.70 €	9,242.97 €	10,167.27 €	11,183.99 €	18,884.25 €	20,772.68 €	22,849.95 €	25,134.94 €	27,648.44 €	48,080.20 €
Incomes from household clients		799.20 €	879.12 €	967.03 €	1,063.74 €	1,170.11 €	1,287.12 €	1,415.83 €	1,557.41 €	1,713.16 €	1,884.47 €
Incomes from commercial clients		1,598.40 €	1,758.24 €	1,934.06 €	2,127.47 €	2,340.22 €	2,574.24 €	2,831.66 €	3,114.83 €	3,426.31 €	3,768.94 €
Incomes from renting the e-3 wheelers		2,997.00 €	3,296.70 €	3,626.37 €	3,989.01 €	10,969.77 €	12,066.75 €	13,273.42 €	14,600.76 €	16,060.84 €	35,333.85 €
Incomes from the use of the solar pumps		388.50 €	427.35 €	470.09 €	517.09 €	568.80 €	625.68 €	688.25 €	757.08 €	832.78 €	916.06 €
Incomes from the use of the mini rice huller mills		799.20 €	879.12 €	967.03 €	1,063.74 €	1,170.11 €	1,287.12 €	1,415.83 €	1,557.41 €	1,713.16 €	1,884.47 €
Other incomes (e-Vehicle renting)		1,820.40 €	2,002.44 €	2,202.68 €	2,422.95 €	2,665.25 €	2,931.77 €	3,224.95 €	3,547.44 €	3,902.19 €	4,292.41 €
Operation and maintenance costs (€)		-1,942.50 €	-1,942.50 €	-1,942.50 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-13,725.15 €
Solar PV panels maintenance					-160.95 €	-160.95 €	-160.95 €	-160.95 €	-160.95 €	-160.95 €	-160.95 €
Battery bank maintenance					-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €
Cable (AC & DC) maintenance					-77.70 €	-77.70 €	-77.70 €	-77.70 €	-77.70 €	-77.70 €	-77.70 €
Consumables					-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €
Inverter maintenance					0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	-9,990.00 €
Biogas consumables					-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €
Biomass consumables					-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €
Miscellaneous					-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €
Biogas and biomass fuel cost and manpower		-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €
Depreciation and amortization (€)		-8,460.42 €	-8,460.42 €	-8,460.42 €	-8,460.42 €	-8,460.42 €	-8,668.55 €	-8,668.55 €	-8,668.55 €	-8,668.55 €	-8,668.55 €
Profit before taxes (€)		-2,000.22 €	-1,159.95 €	-235.65 €	-1,011.58 €	6,688.68 €	8,368.99 €	10,446.25 €	12,731.25 €	15,244.74 €	25,686.51 €
Income Tax Surcharge		0.00 €	0.00 €	0.00 €	0.00 €	-468.21 €	-585.83 €	-731.24 €	-891.19 €	-1,067.13 €	-1,798.06 €
Minimum Alternate Tax (MAT)		0.00 €	0.00 €	0.00 €	0.00 €	-1,003.30 €	-1,255.35 €	-1,566.94 €	-1,909.69 €	-2,286.71 €	-3,852.98 €
Net cash flow (€)	-169,208.40 €	6,460.20 €	7,300.47 €	8,224.77 €	7,448.84 €	13,677.59 €	15,196.35 €	16,816.62 €	18,598.92 €	20,559.44 €	28,704.02 €
Accumulated net cash flows (€)	-169,208.40 €	-162,748.20 €	-155,447.73 €	-147,222.96 €	-139,774.12 €	-126,096.53 €	-110,900.17 €	-94,083.55 €	-75,484.63 €	-54,925.19 €	-26,221.17 €

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Investment cost of the demo site (€)					-4,162.50 €					-4,162.50 €
50 kWp solar biomass-biogas microgrid with 150 kWh battery										
Deployment of other infrastructure & ecoTools										
Electric 3-wheelers and charging station cost					-4,162.50 €					-4,162.50 €
Total incomes	52,888.22 €	58,177.05 €	63,994.75 €	70,394.23 €	105,886.41 €	116,475.05 €	128,122.55 €	140,934.81 €	155,028.29 €	216,354.56 €
Incomes from household clients	2,072.92 €	2,280.21 €	2,508.23 €	2,759.06 €	3,034.96 €	3,338.46 €	3,672.30 €	4,039.53 €	4,443.49 €	4,887.83 €
Incomes from commercial clients	4,145.84 €	4,560.42 €	5,016.46 €	5,518.11 €	6,069.92 €	6,676.91 €	7,344.60 €	8,079.07 €	8,886.97 €	9,775.67 €
Incomes from renting the e-3 wheelers	38,867.23 €	42,753.95 €	47,029.35 €	51,732.28 €	85,358.27 €	93,894.10 €	103,283.51 €	113,611.86 €	124,973.04 €	183,293.79 €
Incomes from the use of the solar pumps	1,007.67 €	1,108.44 €	1,219.28 €	1,341.21 €	1,475.33 €	1,622.86 €	1,785.15 €	1,963.66 €	2,160.03 €	2,376.03 €
Incomes from the use of the mini rice huller mills	2,072.92 €	2,280.21 €	2,508.23 €	2,759.06 €	3,034.96 €	3,338.46 €	3,672.30 €	4,039.53 €	4,443.49 €	4,887.83 €
Other incomes (e-Vehicle renting)	4,721.65 €	5,193.81 €	5,713.20 €	6,284.51 €	6,912.97 €	7,604.26 €	8,364.69 €	9,201.16 €	10,121.27 €	11,133.40 €
Operation and maintenance costs (€)	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €	-3,735.15 €
Solar PV panels maintenance	-160.95 €	-160.95 €	-160.95 €	-160.95 €	-160.95 €	-160.95 €	-160.95 €	-160.95 €	-160.95 €	-160.95 €
Battery bank maintenance	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €	-1,498.50 €
Cable (AC & DC) maintenance	-77.70 €	-77.70 €	-77.70 €	-77.70 €	-77.70 €	-77.70 €	-77.70 €	-77.70 €	-77.70 €	-77.70 €
Consumables	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €
Inverter maintenance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
Biogas consumables	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €
Biomass consumables	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €	-111.00 €
Miscellaneous	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €	-55.50 €
Biogas and biomass fuel cost and manpower	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €	-1,665.00 €
Depreciation and amortization (€)	-8,876.67 €	-8,876.67 €	-8,876.67 €	-8,876.67 €	-8,876.67 €	-9,084.80 €	-9,084.80 €	-9,084.80 €	-9,084.80 €	-9,084.80 €
Profit before taxes (€)	40,276.40 €	45,565.23 €	51,382.93 €	57,782.41 €	93,274.59 €	103,655.10 €	115,302.61 €	128,114.86 €	142,208.34 €	203,534.62 €
Income Tax Surcharge	-2,819.35 €	-3,189.57 €	-3,596.81 €	-4,044.77 €	-6,529.22 €	-7,255.86 €	-8,071.18 €	-8,968.04 €	-9,954.58 €	-14,247.42 €
Minimum Alternate Tax (MAT)	-6,041.46 €	-6,834.78 €	-7,707.44 €	-8,667.36 €	-13,991.19 €	-15,548.27 €	-17,295.39 €	-19,217.23 €	-21,331.25 €	-30,530.19 €
Net cash flow (€)	40,292.27 €	44,417.55 €	48,955.36 €	53,946.95 €	81,630.85 €	89,935.77 €	99,020.83 €	109,014.39 €	120,007.30 €	167,841.80 €
Accumulated net cash flows (€)	14,071.10 €	58,488.65 €	107,444.00 €	161,390.95 €	243,021.80 €	332,957.57 €	431,978.40 €	540,992.79 €	661,000.09 €	828,841.88 €

Income Tax Surcharge	7%
Minimum Alternate tax (MAT)	15%

Discount rate (%)	10%

NPV	87,672.29 €
IRR (%)	13.731%
First positive accumulated cash flow	14,071.10 €
Payback (years)	Year 11

Table 41. Economic model for the Keonjhar Demo Site, including the cash flow model and a profitability analysis, in euros.

The cash flow model shows that the Keonjhar Demo Site has positive results. Firstly, the net present value of the project, with a discount rate of 10%, amounts to €87,672.29 along 20 years. Additionally, the IRR is 13.731%.

On the other hand, the payback period is 11 years.

The following figure shows the Cash Flow Diagram of the Keonjhar Demo Site:

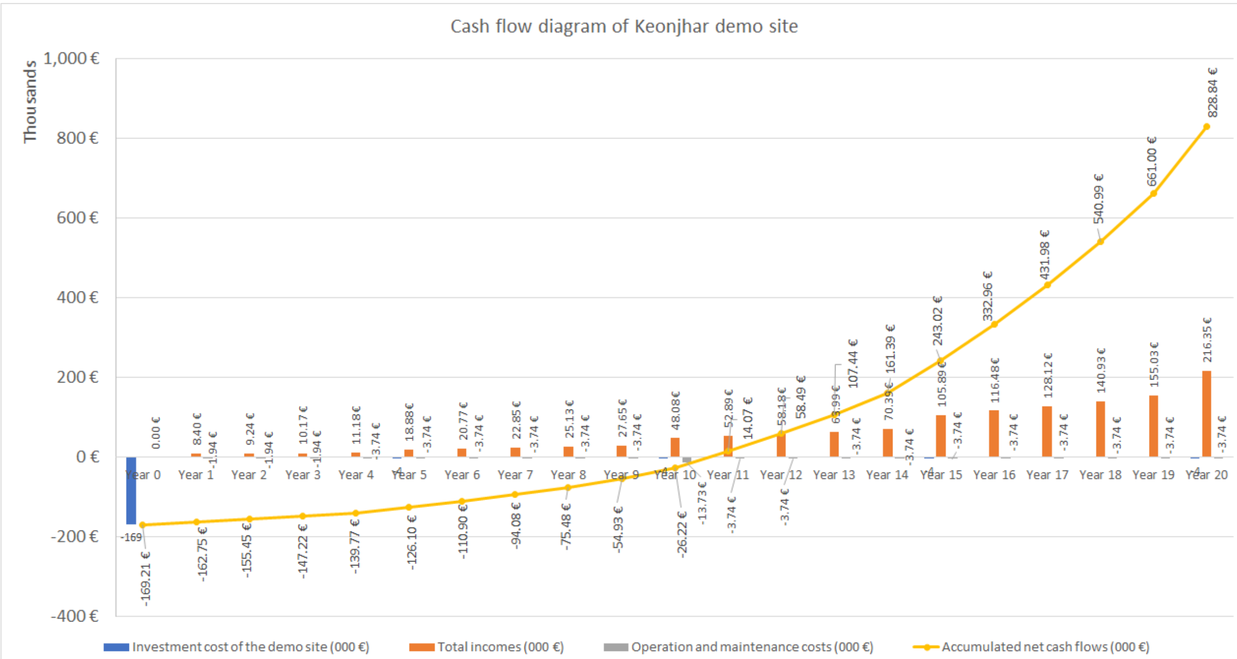

Figure 44. Cash flow diagram of Keonjhar Demo Site

It can be remarked that the previous economic sustainability model, developed in 2022, showed negative results, with an IRR of 9.29%, and a net present value of €-9.263.91 (with a discount rate of 10%). This was due to the fact that the domestic consumers were expected not to be charged any cost.

The new analysis shows that the microgrid business model only can become sustainable if it receives some economic support from the government (either subsidized access to finance, or a part of the investment cost), or if new revenue streams are identified, such as flexibility services or demand response. In this case, it has been decided to charge residential consumers with a reduced fee, of ₹ 80 per month, which allow them to use 30 kWh per month. If they used more electricity, each unit would be charged at 10 rupees.

4.3.6. Financing tools applicable to the Demo Site

As previously described, the total investment cost of the Keonjhar Demo Site amounts to ₹ 15,244,000, or €169,208.40.

In this case, IIT KGP will be the partner in charge of the exploitation and demonstration of the Demo Site.

According to this limited amount, the following financial instruments can be considered:

- Loan: This is the most common financing instrument. A loan is offered by a bank, or another financial institution, which lends the money to the microgrid developer and operator, during a term. This term is, in general, between 3-10 years, and in any case should not be longer than the expected useful lifetime of the assets. Loans, in general, cover only between 50% and 70% of the cost of the project. On the other hand, banks require the existence of corporate and personal guarantees from the client.

  As there exists a guarantee, the interest rate of loans is lower than in alternative financial instruments. Loans can be used for any size of projects and investments.

- Leasing: This instrument can be used in projects where there is a specific asset, which can be recovered by the owner if the user does not pay the yearly fee. A leasing contract can cover between 50% and 70% of the cost of the asset, and its duration depends on the lifetime of the asset, generally, between 5 and 12 years.

  As happens with loans, corporate and personal guarantees can be required. The difference with the loan is that, in this case, the owner of the asset is the financing company, called the lessor. The user or lessee pays a periodic fee for the use of the good. At the end of the leasing contract, the user can purchase the good, in general, paying the last fee, or for free.

  Leasing contracts do not include the maintenance and insurance of the asset. The interest rate of leasing contracts is higher than the interest rate of loans. On the other hand, it is important to consider that the leasing is considered as debt in the financial statements of the company.

- Renting: This instrument is quite similar to leasing. In this case, there is a specific equipment (the microgrid), which is the main guarantee of the operation. The typical duration of a renting contract is between 2 and 10 years, and covers between 50% and 100% of the cost of the project. In leasing, the cost which can be funded is limited to the equipment, but renting can cover other costs, such as services, project design, civil works, licenses, and others. Besides, renting includes the maintenance and insurance of the asset.

  The asset is not owned by the user, what involves that renting contracts are not considered as debt, they are an expense. The renting company is paid for the use of the equipment and for the maintenance. In a renting contract, the user has not the option to purchase the asset at the end of the contract, as happened with leasing.

The client is required to present some corporate and personal financial guarantees. The main advantage of renting is that it is not considered as debt in the company's annual statements.

- Crowdfunding: The option of crowdfunding in India can be limited due to the reduced economic capacity of the potential crowdlenders, the final users. For this reason, in the case of Keonjhar Microgrid, it is not considered as an option.

  However, in the European Union, it could be considered. In crowdfunding, an online platform allows individuals to support a project (normally related to energy efficiency, renewable energy, water treatment, health, electric mobility, circular economy, or a sustainable or social impact project), investing a small amount of money. During the lifetime of the project, lenders are returned their investment, with an interest rate.

It can be also mentioned that a community bank account has been opened in Bank of India. This account will be used to manage the expenses and incomes of the energy community. The incomes from the microgrid (payments from household clients, commercial clients, the renting of the e-3 wheelers, the use of the solar pumps, the mini rice huller mills and the e-Vehicle renting) will be deposited in this account. Besides, these funds will be used to pay maintenance and other operational costs.

5. Conclusions

The objective of Work Package 8 is the design, development, and testing of new business models which can increase the integration of renewable energy, foster the development of energy communities, and the adoption of advanced demand side management mechanisms in isolated energy systems.

The main result of RE-EMPOWERED is the development of the ecoToolset, which is being tested in the Demo Sites. It is essential to design business models specially tailored according to each ecoTool and Demo Site, to allow the full integration of ecoTools and its use by the energy consumers. Besides, the use of ecoTools have to be economically, socially and environmentally feasible for energy consumers and for the asset owner. ecoTools will also increase the engagement of citizens, and will encourage citizens to adapt their energy consumption to the availability of renewable energies, while keeping energy prices affordable.

This Deliverable focuses on the development and evaluation of business models for each Demo Site of RE-EMPOWERED, including the Demo Sites in the European Union (Kythnos Island in Greece, the Gaidouromantra microgrid, as a particular case of Kythnos, and Bornholm Island in Denmark), and 2 Demo Sites in India (Ghoramara microgrid in the state of West Bengal and Keonjhar microgrid in the state of Odisha). The described business models are not theoretical, but are actually being tested in each Demo Site, and have been designed according to the specific characteristics of each Demo Site, the availability of renewable energy resources, the willingness to pay of the different consumers, the energy uses, and the ecoTools which have been installed. The main tool used to develop business models are business canvases.

Besides, an economic sustainability analysis has been carried out for each ecoTool and Demo Site, using cash flow models and cash flow diagrams. These analyses are useful to evaluate the economic viability of ecoTools, from the point of view of the tool developer and the final user, as well as the profitability of Demo Sites.

Concerning ecoTools, a cash flow model has been carried out, both from the point of view of the ecoTool developer, and from the final user. These cash flow models have been useful to determine a selling price, and a number of units to be sold per year, among other. The objective of the analyses of cash flow models has been to make ecoTools profitable for the ecoTool developer (or the entity in charge of commercializing them), and also for the final user. If the business model is not attractive for any of these parts, then the ecoTool will not be commercialized.

The carried-out analyses show that, for all the Demo Sites, the business models can be viable, as long as affordable tariffs are paid by final users. In some cases, electricity in Demo Sites has been provided for free, and it can be difficult to make consumers be willing to pay for electricity. However, the improvement in the security of supply, and the provision of new services, as well as the creation of energy communities, can offer value enough to make citizens willing to pay for electricity. It should be also considered that the proposed ecoTools will improve the access to electricity in Demo Sites, allowing for a better life quality for citizens living in zones with limited or no connection to continental grids, as well as an increase in the economic activity. Besides, it will be possible to increase the penetration of renewable energies in Demo Sites, reducing imports of fossil fuels and greenhouse gas emissions.

In the following paragraphs, a summary of the main results is offered for each Demo Site:

- Bornholm Island (Denmark): The Bornholm Island Demo Site consists of a straw heat plant, four electric boilers for reserve and peak loads, a wood pellet boiler for backup, and a hot water storage tank. To produce electricity, several solar PV plants in rooftops and ground-mounted are used.

  The business model developed in the Bornholm Island is based on the combination of all energy sources to maximize the use of renewable energies. As more renewable energy capacity is installed in the island, electricity generation will be balanced with demand by using demand-side management mechanisms. Besides, electric boilers will be used to produce heat from electricity when electricity generation is very high, and when electricity prices are low. Heat is stored in the accumulation tanks, and replaces heat produced with the straw heat plant.

  Besides, two measures are taken to make heat produced with electricity competitive compared to heat produced with straw: the use of electric boilers to offer balancing services for the TSO, and the signature of power purchase agreements between the solar PV owners and Bornholms Varme A/S, saving the DSO and TSO fees.

  The before described business model is sustainable, as the net present value reaches almost €1 million along 20 years, and the IRR is 11.1%, while the payback period is 8 years.

- Kythnos Island (Greece): Kythnos is a totally isolated island, where the electricity generation is produced on site, with eight diesel generators, 3 solar PV plants and 2 solar PV rooftop installations. More than 96% of the electricity is produced with diesel generators, due to the difficulty to adjust renewable power generation and demand.

  The proposed business model for Kythnos Island involves the creation of energy communities, which will allow to increase the use of solar PV plants, and the use of demand response mechanisms, to ensure that power demand matches renewable electricity generation.

- Gaidouromantra Microgrid, in Kythnos Island (Greece): Gaidouromantra is a settlement made of 14 vacation houses in Kythnos Island, totally isolated from the rest of the grid. Electricity is produced in a microgrid, with 6 distributed solar PV plants, which have a total power capacity of 11.145 kW, a Lead-Acid battery bank and a battery. The electricity generation is backed with a 3-phase diesel generator.

  The business model chosen for Gaidouromantra is the creation of an energy community, which could be created by the 14 residents in the island. This energy community would be in charge of the operation and maintenance of the microgrid. Funds for the energy community are obtained with a pay-as-you-go model.

The economic sustainability model for the energy community, has moderately positive results, with a net present value of €3,624 along 20 years.

- Ghoramara Island (West Bengal, India): This island in India is located in the Sundarban delta, totally isolated from the mainland. Electricity was produced with a few solar PV panels, but recently the RE-EMPOWERED project has installed a 160 kW off-grid system based on solar PV, wind, and a BESS, along with 2 wind turbines, and a 10-kW advanced microgrid, with solar PV, wind and another BESS.

  The business model in the island considers the management of the microgrid by a user cooperative, and the development of several income sources, based on the electricity sale to domestic users, sale of electricity for house lighting systems, and the investment and management of electric boats and electric three-wheelers, along with two electric loaders. Besides, demand response measures will be applied.

  To make this model economically feasible, it is necessary that the investment cost of the microgrid is covered by subsidies from the government, although the investment cost of other assets, such as the electric boat or the electric chargers could be covered by the microgrid developer. Even if some incomes are obtained, as mentioned in the paragraph before, these incomes are not enough to recover the total investment. If such support is obtained, then the project can reach a net present value of €115,426,54 along 20 years, an internal rate of return of 19.40% and a payback of 11 years.

- Keonjhar (Odisha, India): Kanheigola, Nola and Ranipada are small villages in Keonjhar, not connected to the grid. Electricity is generated in Ranipada with a 22 kWp solar PV facility. A new 50 kW microgrid has been developed in Keonjhar, with 30 kWp solar PV, 10 kW biomass and 10 kW biogas. Besides, a battery bank with 340 kWh will be available.

  The business model in Keonjhar is the development of a new energy community, the Ranipada Gram Shakti Samooh, with 75 members. Additionally, electric 3-wheelers, charging facilities, mini rice huller mills and solar pumps are installed, and will be used by Keonjhar inhabitants paying a fee.

  This model is economically viable, with a net present value of €87,672,29 along 20 years, with a discount rate of 10%, and an internal rate of return of 13.731%. Besides, the payback period is 11 years. The results for the Keonjhar microgrid are different than those for the Ghoramara Island, as there is no need for any support from the government in the Keonjhar case. This is due the the lower investment cost, as the cost of the microgrid is around one third of the Ghoramara microgrid, while incomes are only one half of those of Ghoramara Island.

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Appendix A- Review of the Regulatory framework for renewable energies and energy communities in Denmark

Since 1976, Denmark has developed different regulations to support renewable energies and energy efficiency in the country. In that year, Denmark launched the Energy Research Programme (directly related to the First Energy Plan, or *Dansk Energipolitik*), focused on strategic energy projects, especially those which needed R&D activities, and excluding nuclear energy. Among the technologies supported by this Programme, it is possible to mention the use of biomass to produce heat and electricity, wind energy, solar PV, fuel cells, energy efficiency, hydrogen technologies, biofuels, and wave energy. The average level of subsidy was 50% of eligible costs, which could reach 100% in special cases.

The first law regarding renewable energy was the 1976 Electricity Supply Act (its last update is the Consolidated Act No. 271 of 9 March 2023). This Act sets the regulatory framework of the electricity sector, including the generation, transport, trade, and supply of electricity. Only licensed companies are allowed to carry out these activities, using public grids.

The Electricity Supply Act, in its original version, included the possibility that the Minister of Energy forced electricity supply companies to use some types of energies in the supply mix, or to take energy efficiency measures. This law has been reviewed periodically, to include changes in regulation and technological advances. For instance, in 1989, there were major modifications in the Act, including the obligation for power suppliers to purchase power produced with renewable energy plants and Combined Heat and Power plants. In 1994, there were some amendments regarding environmental protection. Finally, in 2002, the electricity market was liberalized, according to the Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity.

Similarly to the Electricity Supply Act, the Natural Gas Supply Act was enacted in May 1979, and it is regularly updated. The main objective of this Act was to reduce the importance of oil in the Danish energy supply, to minimize the impact of oil crises similar to these which took place in 1973 and 1979. The last version is the Consolidated Act No. 423 of 16 August 2023. This act regulates the Danish natural gas supply system. It ensures that the transmission, distribution, supply, and storage of natural gas consider the objectives of security of supply, at an economic cost, as well as the environment and consumer protection. It is applied to natural gas, liquified natural gas, biogas and other types of gas which can be transported using the natural gas system, in the Danish continental shelf area. As happened in the electricity market, the natural gas market was liberalized, under the Directive 98/30/EC of the European Parliament and of the Council of 22 June 1998 concerning common rules for the internal market in natural gas. Since January 2004, all natural gas consumers in Denmark have the right to choose their own natural gas supplier, or to be supplied by a company with a universal service licence.

Two relevant energy plans were developed by independent energy expert groups: the “Sketch for an energy plan in Denmark” (*Skitse till alternativ energieplan for Danmark*), published in 1976, and “Energy for the future: alternative energy plan” (*Energi for fremtiden: Alternativ energiplan*), launched in 1983. These plans included renewable energies as appropriate alternatives to nuclear power, for example, wind energy, other renewables, energy efficiency and natural gas.

The following relevant regulatory change was the Act on Support for Utilization of Renewable Energy Sources, enacted in 1981 (in line with the Second Energy Plan, *Energiplan 81*). It was designed to firmly support renewable energies and includes grants to develop these projects. Despite the long time that has gone by since its first version, this Act is regularly updated, to include changes in technology and European regulation. The last version is the Consolidated Act No. 1791 of 2 September 2021. The Act tries to encourage the development of renewable energy projects, with the objective of reducing the energy dependency of Denmark, increasing the security of supply and reducing the greenhouse gas emissions. The level of subsidies offered has changed along the time, considering the advances in each technology.

In 1985, the parliament rejected nuclear energy. As a result, there was an agreement between the Ministry of Energy and the utilities, called the “100 MW Agreement”, to develop 100 MW of wind power between 1986 and 1990. The objective of the plan was to support the growing local wind energy industry. The plan included capital grants of up to 30% of the installation costs, which were reduced to 20% and 10%, until 1988, when the subsidy was reduced by half.

In 1990, Denmark launched the Third Energy Plan, *Energi 2000*. It included the objective to reduce Danish CO_2 emissions by 20% between 1988 and 2005, compared to 1988 levels.

In 1992, the “fair price” for electricity generated with wind energy was defined as 85% of the retail electricity price. As defined in the Electricity Supply Act, these plants are guaranteed interconnection to the grid, and the power suppliers are obliged to purchase the electricity.

In 1993, for renewable electricity projects, a feed-in tariff, or price supplement, was designed. It makes the power purchase price independent from the electricity rates. Measures to promote the manufacturing of wind turbines were also included, which explains why some of the main worldwide leaders in this sector are Danish companies.

In Denmark there are different incentives to promote the development of renewable energy projects. They can be divided into price supplements (feed-in-tariffs or premium tariffs) and subsidies to the project construction.

In turn, feed-in tariffs can be divided into four types:

1. Premium on the market electricity price. In some cases, the sum of the premium and the market electricity price is capped and should not be higher than a certain maximum, while for some plants, the bonus to be added to the market electricity price is fixed and there is not a maximum.

2. Fixed settlement price, this is, the project developer receives a fixed electricity price. The difference between the market price and the fixed guaranteed price is then the subsidy it receives.

3. Contract for Difference (CfD) for tendered offshore wind energy projects. In this case, the amount of the subsidy can be calculated as the difference between the tendered price and the spot market price.
4. Fixed yearly payment, which does not depend on the electricity production.

On the other hand, the subsidies to the project construction are payments for a percentage of the costs, after its justification and approval. These subsidies are applied to technologies such as solar PV, wave power, biogas, and biomass. During the last years, feed-in tariffs are being reduced for new projects, as technologies have evolved and costs have been reduced.

For instance, and since some renewable energy technologies are now totally competitive, since 2020 new solar PV power plants are not offered subsidies, and contracts for difference are used for offshore wind farms.

Another important law which was developed in 1993 is the Biomass Agreement. According to this Agreement, the government set a target to increase the use of biomass from 50 PJ to 75 PJ by 2000, this is, 10% of the total fuel consumption in Denmark. To do this, two or three large biomass plants had to be built before 2003. The objective was that the two main electricity suppliers, Elsam and Elfraft, began to use 1.2 million tonnes of straw and 0.2 million tonnes of wood in large-scale power plants. However, finally none of these objectives was reached. For this reason, the Biomass Agreement was modified in 1997 and 2000, and the period to reach the objectives was extended until 2005. The costs for the utilities to fulfil with this Agreement was passed to electricity consumers as an extra charge. A feed-in tariff of DKK 0.30/kWh was offered for 10 years, as well as an additional DKK 0.10/kWh until the green certificates market is established.

In 1996, the Electricity Supply Act was updated, to include priority access to the grid, to renewable energy power plants. This update entered into force in 1998.

At the same time, the Danish government launched the Fourth Energy Plan (*Energi 21*). This plan included the following objectives:

- To reach 12-14% of the energy consumption of the country from renewable energies in 2005, and 35% by 2030.
- Ban on construction of new coal thermal power plants.

Denmark has also promoted the installation of solar PV self-consumption projects, especially since the establishment of the net metering for privately owned solar PV systems, which has been in force since 1998. The electricity surpluses of solar PV self-consumption plants are purchased at the same price as the utility sells its electricity. Actually, there is not a purchase of electricity, but the surpluses of generation, which are sold to the grid, are offset with the consumption of the clients in other moments. Besides, the electricity surpluses sold are exempted from paying the Public Service Obligation (PSO), a surcharge on the electricity tariff, aimed at promoting renewable energies, as well as other taxes and duties, such as VAT. In 2002, the net metering scheme was extended for another four years, until 2006.

In 1998, the Danish Government launched the SOL-300 project, which was aimed at developing 750 kWp of solar PV projects in roofs. 300 solar PV projects were developed, and most facilities were installed before 2001. In 2002, a new programme succeeded SOL-300, SOL-1000, with an objective of installing up to 1 MWp, and 1000 solar PV rooftop installations.

In 1998, the Danish Government also signed a binding agreement with the two main electricity providers, to install 750 MW of offshore wind farms by 2008, as the first phase of a planned installation of 4,000 MW of offshore wind turbines by 2030. Although two demonstration projects were completed, with a total capacity of 320 MW, in 2002 the obligation to build 750 MW was cancelled.

In 1999, the existing feed-in tariff scheme to promote renewable energies (created in 1993) was replaced for a new type of subsidy. These subsidies are based on a fixed settlement price for the first 10 years, and a premium additional to the market price for the following 10 years (with a maximum price to be received). This scheme did not guarantee interconnection for new renewable energy power plants.

There was an attempt to develop a renewable portfolio standard (RPS) mechanism based on a system of tradable green certificates. However, this new regulation was rejected by the parliament.

In 2001, these subsidies were complemented with a grant scheme to replace old and badly placed wind turbines. An owner who replaced a small old turbine could receive an additional subsidy of DKK 0.17/kWh for 12,000 hours for each new wind turbine connected to the grid between April 2001 and January 2004. After this period of 10 years, the wind turbines were not guaranteed a fixed feed-in tariff or price surcharges. Owners of old wind turbines received a scrapping certificate and financial support to carry out the wind turbine replacement.

The subsidies to replace old wind turbines were changed for a new scheme in 2004. In this case, the additional subsidy was a price supplement of DKK 0.12/kWh for the electricity production during the first 12,000 full-load hours, for doubling the installed capacity of the decommissioned wind turbine. The supplement is added to the market price and the ordinary subsidy to wind turbines, but with a cap of DKK 0.48/kWh.

These amounts were reviewed and reduced in 2008, to only a price supplement of DKK 0.08/kWh for the electricity production during the first 12,000 full-load hours, if the installed capacity of the new wind turbine is the double of the capacity of the old turbine. This price supplement is fixed, and does not depend on the spot market price. It is applied to wind turbines connected to the grid on 21st February 2008 or later. Owners of wind turbines can opt for receiving a price supplement of DKK 0.12/kWh, instead of the price supplement of DKK 0.08/kWh, on condition that the sum of the spot market price and the supplement, on a monthly basis, does not exceed the limit of DKK 0.38/kWh.

In 2008, the Danish government launched the Act on the Promotion of Renewable Energy (No. 1392 of 2008). This Act collects many of the measures which had been in force since long time ago, to promote the use of renewable energies, such as wind, hydro, biogas, biomass, solar PV, wave and tidal energy, as well as geothermal energy.

Among the measures included in the act, it is possible to mention the following:

- New schemes to promote the development of onshore wind turbines: Loss of value scheme, which provides clarification about the payment in case of loss of value to real property after the installation of a wind turbine. Individuals installing one or more onshore wind turbines have to offer at least 20% of the turbine ownership shares for sale, to residents who live near the wind farm. Green schemes which involve subsidies for these municipalities which accept to have new wind turbines installed were also created. All municipalities, collectively should prepare and adopt a supplement to their plans, reserving areas for wind turbines, in 2010 and 2011 (75 MW each year).

  These measures have made local communities involved in the development of renewable energies, reducing so the resistance to space use, and to noise and visual impact, making communities economically benefit from the electricity production.

- Grants for the replacement of old wind turbines are also included in this Act.
- Detailed feed-in premium tariffs for wind, biomass, biogas, and other renewable energy source electricity production are included.
- A fund of DKK 25 million per year, during 4 years is created to promote the development of small-scale, grid-connected renewable energy plants.

In December 2013, power utilities were obliged to install smart meters before December 31st, 2020, in all electricity supply points.

In December 2019, Denmark published its National Energy and Climate Plan, following the regulation from the European Commission.

The objectives stated in this plan are as follows:

- To reduce greenhouse gas emissions by 70% by 2030, compared to 1990. Denmark will work towards net zero emissions by 2050 at latest in the EU and in Denmark.
- To reduce Denmark's non-ETS greenhouse gas emissions in 2030 at least by 39%, compared to Denmark's emissions in 2005.
- To ban sales of all new diesel and petrol cars as of 2030.
- To reach 55% of the final energy consumption coming from renewable energy sources by 2030, and 100% by 2050.
- To reach 100% of the electricity consumption coming from renewable energy sources by 2030.
- To ensure that at least 90% of district heating consumption is based on energy sources different from coal, oil, or gas by 2030.
- To phase out coal in electricity production between 2019 and 2030.
- To promote energy efficiency measures, creating a competitive subsidy scheme for private companies, funded with DKK 300 million per year during the period 2021-2024, and

another competitive subsidy scheme for buildings with DKK 200 million per year during the period 2021-2024.

In June 2020, the Climate Ministers of the Netherlands and Denmark signed a Memorandum of Understanding (MoU), to transfer between 8 and 16 TWh of renewable energy from Denmark to the Netherlands.

To do so, the Netherlands would invest DKK 1 billion in large-scale Power to X plants of 100 MW in Denmark. Besides, storage and renewable energy technologies for trucks, ships and aircraft would be developed. This collaboration benefits from the large experience of Denmark in wind energy and the Netherlands knowledge on hydrogen production, and is also expected to help the Netherlands to reach its renewable energy penetration targets.

The agreement also includes some more general topics, such as:

- Development of cooperative policies to decarbonize the heating sector, while ensuring that heating can be supplied securely and at a low price. This includes the research on low temperature heat systems, heat market regulation, geothermal energy, heat storage and heat pumps.
- Organization of heat distribution systems, focusing on the role of local authorities, and creating public support for heat distribution systems.
- Offshore wind, including the development of offshore energy infrastructure, sector coupling, promoting the potential of offshore hubs in the North Sea, and join support to offshore wind development in third countries.
- Decarbonize the natural gas system, especially with hydrogen and biomethane, and promoting an international decarbonized trade.
- Clean fuel developments, including Power-to-X and biofuels.
- Development and deployment of Carbon Capture, Use and Storage (CCUS) technologies for industrial decarbonization, including waste-to-energy.
- Increasing the European climate ambitions, including the European discussions on legislation and policies.

On September 30th, 2020, in Szczecin, Poland, eight countries located in the Baltic Sea, namely Denmark, Germany, Estonia, Latvia, Lithuania, Poland, Finland and Sweden, along with the European Commission signed the Baltic Sea Offshore Wind Joint Declaration of Intent. These countries recognize the Baltic Sea Region as an area of dynamic economic development, and commit to working together to increase the offshore wind energy penetration, and to improving the transmission infrastructure across the Baltic Sea. Besides, a higher political, economic, and technological integration in the Baltic Sea Region, by regional cooperation will be reached. The parties will strive to develop commercially viable renewable offshore wind energy projects, and to increase the penetration of this technology.

In December 2020, the Danish Parliament agreed on phasing out the extraction of oil from the North Sea. This involves the cancellation of the ongoing 8th licensing round, and do not launch any additional licensing round. In any case, oil extraction in the North Sea deposits will be stopped by 2050.

Measures will be taken to reduce the economic impact on the zones whose economic activities relies on oil production (around 4,000 workers are employed directly and indirectly in this economic sector). An analysis about the potential electrification of current North Sea oil production will be carried out, as well as an analysis of the potential of carbon capture and storage in old oil and natural gas wells.

In 2021, the European Commission approved that Denmark created state aids for €400 million to develop electricity production from renewable energies. These subsidies are awarded by means of competitive bidding processes, organized until 2024. The bids are focused on different technologies, such as onshore and offshore wind, hydroelectric and wave energy, as well as solar PV. However, the tenders are technology neutral.

Another important milestone in the regulatory framework of Denmark was the reception of the European Union Recovery and Resilience Facility, in 2021. These funds, created under the NextGenerationEU instrument, are funds which the European Union offers to the European countries to carry out reforms and investments aligned with the EU's objectives and priorities, and defined according to the challenges of the country. Many of these objectives are related to climate neutrality, including renewable energy and energy efficiency.

Denmark received €1.55 billion in grants, from which 59% are used to support climate objectives (€922.1 million), and 25% (€382.3 million) in digital transition. The Danish Recovery and Resilience Plan was accepted by the European Council on the 13th of July 2021. Among the measures which are included in this plan, it is possible to mention the following ones:

- Component 3: Energy efficiency, green heating and carbon capture and storage: €274.3 million. This component includes energy efficiency measures, such as replacement of oil boilers and natural gas furnaces (€86.7 million), energy efficiency in industry (€42.4 million), energy renovations in public buildings (€42.4 million), energy efficiency in households (€76.0 million) and research on carbon capture and sequestration potential (€26.9 million).
- Component 4: Green tax reform: €580.3 million. It is focused on creating incentives to reduce greenhouse gas emissions. It includes the shift from the current taxes on energy, to taxes on CO_2 emissions, as well as to consider other greenhouse gases.
- Component 5: Sustainable road transport: €218.5 million. Subsidies to choose green cars, the development of green transportation and infrastructures and analyses, tests, and campaigns for greener transport.
- Component 7: Green research and development: €242.1 million: it is focused on research and development in companies, especially about Power-to-X technologies, projects in environment-friendly agriculture and food production, and research in methods to reduce plastic and textile waste.

It can be also mentioned that in 2021, the Danish government agreed to build two “energy islands”, with a minimum capacity of 4 GW. The objective is to transform low-carbon electricity produced in the energy islands into green hydrogen to be processed into fuels. Besides, these islands can be connected to other European countries, to provide them with clean energy.

These two islands will be:

- An artificial island to be built in the North Sea, with a minimum of 2 GW of offshore wind connected by 2030, to Denmark and the Netherlands. The long-term objective is that this island will reach a total offshore wind capacity of 10 GW. The artificial island will be owned by a partnership of Denmark with countries such as Germany, Belgium, and Luxembourg. The total investment in this island will reach DKK 210 billion, equivalent to €34 billion.

- In the Baltic Sea, 3 GW of offshore wind energy will be built in Bornholm by 2030, with connections to Zealand and Germany. On the island of Bornholm, the current will be transformed into direct current to be transported over long distances in sea and land cables.

On January 19th, 2022, the Kingdom of Denmark opened its first green bond, with a coupon rate of 0.00% and a maturity date on 15th November 2031. The bond is negotiated along with the country’s conventional 10-year benchmark bond, as a “twin bond”. However, the funds obtained from the sale of green bonds will be only used in eligible green investments by the central government, focused on renewable energy and the green transition of the transport sector. These eligible green investments are selected according to the EU classification system for sustainable economic activities (the EU Taxonomy).

Finally, the government of Denmark unveiled in April 2022 the Denmark’s National Reform Programme 2022, or Budget Agreement. This Programme includes the reforms and investments that Denmark will carry out to follow the specific recommendations from the EU, related to core welfare, green transition, and balanced economy.

Regarding renewable energies, the main topics included in this Reform Programme are:

- Increase of the renewable energy capacity in Denmark, including 2 GW of offshore wind which will be added to the grid by 2030 (built in the before-described artificial island in the North Sea). The objective is to reduce 70% of CO_2 emissions by 2030, compared to 1990 levels, and to become carbon neutral by 2050.
- Advance with the “energy island” project, which will have a capacity of 3 GW, and up to 10 GW in the long term.
- Improvement of the regulatory framework for onshore wind and solar PV.
- A carbon capture and storage strategy will be developed to reduce CO_2 emissions by 0.5 million tonnes CO_2 in 2025 and in 2030.

In March 2022, the Danish government established a goal to install a total of 4-6 GW of electrolysis capacity by 2030, to produce hydrogen using power-to-X. A tender of DKK 1.25 billion was launched on April 19th, 2023, and was opened until the end of 2023. The support is given as a subsidy per produced amount of green hydrogen, and is paid during 10 years.

This tender was continued in May 2024, with the Power-to-X (PtX) Tender Pool. It offers grants of DKK 11.1 million in 2024, DKK 65.9 million in 2025, approximately DKK 131.9 million annually in the period 2026-2034, and DKK 55.0 million in 2035.

In May 2022, the Danish Government allocated DKK 250 million to promote green heating and reduce the use of natural gas in Denmark. These funds include subsidies for:

- Disconnecting households from natural gas boilers, shifting to heat pumps.
- Promoting energy saving activities, such as expanding the *Boliganalysen* scheme (a digital tool developed by Viegand Maagøe, which informs householders about potential for energy improvements in their houses, and offers opportunities for savings in energy bills) and the SparEnergi.dk website, to offer better energy saving information to citizens.
- Developing district heating facilities, offering support for planning, project approvals and cooperation with district heating companies, along with the development of small-scale, joint heat supply projects.

On June 24th, 2022, the Danish government, along with the Liberal Party of Denmark, the Socialist People's Party, the Social Liberal Party, the Red-Green Alliance and the Conservative People's Party, came to an agreement to compensate the Danish households for rising prices, an increase in the employment deduction and a reduction in the taxes on electricity. This agreement is called the "Danish Climate Agreement on Green Electricity and Heat".

Besides, a new green fund of DKK 53.5 billion was created to promote green transition projects from 2024 to 2040, reducing the use of fossil fuels. This includes DKK 1.5 billion in 2024, and DKK 3.5 billion annually from 2024 to 2040. Eligible projects should be related to energy supply, food and agriculture, buildings and infrastructure, materials and resources, or transport and mobility. This fund should get 100% green gas use in all sectors, and phase out natural gas in household heating, at the latest by 2035.

Additionally, the Green Business Transport Fund in Denmark, with DKK 45.9 million, supported 49 projects focused on the decarbonization of the transport sector, including charging infrastructure for taxis and trucks, and biogas and hydrogen projects.

Denmark will quadruple onshore wind and solar PV generation by 2030, what means 50 TWh per year.

On August 30th, 2022, the Heads of the Governments and Energy Ministers of eight countries located around the Baltic Sea met in Copenhagen, and agreed to develop up to 19.6 GW of offshore wind energy projects by 2030, from the current 2.8 GW. These countries are Denmark, Germany, Poland, Finland, Sweden, Estonia, Latvia, and Lithuania.

To do so, they launched the Marienborg Declaration and the Declaration of Energy Ministers, during the Baltic Sea Energy Security Summit. They commit to reducing the dependency on Russian fossil fuels, and to contribute to the greenhouse gas reduction targets of the European Commission.

This commitment involves an increase in the offshore wind capacity of Denmark to 6.3 GW, by 2030. It also includes collaboration to develop cross-border renewable energy and hybrid offshore projects, such as the Danish-German collaborations to develop the first-of-a-kind Kriegers Flak Combined Grid Solution, and the above-described Bornholm Energy Island Project.

On May 30th, 2023, a political agreement was signed to develop tenders for 6 GW of offshore wind energy projects at the North Sea I (at least 3 GW), Kattegat II (at least 1 GW), Kriegers Flak II (at least 1 GW), and Hesselø (800 megawatts [MW]-1.2 GW) offshore wind areas, as well as up to 3 GW in the Bornholm Energy Island. The government will participate in these offshore wind farms, purchasing a 20% share. Besides, some of these wind farms are also allowed to deploy even more capacity, reaching up to 14 GW or more.

The tenders of 6 GW of offshore wind energy were launched in April 2024.

A new Declaration was signed on April 10th, 2024 by the same eight countries, along with the European Union, the NATO, the European Agency for the Cooperation of Energy Regulators (ACER), the European transmission system operators (TSOs) and the European wind industry, in the Baltic Sea High Level Energy Security Meeting celebrated in Vilnius. After the Russian invasion of Ukraine and different sabotage acts to energy infrastructure in the Baltic Sea, it is essential to protect offshore and underwater infrastructure within NATO and EU.

The Baltic countries reaffirmed their intention to implement the actions included in the EU Winter Power Package to promote the development of offshore wind energy in the Baltic Sea, and to decarbonize their energy systems as soon as possible.

On January 2024, the Danish Export and Investment Fund (EIFO) allocated DKK 634.1 million of subsidies to support four companies specialized in wind energy and technology for Power-to-X, specially in developing new production capacity, or expanding production facilities. Four companies received these amounts, and the total expected investments will reach DKK 4.2 billion.

On July 1st, 2024, Denmark published its final National Energy and Climate Plan 2023-2030, which has the following objectives:

- To reduce greenhouse gas emissions by 70% by 2030, compared to 1990. Denmark will work towards net zero emissions by 2045, and has set a target of 110% reduction in 2050, compared to 1990.
- To reach 55% of the final energy consumption coming from renewable energy sources by 2030, and 100% by 2050.
- To reach 100% of the electricity consumption coming from renewable energy sources by 2030.

Other objectives are not specifically described in the new National Energy and Climate Plan, but are similar to that of the Plan for 2019-2030.

<u>Energy Agreements</u>

On 21st February 2008, the Danish government, made up by the Danish Conservative People's Party (Det Konservative Folkeparti) and the Liberal Party of Denmark (Venstre), agreed with the

Social Democrats (Socialdemokraterne), the Danish People's Party (Dansk Folkeparti), the Socialist People's Party (Socialistisk Folkeparti), the Danish Social-Liberal Party (Det Radikale Venstre) and the Liberal Alliance (Ny Alliance) an agreement about energy policy for the period 2008-2011 (called the Energy Agreement 2008-2011). The objective of this agreement was to reduce the dependence of Denmark on fossil fuels, increasing the objectives of energy efficiency and renewable energy penetration. The targets included in this agreement are:

1. To reach 20% of the gross energy consumption coming from renewable energy sources by 2011.
2. To install 400 MW of new offshore wind turbines by 2012, and 75 MW of onshore wind turbines in 2010 and 2011.
3. To reduce energy consumption by 2% by 2012, and 4% by 2020, taking as reference the energy consumption in 2006.
4. Besides, to reach these objectives, the government committed to increasing the funding for R&D and demonstration of energy technologies (specially wave and solar PV) to €135 million per year.
5. To make hydrogen vehicles tax free, and electric vehicles until 2012. A pool of DKK 35 million is made available for electric vehicle research.

In February 2011, the government published the Energy Strategy 2050. Its goals include:

- To achieve total independence from coal, oil, and gas by 2050, with an intermediate objective of reducing the consumption of fossil fuels by 33% by 2020, compared to 2009.
- Reduction of thermal production from 71% to 40% of the total energy generation, between 2009 and 2020.
- To reach 40% of the electricity consumption coming from renewable energies, including wind, biomass, and biogas.
- To develop a district heating network, fed with renewable heat from biomass, to increase the use of renewable energies in the heating sector.
- To reduce gross energy consumption by 6% by 2020, compared to 2006 energy consumption levels, by means of energy efficiency measures.
- Companies should increase energy savings by 50% in 2013 and 75% by 2017 to 2020.
- Use of smart meters in the residential sector. Ban for oil boilers in all new constructions and in all houses by 2017, replacing them for biomass, biogas, and solar thermal energy.

- Support to offshore wind energy, and the wind manufacturing sector. Support to research and development projects in solar and wave energy, as well as large heat pumps to be used in district heating plants.

- Development of a public service obligation tax on electricity and natural gas, and increase of taxes on oil, natural gas and coal, to discourage citizens from using these energies. The obtained revenues would be used to finance the energy transition of Denmark.

The Energy Agreement 2008-2011 was updated in 2012 with the Energy Agreement 2012-2020. The objective of this new document is to establish the objectives in terms of climate and energy up to 2020, and to define the direction which Denmark would follow until 2050.

The most relevant objectives of this new Agreement are:

- To reach 35% of the final energy consumption coming from renewable energy sources by 2020, and 100% by 2050.

- To reach 50% of the electricity consumption coming from wind power by 2020.

- To reduce greenhouse gas emissions by approximately 40% by 2020, compared to 1990 levels. 34% of reduction would come from the use of wind energy, and the remaining 6% from efforts in the transport and agriculture sectors.

- To reduce gross energy consumption by 7.6% by 2020, compared to 2010 energy consumption levels.

- To reach a use of 10% of renewable energies in transport by 2020.

The Energy Agreement 2012-2020 also included the obligations for energy companies to achieve specific energy savings compared to the current standards, and the design of a comprehensive strategy to improve the energy efficiency of buildings, the promotion of demonstration projects for new renewable energy technologies (e.g., wave, solar, geothermal), encouragement of the shifting from coal to biomass boilers and from oil to natural gas boilers and heat pumps, subsidies for energy efficiency and renewable energy measures in industry, and promotion of clean transport (using electricity and biofuels). Additionally, the installation of fossil-fuel based boilers in new buildings was banned from January 1st 2013 onwards.

Finally, a new Energy Agreement 2020-2024 was defined on 29th June 2018, to update the agreement of 2012. This agreement was signed by the government (the Liberal Party of Denmark, Liberal Alliance, and the Conservative People’s Party), Social Democracy, the Danish People's Party, the Red-Green Alliance, the Alternative, the Social Liberal Party, and the Socialist People’s Party. It includes the following objectives:

- To reach 55% of the final energy consumption coming from renewable energy sources by 2030, and 100% by 2050.

- To reach 100% of the electricity consumption coming from renewable energy sources by 2030.
- To ensure that at least 90% of district heating consumption is based on energy sources different from coal, oil, or gas by 2030.
- To develop new offshore wind energy farms, with a power capacity of at least 800 MW, to be connected to the grid in 2024-2027, and other two offshore wind farms by 2030.
- To reduce electricity taxes for customers.
- To reduce greenhouse gas emissions by 70% by 2030 and 100% by 2050, becoming carbon neutral.
- To promote energy efficiency measures, the existing energy savings obligation scheme was finished by 31st December 2020. It was replaced for competitive subsidies, to encourage companies and buildings to replace oil boilers for heat pumps in these buildings which have not access to district heating or to the natural gas grid. Other subsidies are offered to refurbish public buildings, and for information activities about energy efficiency measures.

Finally, in June 2020, the Danish Parliament passed the Climate Act, which has as objective to reduce Denmark's emissions by 70% in 2030, compared to 1990, and reach the climate neutrality in 2050. A rolling five-year target is defined. In 2021, a new emission reduction target of 50-54% by 2025 was included.

In 2022, the government proposed to advance the goal of climate neutrality to 2045, reaching a 110% emissions reduction by 2050, compared to 1990. In that year, the Climate Agreement on Green Power and Heat stated the objective of phasing out fossil fuel based heating services in all buildings by 2035.

To sum up, Denmark is one of the countries with a higher renewable energy penetration. It also has a large experience in onshore and offshore wind energy, and has a large share of bioenergy in heating production. In 2022, around 81% of the electricity generation was produced with renewable energies: 54% from wind, 20.7% from biomass and 6.3% from solar PV[19]. It has been able to overcome the objectives defined by the European Commission by 2020.

Local context at the Demo Site

In the specific case of Bornholm, a group of citizens, supported by the Bornholm municipality, are developing a 100 MW offshore wind turbine, based on local funding. The wind farm is expected to be commissioned by 2025. Besides, new solar PV plants (50 MW) are also planned.

Regarding the used technology of the pilot site, district heating systems have become very common in Denmark: 64.5% of all Danish homes are connected to a district heating system. The use of renewable energy for heating supply has become a major priority in the 1990s, and

[19] Source: *Denmark 2023 Energy Policy Review*. International Energy Agency.

especially since the Biomass Agreement was passed in the Parliament in June 1993. Before 2018, any decentralized combined heat and power plant received subsidies for generating electricity (feed-in tariffs). However, policies introduced in 2018 limited the subsidies to those plants which generated electricity using renewable energy sources.

Citizens in Bornholm have invested in energy production for the last 30-40 years. At present there are about 1,000 households with approximately 8 MW of rooftop PV panels. This high number is due to the PVTP Island project I-III and favourable support mechanisms up to 2015. There are 50 households with their own wind turbines of up to 25 kW. Both PV and wind turbines are grid connected.

The Municipal Energy Plan foresees to increase the renewable energy installed capacity in 50 MW of solar PV, and 100 MW of wind turbines near the shore.

A newer 50 kW PV installation at the public indoor swimming pool in Gudhjem has been raised by crowdfunding among local citizens.

Regulation related to energy communities

In Denmark, citizen-led initiatives in the energy system have been common since a long time ago. Since the beginning of the 21st century, some utilities have been owned by consumers, cooperatives, or municipal entities.

The Act on Support for Utilization of Renewable Energy Sources (Consolidated Act No. 1791 of 2 September 2021) and the Electricity Supply Act nº984 of 2021 have set the basis for the definition of rules for energy communities.

The Order BEK 2021/1069 developed the rules for energy communities, and transposed the European Regulation set in 2019. Although the regulation differentiates between Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs), following the definitions developed by the European Commission, nearly all rights and obligations are the same for both, and there is not a real differentiation. Energy communities are referred as *Energifælleskaber* (Energy Communities), rather than being differentiated as *Borgerenergifællesskaber* (Citizen Energy Communities) and *VE-fællesskaber* (Renewable Energy Communities)[20].

Electricity can be shared behind the meter or using the power grid. Electricity sharing behind the meter is restricted to a single building, for example, a housing cooperative with a rooftop solar PV. Electricity sharing using the power grid is more common.

Energy communities can be created as an association, partnership, cooperative or capital company. Some examples of energy communities are:

- Eco-villages (*økosamfund)*: They are usually organized as communal institutions, with collective ownership. Their objective can be not only producing electricity or heat for its consumption, but also to reach energy independency, and to use renewable energy.

[20] Source: https://pub.norden.org/nordicenergyresearch2023-03/denmark.html.

- Housing cooperatives: They are neighbours who decide to install either solar PV, or hybrid solutions, or both solar PV and heat pumps in the roof. They are allowed to share the produced electricity using the internal grid.
- Villages and new neighbourhoods can create energy communities, using adjacent areas to produce heat or electricity, using wind turbines or solar PV projects.

In 2021, the Danish government and the Danish political parties decided to create a grant pool of DKK 4 million, which supports the creation of local energy communities in Denmark, along the period 2022-2025.

A financing pool will be maintained by the Danish Energy Agency, to fund local energy communities which develop projects related to energy transition. The total allocated fund (DKK 4 million) was allocated in 2022, including DKK 1 million for projects which offered information and knowledge about renewable energies to local communities, and DKK 3 million to larger projects.

The continuation of the financing pool is being evaluated.

Appendix B- Review of the Regulatory framework for renewable energies and energy communities in Greece

Greece became a member of the European Union in 1981, and has followed the policy directions of the Union since then. For this reason, all policies have been designed to ensure a secure energy supply, constant and predictable, at economic prices, while reducing the environmental impact and the greenhouse gas emissions.

Until the 1990s, the electricity market was monopolistic, and was only controlled by the Public Power Corporation (PPC), an entity created in 1950 under the Law 1458/1950. PPC was a vertically integrated state-owned public company, which was the sole company which could develop hydro and thermal power plants (based on indigenous lignite) The private sector could not invest in the electricity sector.

In 1982, the PPC created the Alternative Energy Sources Department (PPC/DEME), which was in charge of building the Kythnos wind farm.

The first law related to the use of renewable energies and other alternative energy sources was Law 1559/1985: Regulation of alternative forms of energy and specific issues of power production. This law includes the right of third parties to produce a certain amount of electricity from renewable energy sources using their own facilities, which would be the only power generation units not owned by PPC However, the production should be limited to the producer's needs, and any surplus could be only sold to PPC, and not to third parties. The total capacity of grid-connected renewable energy plants for self-consumption had to be lower than three times the total installed power of the equipment of the developer or its energy needs for wind, solar and hydro. For geothermal energy and cogeneration, the limit is twice the installed capacity. Municipalities and other public-owned companies were also allowed to develop renewable energy projects.

On the other hand, Law 1416/1984 allowed local governments to produce electricity from renewable energy sources to sell it to the PPC. The result of Law 1416/1984 and Law 1559/1985 was an increase in renewable energy installed capacity of Greece in 24 MW developed by the PPC and 3 MW developed by local governments until 1995.

Law 1475/1984 regulates the exploitation of geothermal energy, specifically its exploration and exploitation. Geothermal resources belong to the Greek State, which can assign them to other public sector entities for their exploitation. These entities have to prove the benefit of the investments.

In 1987, Law 2689/1987 included some criteria for the installation of wind turbines in the boundaries of inhabited areas, uninhabited, rural, and industrial areas.

In September 1987, by Presidential Decree 375/1987, the Centre for Renewable Energy Sources and Saving (CRES) was created following the article 25 of Law 1514/1985 on the Promotion of scientific and technological research. This institution, controlled by the Ministry of Industry, Energy and Technology, is in charge of providing the know-how, and to carry out the R&D activities and implement pilot projects related to renewable energy (solar PV, wind, hydro, geothermal and biomass) and energy efficiency. Since 1999, the CRES is the national coordinating centre of renewable energies and energy efficiency, and has laboratories for the certification of these technologies.

In 1990, the Law 1892/1990 on Economic Development included objectives to modernize, develop and regulate investments for renewable energy production and electricity generation in Greece. To achieve these objectives, it included subsidies between 40% and 55% of the investment in renewable energy projects, as well as tax exemptions of 100%. This law supported the development of twelve wind parks, totalizing a power capacity of 90 MW, with a funding rate of 40%. Besides, low interest rate loans were offered for solar PV projects.

In 1994, there were different regulatory changes aimed at supporting the development of renewable energies in Greece. First, the Public Power Corporation designed the Public Power Corporation's Development Plan for 1994-2003. This Plan included a program to increase the renewable energy installed capacity of Greece by 306 MW of large hydro, 17 MW of small hydro and 37 MW of wind, to be in operation by 2003.

In 1994, the Second Community Support Framework (CSF II) was launched. It was a subsidy program, which lasted since 1994 to 1999, and offered grants around €92 million to 77 renewable energy investment projects. The grants were around 43% of the total investment cost of projects. The program was very successful to stimulate renewable energy development, especially during the period 1997-2000.

As part of the CSF II, the Operational Programme for Energy (OPE) offered capital cost grants for 125 renewable energy projects (130 MW of wind energy, 72 MW of small hydro, 46 MWh of biomass district heating, 42 MW of CHP of biomass, 5 MWh of other biomass projects, 42 solar central active systems, 8 projects for solar PV systems and 5 projects for passive solar systems). Besides, around 300 projects related to energy efficiency and replacement of fossil fuels and electricity for natural gas in the industry and tertiary sector were approved between 1994 and 2006. The total budget of the OPE was 340 million € for the period 1994-1999 and 505 million € for the period 2000-2006. Capital grants depended on the technology, being up to 50% for solar PV projects, 30% for onshore wind farms and 40% for small hydro, biomass, geothermal and passive solar. Tax exemptions and reduced interest rate loans were also offered.

Law 2244/1994 was the first Greek policy specially focused on the promotion of renewable energy projects in the country. It offered incentives to encourage investments in renewable energy generation for the private sector. However, the Public Power Corporation (PPC) continued being the only electricity buyer and retailers. Production by self-consumers and independent producers was liberalized up to 50 MW. Self-consumers are also allowed to counterbalance 80% of the electricity produced using renewables with electricity consumption from the grid.

The law also created an obligation of the Independent Power Producers (IPP) to sell the electricity to the PPC, using power purchase agreements, except for the automotive industry which could use the electricity in their own facilities. Besides, the PPC was obliged to purchase the electricity.

The law includes feed-in tariffs for the renewable electricity produced, at a level of the 90% of the medium-voltage retail price of electricity (for the mainland interconnected system) and 90% of the low-voltage household tariff (for the non-interconnected islands). These feed-in tariffs did not differentiate between the different renewable energy technologies.

Law 2244/1994 led to the development of the first private wind farms in Greece, developed between 1997 and 1998.

Law 2364/1995 created the Board for Energy Planning and Control (BEPC). Besides, households are offered tax exemptions to buy renewable energy equipment and natural gas boilers: 75% of the cost of the facility can be deducted from taxable income. This led to a subsidy around 30% of the installation cost of the facility.

The abovementioned Law 1892/1990 on Economic Development was superseded by Law 2601/1998 on Economic Development. It continued offering subsidies for renewable energy projects which produce electricity. Depending on the location of the project, subsidies on the investment ranged from 15% to 40%. Residential and service sector users which decide to install solar heating systems can benefit from a maximum income tax deduction of 75%. Besides, loans at reduced interest rates and tax credits were also offered. Up to 2001, 38 projects had been approved.

Besides, in 1998, the PPC Renewables, S.A. was created as a subsidiary of PPC in 1998, with the specific objective of the development of power generation units based on renewable energies.

Law 2773/1999, approved in February 1999 deals with the liberalization of the Greek electricity market, and the privatization of PPC. According to Presidential Decree 333/2000, PPC became a public limited company on January 1st, 2001. The electricity transmission system was unbundled as follows:

- The operation of the electricity transmission system becomes the responsibility of a new independent company, the Hellenic Transmission System Operator (HTSO, or HEDNO, S.A.). HEDNO is also responsible for the interconnection of RES plants with a capacity of less than 8 MW to the Interconnected Distribution Network, and all renewable energy plants in Non-Interconnected Island grids, according to the “Non-Interconnected Island Power Systems Management Code”. HEDNO, S.A. is owned by PPC, but operates independently.
- The Regulatory Authority for Energy (RAE) is the entity which supervises all the Greek electricity sector (generation, transmission, distribution, and power supply), and controls that the liberalization of the energy market is carried out on time. It is also in charge of the definition of the measures and strategies of the country related to energy needs and renewable energy penetration.

Other relevant entities related to renewable energies are:

- Renewable Energy Sources Operator & Guarantees of Origin (DAPEEP, S.A.) is the entity in charge of the renewable energy markets of the Greece National Interconnected System (Transmission System and Distribution Network of Mainland and Interconnected Islands), and oversees the management of the Guarantees of Origin of electricity produced with renewable energy projects and combined heat and power units.

- Independent Power Transmission Operator (IPTO) is the responsible for the interconnecting the renewable energy plants, when they have a capacity of more than 8 MW. It is also the power transmission operator in Greece, which owns and operates the Hellenic Transmission System (HETS).

In addition, the electricity sector is divided into two parts:

- The transmission and distribution networks, which continue being monopolistic and regulated.
- The electricity generation and supply, which were totally liberalized.

In 2001, the electricity market was totally liberalized, leading to the option for any company or individual to produce electricity. All clients were gradually offered the option to choose their energy supply, and this process was ended by July 2007 (except in the case of remote island consumers).

However, it is remarkable that the Public Power Corporation (PPC) has been mostly controlled by the Greek government, which had the majority of the company. Until 2021, the Republic of Greece owned 51% of the company.

According to Law 2773/1999, renewable energy projects are given a priority access to network dispatching, limited to projects with an installed capacity under 50 MW (10 MW for hydropower). The Transmission System Operator and the Public Power Corporation (PPC) have to offer connection to new renewable energy generators.

Ten-year renewable energy contracts between independent producers and the System Operator were also signed. The feed-in tariff paid by the PPC is composed of an energy and a capacity charge, except for non-interconnected islands, where only the energy charge is paid. The energy charge is 90% of the energy price of the medium-voltage domestic end-use tariff, while the capacity charge is 50% of the capacity price of the same tariff. However, for non-interconnected islands, the price is 70% of the low-voltage end-use tariff, except for co-generators using renewable energy, which receive 90% of this tariff.

This law also included a 2% tax on electricity production from renewables at the local level.

In 2000, the Operational Programme for Energy (OPE) created in 1994 was replaced for a New Operational Programme for Energy. The total budget of the new programme included €3,445 million, from which €505 million were aimed to renewable energy projects, €340 million for energy efficiency projects, and €343 million for CHP with natural gas. Similarly to the first OPE, it included public subsidies for renewable energy projects: 30% for wind farms, 40% for small hydro, biomass, geothermal and passive solar, and 50% for solar PV.

In 2003, the Common Ministerial Decision 1726/2003 created strict deadlines for every step of the licensing procedure for renewable energy projects. If the public administration is not able to give an answer in a specified period, then the answer is considered to be positive, and the procedure continues. This allowed to reduce the times for licensing procedures.

In 2003, the Republic of Greece launched the Second National Climate Change Programme (approved by Act of the Ministerial Council 5/27.02.2003), which includes measures and policies aimed at making Greece fulfil the Kyoto commitments. The main actions included in the programme are: a) Development of natural gas in all final demand energy sectors and power generation, b) promotion of renewable energy sources for electricity and heat production, c) energy saving measures in the industrial, residential and tertiary sectors, d) promotion of energy efficiency equipment in the residential and tertiary sectors, e) structural changes in agriculture and the chemical industry, f) emission reduction actions in transport and waste management.

In 2003, the Law 3175/2003 on the Exploitation of Geothermal Potential mentioned again that the Greek Republic is the only entity authorized to use geothermal resources. However, the State can appoint private investors to use these resources.

Law 2601/1998 on Economic Development was replaced with the New Development Law 3299/2004 (Law 3299/2004 on Private Investment Incentives for Economic Development and Regional Convergence). This law increases the subsidies to the investment in renewable energies (biofuel production, electricity generation from wind power, geothermal, biomass and hydropower) to 20%-40% (depending on the part of the country where the project is carried out, since the country is divided into three zones). The grant can be increased by 10% for medium-scale companies and up to 20% for small ones. Alternatively, a tax exemption of 100% for the cost of the installation was offered.

Between 2001 and 2004, there was a limited development of new renewable energy capacity, due to the reforms of the electricity market, and the limited grid capacity.

Law 3423/2005 on Introducing Biofuels and other Renewable Fuels to the Greek market regulates the supply of biofuels and develops a national scheme (Biofuels Allocation Programme), defining the amounts of biofuels to be allocated to distributors each year.

In June 2005, the 211 Greek electricity consumers with a demand higher than 1,800 kW were encouraged to voluntarily reduce their demand by 10% between 11:00 and 15:00 for a maximum of 10 days in July, after a 24 hours' notice. Those consumers which agreed to reduce their consumption and achieve to do so, receive a discount in their monthly electricity bill, while if they do not, they have to pay an additional charge. For these consumers which do not enter into these voluntary agreements, there exist an obligation to reduce their peak hour consumption by 10% for the month of July. If they achieve to do this, they receive a discount lower than that offered in the agreements. If not, they have to pay a fine.

Law 3468/2006 on Generation of Electricity using Renewable Energy Sources and High-Efficiency Cogeneration of Electricity and Heat and Miscellaneous Provisions was issued in October 2006. It transposed Directive 2001/77/EC of the European Parliament and of the Council of September 27th, 2001, on the promotion of electricity produced from renewable energy sources in the internal electricity market. It is focused on the development of wind energy, solar energy, wave energy, tidal energy, biomass, gases coming from landfills and biological treatment plants, biogases, geothermal energy, and hydro power plants. The law regulates the authorization of new renewable energy power plants, priority access to the grid for these plants (independently of the installed capacity, except for hydroelectric plants, for which the capacity is limited to 15 MW), and the priority dispatch of renewable energy production.

This law includes a national target for the percentage of renewable energy of 20.1% of the net domestic power consumption by 2010.

Another important article of Law 3468/2006 is Article 13 Billing of electricity produced by RES plants or through high-efficiency co-generation and in hybrid stations. It defines fixed feed-in tariffs for renewable power plants with a capacity up to 35 MW. For example, some of the feed in-tariffs were as follows:

- Onshore wind energy: €73/MWh in the continental system, €84.6/MWh in plants in non-interconnected islands.
- Offshore wind energy: €90/MWh.
- Small-scale hydroelectric plants (up to 15 MW): €73/MWh in the continental system, €84.6/MWh for plants in non-interconnected islands.
- Solar PV with an installed capacity lower than, or equal to 100 kW peak: €450/MWh in the continental system, €500/MWh for plants in non-interconnected islands.
- Solar PV with an installed capacity higher than 100 kW peak: €400/MWh in the continental system, €450/MWh for plants in non-interconnected islands.
- Solar energy (not solar PV) with an installed capacity of up to 5 MWe: €250/MWh in the continental system, €270/MWh for plants in non-interconnected islands.
- Solar energy (not solar PV) with an installed capacity of over 5 MWe: €230/MWh in the continental system, €250/MWh for plants in non-interconnected islands.
- Geothermal energy, biomass, landfill gases, biogases, other RES and high-efficiency cogeneration of heat and electricity: €73/MWh in the continental system, €84.6/MWh in non-interconnected islands.

Apart from the feed-in tariff, subsidies of 40% of the investment cost were available.

The terms for sale of electricity produced with renewable energy, in power purchase agreements were improved, to make easier for these projects to receive financing. The 10-year validity period of the power purchase agreement can be extended for another 10-year period, with only a unilateral declaration of the power producer.

Besides, a photovoltaic development programme had to be prepared by the Regulatory Authority for Energy (RAE). It also allowed, for the first time, the development of offshore wind farms, and included the remuneration for projects combining renewable power generation and storage.

It also created a guarantee of origin system, and changed the definition of small-scale hydro plants from 10 MW to 15 MW, to increase the number of mini hydro plants which benefitted from this regime.

In June 2009, Law 3468/2006 was complemented with a new feed-in tariff for small rooftop solar PV systems, up to 10 kWp, for residential users and small companies. This feed-in tariff amounted to €550/MWh, guaranteed for 25 years. Residential users have the obligation to cover part of the demand of hot water with renewable energy sources, such as biomass or solar water heaters.

In 2009, there was a programme to help local public authorities (municipalities) to develop energy saving projects. It was limited to municipalities with more than 10,000 inhabitants and prefecture capitals. Projects could be developed in the following areas: existing municipal buildings, public areas of urban environment, urban transport, other urban municipal infrastructures, dissemination, networking, and information. The total budget of the programme reached 82.86 million €, and could support 103 projects.

In 2009, the Operational Programme "Environment and Sustainable Development" 2009-2013 included 14 calls for different projects developed by the public sector, in energy efficiency and renewable energy projects. The budget amounted to €330 million and supported projects related to renewable energy for electricity and heat production (shallow geothermal, solar PV, solar thermal energy to produce hot water, high efficiency combined heat and power, and use of thermal energy for cooling), as well as energy efficiency in public buildings (improvement of thermal insulation, replacement of frames and glazing, green roofs, replacement of boilers for new systems based on renewable energy or natural gas).

Law 3851/2010 Accelerating the development of Renewable Energy Sources to deal with climate change and other regulations addressing issues under the Authority of the Ministry of Environment, Energy and Climate changed included ambitious renewable energy targets, which are defined as follows:

- The share of renewable energy had to reach 20% of the gross final energy consumption by 2020.
- The share of renewable electric energy had to be 40% of the gross electrical energy consumption by 2020.
- The share of renewable energy in heating and cooling had to be at least 20% of the final energy consumption for heating and cooling by 2020.
- The share of renewable electric energy in transport had to be at least 10% of the gross electricity consumption in transport by 2020.

Besides, a Special Renewable Energy Investment Service was created to act as an interface between public institutions and investors, and to assess the main challenges to renewable energy deployment and manage the support of funding allocation process.

A share of the taxes on renewable energy projects paid by producers to regional and local authorities is allocated to local households, as credits for the electricity bill to share the benefits of living near renewable energy generation plants. This is aimed to increase the public acceptance of new renewable energy projects.

Moreover, the licensing process for renewable energy power plants was made easier, and the whole licensing process should have a duration under 30 months. The grid priority access for renewable energy projects disappeared, instead, they are given access on a first-come first served procedure until the network is saturated. The grid utility has 4 months to provide access to the grid since it is demanded. A preliminary environmental impact assessment (EIA) is no longer needed, only one assessment is asked.

Feed-in tariffs were also defined in Law 3851/2010, including its reduction and review every year.

It also included the obligation for all new buildings which ask for a construction license after 1st January 2011, to install solar water heaters. The total energy consumption of all new buildings must be met with renewable energies by 31st December 2019, and for public sector buildings, by 31st December 2014.

Law 3855/2010 on Measures to improve energy efficiency in end use, energy services and other provisions set the national targets for energy savings, amounting to 9% of the average annual final value of energy consumption, and defined measures to reach these goals. It also set the institutional and financial framework to improve the energy end-use efficiency, and the development of an energy services company sector.

In 2009, the new Ministry for the Environment, Energy and Climate Change (MEEC) was created, to coordinate the different bodies in charge of renewable energies.

In 2010, the National Renewable Energy Action Plan (NREAP) was launched. This plan included the path to achieve the 2020 renewable energy targets (as defined in Law 3851/2010), by means of feed-in tariffs, use of solar water heaters in public administration buildings, energy efficiency measures and tax reductions for these projects.

Law 4001/2011 on the Operation of Electricity and Gas Energy Markets, for Exploration, Production and Transmission Networks of Hydrocarbons and other provisions transposed the European Directives related to the liberalization of electricity and natural gas markets in Greece.

In February 2011, the programme “EXOIKONOMO at home”, or Efficient Use of Energy and Energy Saving was launched to offer citizens incentives to carry out energy efficiency measures in their homes. The programme included measures related to the improvement of the thermal insulation of the building shell, the replacement of windows or door glazing for more efficient ones, the replacement of low performance oil boilers for natural gas boilers or systems based on renewable energies, and the installation of solar water heaters.

The EXOIKONOMO programme was also designed for municipalities, focusing on projects carried out in existing municipal buildings and urban infrastructures, as well as studies, energy audits and communication and dissemination actions. Since 2011, different EXOIKONOMO programmes have been developed to promote energy efficiency in a number of sectors.

These programmes were complemented with the programme “Building the future”, aimed at reducing the energy consumption of buildings, offering financial instruments such as energy performance contracts, industrial and commercial voluntary agreements, the development of an Energy Services Company market and White Certificates. Projects included: the improvement of the thermal insulation of the building, the replacement of the windows or doors for other better thermally isolated, the replacement of low energy performance heating oil boilers for high performance natural gas boilers or renewable energy systems, the installation of solar water heaters, the installation of shading systems, the use of advanced air conditioning systems based on geothermal heat pumps, and the use of intelligent networks for energy management and control.

In 2014, a net metering system for autonomous producers was introduced in Greece. This net metering process is described in FEK B’ 3583/2014. Besides, “virtual net metering” was introduced in 2016, amending Law 3468/2006. According to it, city and regional councils, schools, universities, farmers, and farming associations are allowed to develop solar PV and wind energy projects located at a considerable distance from the place of the actual power consumption.

In 2016, according to the Article 8 of the EU Energy Efficiency Directive, large industry companies were obliged to carry out energy audits every four years, or to implement an energy or environmental management system. This was defined by Law 4342/2015. In Article 14, energy audits are defined as a methodology to identify potential energy efficiency improvement measures.

Since 2006, feed-in tariffs (FIT) were the main instrument, along with subsidies and tax rebates, to promote renewable energy projects. In August 2016, Law 4414/2016 (amended by Law 4513/2018) changed this mechanism to a feed-in premium (FIP). This involves that, instead of receiving a fixed price for the electricity, producers receive an additional remuneration to the price of the electricity in the markets. Therefore, producers must participate in the wholesale electricity markets, either directly, or through renewable energy aggregators, and to take some balancing responsibilities. Wind farms up to 3 MW and other renewable energy power plants up to 500 kW continue receiving feed-in tariffs.

Feed-in premiums are awarded to renewable and CHP plants through technology-specific auctions. Auctions have been called with a specific capacity for each technology since 2017. The first tender was launched in December 2016, for solar PV projects. Projects with a capacity lower than 1 MW were tendered separately from projects with a capacity higher than 1 MW. Until now, these tenders have focused on solar PV and wind projects.

In January 2017, an energy efficiency obligation programme was launched in Greece, which makes energy suppliers obtain yearly savings, with an annual target based on the market share of the entity. The objective is to reach a reduction of the energy consumption of 10% (332.7 toe) by 2020.

In 2020, the National Energy and Climate Plan (NECP, or ESSEK in Greek) was launched. This Plan includes the updated targets for renewable energy penetration, which were previously defined in the National Renewable Energy Action Plan and Law 3851/2010, dating both back to 2010, and is aimed to be the strategic plan for the Greek Government on climate and energy. These objectives are as follows:

- The share of renewable energy will be at least 35% of the final energy consumption by 2030.
- The share of renewable electric energy will be at least 61% of the gross final electricity consumption by 2030.
- The share of renewable energy in heating and cooling needs to exceed 43% of the final energy consumption for heating and cooling by 2030.

- The share of renewable energy in transport sector should exceed 14% of the gross energy consumption in transport by 2030.
- Reduction of greenhouse gas emissions by 42% in 2030 compared to 1990, or 56% compared to 2005 levels.
- To improve energy efficiency by at least 38%, compared to the foreseen evolution of the final energy consumption by 2030, as estimated in 2007.

To reach these objectives, competitive tenders are called periodically for commercially mature renewable energy technologies. Besides, these technologies are obligated to participate in the market. Specific renewable energy projects can be supported with grants, especially high domestic added value pilot projects. Finally, licensing procedures should be simplified and optimized.

For heating and cooling systems, tax incentives will be used to promote the installation of efficient systems in the residential and tertiary sectors. This includes the replacement of fuel boilers for natural gas systems, considering this fuel as transition fuel to reduce the greenhouse gas emissions of heating systems. Besides, the Republic of Greece will develop a regulatory framework to produce thermal energy from renewable energies, and to feed biomethane into the natural gas network. The use of residual biomass and energy efficient bioenergy projects will be also encouraged.

Finally, for the transport sector, investments will be made in developing electric vehicle charging points, as well as incentives for their use. Pilot projects to use renewable gaseous fuels in the transport sector will be carried out.

The Just Transition Fund is a financial instrument to support actions to reduce greenhouse gas emissions. It focuses on the complete de-lignification of the country by 2028, one of the objectives of the NECP. It has a budget of € 31 million.

In particular, Law 4685/2020 on the reform of the environmental legislation and the renewable energy sources licensing process includes the producer’s certificate issued by the Regulatory Authority for Energy (RAE), trying to simplify the process of obtaining the licensing for power plants, especially the environmental licensing procedures. Solar PV projects under 1 MW are exempted for obtaining a licence.

In 2020, a Legislative Act of the President allowed to extend the regulatory deadlines for obtaining licences for renewable energy projects in Greece, due to the COVID-19 pandemic.

In that year, besides, the Ministry of Interior of Greece launched the Antonis Tritsis Program for the Development of Local Government Organizations. The program is focused on the project development, in the fields of Water Infrastructure, Interventions and actions to improve energy management and utilization of renewable energy sources in water and wastewater management infrastructure, rural development and rural road construction, urban revitalization, and actions for infrastructure needed in earthquake protection. The plan included actions focused on the exploitation of geothermal and renewable energy resources, smart distribution, storage, and energy consumption systems.

The Greek government announced, in the summer of 2020 the National Plan for E-Mobility. This plan has a budget of €100 million to promote the electric mobility in Greece, including some incentives to purchase e-taxis, e-scooters, and e-bicycles. It also includes new regulation for charging points, and incentives to produce electric vehicles. The plan has the objective of achieving that one in three new vehicles in Greece to be electric in 2030.

Law 4864/2021 offers incentives for projects considered as “strategic investments”, this is, projects which make a relevant impact on the national or local economy, and need for a large budget. These projects are offered regulatory incentives, such as location incentives and the fast-track licensing procedure, financial subsidies, and tax exemptions.

Similarly to the case of Denmark, it is important to remark that Greece received in 2021 funds from the European Union Recovery and Resilience Facility.

Greece has received €30.5 billion: €17.77 billion (58%) in grants and €12.73 billion (42%) in loans, to support a number of reforms and investments to make Greece become more sustainable, resilient and better prepared to face the green and digital transition. Most of the objectives of the Greek Recovery and Resilience Plan are related to climate: 37.5% (€11.4 billion), while 23.3% (€7.1 billion) is related to digital transition.

The Greece Recovery and Resilience Plan (Greece 2.0) was accepted by the European Council on the 13th of July 2021, and a pre-financing payment of €4 billion was disbursed on 9th August 2021. Among the measures which will be included in this plan, it is possible to mention the following:

- Component 1: Green transition: €6.19 billion. This component includes 4 parts: Power up (€1.20 billion) is related to increasing the share of renewable energy sources in gross final energy consumption, improving energy efficiency in houses and businesses and reducing greenhouse gas emissions. Renovate (€2.71 billion) is related to building renovations and energy efficiency upgrades in urban areas, to reduce CO_2 emissions and enhance climate neutrality of buildings and cities. Recharge and fuel (€0.52 billion) will focus on the promotion of cleaner, smarter, and cheaper public and private transport, including electric vehicles, 8,600 electric vehicle charging points, and other related technologies. Finally, Sustainable use of resources, climate resilience and environmental protection (€1.76 billion) includes projects in circular economy, efficient use of natural resources, climate change adaptation and mitigation, protecting the natural environment, for example, through reforestation.

- Component 2: Digital transformation: €2.18 billon. It includes 3 parts, related to the use of 5G infrastructure, optic fibre infrastructure in buildings, digital transformation of key archives in the Public Sector and digitalization of tax authorities.

- Component 3: Employment, skills and social cohesion: €5.18 billion, with 4 subcomponents: Increasing job creation and participation in the labour market, Education, vocational education and training, and skills, Improve resilience, accessibility and sustainability of healthcare, and Increase access to effective and inclusive social policies.

- Component 4: Private Investments, and Transformation of the economy: €4.88 billion, including 7 parts: Making taxes more growth friendly and improving tax administration and tax collection, Modernise the public administration, including speeding up the implementation of public investments, improving the public procurement framework, capacity building measures and fighting corruption, Improve the efficiency of the justice system, Strengthen the financial sector and capital markets, Promote research and innovation, Modernise and improve resilience of key economic sectors, and Improve competitiveness and promote private investments and exports.

In 2021, due to the increasing energy prices in Greece, derived from the global energy crisis, some emergency measures to reduce the electricity and natural gas prices for households and businesses were taken. Among them, it is possible to mention:

- Electricity subsidy for all households, for €150/MWh (for consumption lower than 150 kWh/month) and €110/MWh (for consumption between 151 and 300 kWh/month). Households which receive the Social Tariff can receive a monthly support of €170/month for 300 kWh.

- Electricity subsidy for all businesses, amounting to €65/MWh. Additionally, some connection fees are suspended from November 2021 to March 2022.

- Natural gas subsidies for all households, amounting to €20/MWh, monthly. Additionally, the State-owned company DEPA offered an additional monthly €20/MWh discount.

- Natural gas subsidies for businesses, for €20/MWh.

These measures were funded with a government Special Support Fund for the Energy Transition, and were operative from September 2021 to February 2022.

The Greek Republic approved in 2022 the National Climate Law, Law 4936/2022, which includes measures and policies to adapt the country to the climate change and ensure that the decarbonization is achieved by 2050. It forbids the production of electricity from solid fossil fuels from December 31st, 2028, and a ban on the sales of new cars using fossil fuels from 2030. The installation of oil boilers is forbidden from 2023 onwards.

In March and April 2022[21], the Greek government announced a battery of measures to reduce the effect of the global energy crisis, including:

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[21] Source: Υπουργός Περιβάλλοντος και Ενέργειας. Μέτρα στήριξης της κοινωνίας από τις επιπτώσεις της διεθνούς ενεργειακής κρίσης για τον Μάρτιο και τον Απρίλιο (Kostas Skrekas: " Measures to support society from the effects of the international energy crisis for March and April"). March 17th, 2022.

- Subsidies for electricity consumption for all households, amounting to €150/MWh in March and €270/MWh for consumption below 150 kWh/month. For the consumption between 150 and 300 kWh/month, the subsidy was €110/MWh in March and €210/MWh in April.
- For consumers who pay the social tariff, the support is €290/MWh for a consumption up to 300 kWh/month.
- For businesses, the subsidy was €65/MWh in March 2022 and €130/MWh in April 2022.
- SMEs with a power supply up to 25 kVA and bakeries received €100/MWh subsidy. €75 million were used to offer a retroactive subsidy for the months of January, February, and March, covering 80% of the price increases.
- Natural gas subsidies for all households, amounting to €20/MWh in March, complemented, with an additional subsidy of €20/MWh provided by the State-owned company DEPA. In April, the subsidy was €40/MWh.
- Natural gas subsidies for businesses, for €20/MWh.

These subsidies continued in May 2022, with:

- Subsidies for electricity consumption for all households, ranging from €100/MWh to €205/MWh, depending on the level of consumption.
- For consumers who pay the social tariff, the support is €215/MWh for a consumption up to 300 kWh/month.
- Secondary residences receive a support of €100/MWh.
- For businesses, the subsidy was €120/MWh.
- SMEs with a power supply up to 25 kVA and bakeries received €50/MWh subsidy.
- Natural gas subsidies for businesses, for €20/MWh.

In June-July 2022[22], the level of subsidies was reviewed, offering €200/MWh for all households, which could be increased to €240/MWh for consumers who pay the social tariff.

For businesses, the subsidy was €192/MWh for a power supply up to 35 kVA, and €148/MWh for those which overcome this threshold. For the agriculture sector, the subsidy was €213/MWh.

Finally, natural gas was subsidized with €30/MWh for professional and industrial consumers.

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[22] Source: Υπουργός Περιβάλλοντος και Ενέργειας. Δήλωση του Υπουργού Περιβάλλοντος και Ενέργειας, Κώστα Σκρέκα, για τα μέτρα στήριξης της κοινωνίας από τις επιπτώσεις της διεθνούς ενεργειακής κρίσης τον Ιούλιο (Statement by the Minister of Environment and Energy, Kostas Skrekas, on measures to support society from the effects of the international energy crisis in July). July 5th, 2022.

In September 2022[23], the government announced new measures to fight the electricity and natural gas price increases derived from the geopolitical problems in Europe. These measures include:

- A mechanism to recover excess revenues for electricity generation, along with measures to increase price transparency, and actions to make easier for consumers to switch to other electricity suppliers, without any penalty.

- Development of an ambitious program of infrastructure and actions to ensure the energy supply to Greece, including a new floating dock in Revithoussa, a new floating LNG gasification terminal in Alexandroupolis, and a quick increase in the renewable energy production, and domestic lignite production.

- Creation of the Energy Transition Fund, to manage the funds coming from the mechanism to recover excess revenues from electricity producers, and use it in measures to support consumers.

- Creation of a new hedging mechanism, to create a reserve account to be used to protect Greek citizens in future crisis. All consumers will have to pay a levy lower than € 1 cent/kWh. At the same time, charges on electricity tariffs are rationalized.

- In September 2022, a fund of €1.9 billion was created to subsidize electricity for all households and the agriculture sector with €639/MWh. For SMEs, the subsidy was €604/MWh for the consumption between 0 and 35 kVA, and €342 for the consumption above 35 kVA. The total subsidy for households was €748 million, while for businesses, the amount was €401 million.

- In October 2022[24], the measure continued, with subsidies for electricity for households, amounting to €436/MWh for a consumption below 500 kWh/month, €386/MWh for the consumption between 501 and 1,000 kWh/month, and €336/MWh for the consumption above 1,000 kWh/month. For households with the Social Residential tariff, the subsidy was €485/MWh.

  For non-residential consumers with a consumption below 35 kVA, the subsidy was €398/MWh for the consumption up to between 0 and 2,000 kWh/month, and €230 for the consumption above 2,000 kWh/month, as well as all other non-residential tariffs of low, medium and high voltage. For the agriculture sector, the subsidy was €436/MWh.

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[23] Source: Υπουργός Περιβάλλοντος και Ενέργειας. Κώστας Σκρέκας: Διαθέτουμε 1,9 δισεκατομμύρια ευρώ για τις επιδοτήσεις του ρεύματος τον Σεπτέμβριο (Kostas Skrekas: We allocate 1.9 billion euros for electricity subsidies in September).

[24] Source: Υπουργός Περιβάλλοντος και Ενέργειας. Κώστας Σκρέκας: «1,1 δισ. ευρώ για τη στήριξη νοικοκυριών, επαγγελματιών και αγροτών τον Οκτώβριο» (Kostas Skrekas: "€1.1 billion to support households, professionals and farmers in October"). September 21st, 2022.

Natural gas was also subsidized: households received a support of €90/MWh, while all commercial and industrial consumers received €40/MWh.

In 2023, measures were focused on the subsidization and promotion of renewable energy projects by households, including[25]:

- Launch, in April, of the programme "Photovoltaics on the roofs", to support the installation of small solar PV projects and energy storage systems in roofs, by households and farmers. The total budget of the programme was €200 million, covering up to 75% of the investment cost for households and 60% for farmers.
- Launch of the "Recycle- Change Water Heater" programme, with €100 million to promote the installation of up to 120,000 new water heaters, saving around 65% of the electricity consumption.

The participation in subsidy programmes is open to all citizens, although disadvantaged ones can be prioritized.

Besides, the measures to reduce electricity and natural gas prices continued along 2023.

In October 2023, the Ministry of Environment and Energy of the Hellenic Republic presented to the European Commission the Draft Updated National Energy and Climate Plan (NECP) 2023-2030. This document is a draft of the revised NECP which was presented in 2021, and was expected to be presented in June 2024. All countries in the European Union have to update these plans regularly, to adapt them to changes in the energy situation in the country.

The new objectives described in the Draft Updated National Energy and Climate Plan are as follows:

- The share of renewable energy will be at least 44% of the final energy consumption by 2030 (compared to 35% in the NECP 2019-2030).
- The share of renewable electric energy will be at least 79% of the gross final electricity consumption by 2030 (compared to 61% in the NECP 2019-2030).
- The share of renewable energy in heating and cooling needs to exceed 46% of the final energy consumption for heating and cooling by 2030 (compared to the objective of 43% in the NECP 2019-2030). The roadmap should allow to reach 100% by 2050.
- The share of renewable energy in transport sector should exceed 29% of the gross energy consumption in transport by 2030 (compared to the objective of 19% in the NECP 2019-2030).

[25] Source: Υπουργός Περιβάλλοντος και Ενέργειας. Κώστας Σκρέκας: «Σταθερός μας στόχος, προσιτές τιμές ενέργειας για όλους» (Kostas Skrekas: "Our constant goal, affordable energy prices for all"). March 24th, 2023

- Reduction of greenhouse gas emissions by 54% in 2030 compared to 1990 (40% was the objective in the NECP 2019). By 2050, the greenhouse gas emissions should be reduced by 93%, compared to 1990.
- In terms of energy efficiency, the final energy consumption of Greece should be no more than 15.4 ktoe in 2030, 7% less than the objective in the NECP 2019-2030 (16.5 ktoe).

<u>Regulation related to energy communities</u>

Law 4513/2018 introduced the concept of energy communities in Greece as a step towards energy democracy. The law aims to enable local actors (citizens, municipalities, local businesses, universities, etc.) to get actively involved in the clean energy transition with some special provisions for islands.

Energy communities have to be democratically governed, and the participation is open and voluntary. Members of an energy community can be:

- Natural persons with full legal capacity, including civil servants.
- Local authorities, companies owned by local authorities, as long as they are SMEs.
- Small and medium-sized enterprises.
- Agricultural and urban cooperatives, as long as they are SMEs.
- Public or private non-profit legal entities, as long as they are SMEs.

Members of the community have to be permanent residents or own a property located in a region where the energy community or the renewable energy project is developed. For legal entities, the registered seat has to be in the region where the energy community or the renewable energy project is developed.

Law 4513/2018 also includes some financial incentives and support measures to energy communities which develop microgrids in islands. Among these incentives, it is possible to mention the following:

- Exemption for the energy community members from the mandatory payment of insurance contributions to the National Social Insurance Fund (EFKA).
- Inclusion of energy communities in national and European funding programmes.
- Exemption of energy communities from the payment of the annual fee for the maintenance of the right to hold an electricity production license.
- Reduction of the guaranteed fee by 50% for renewable energy, combined heat and power and hybrid power plants owned by energy communities.

This law was launched before the Clean Energy for All Europeans package was adopted by the European Commission in 2019. This involves that Law 4513/2018 was not totally compliant with the European regulation. As of November 2022, there were 1,406 active energy communities in Greece, with 799.54 MW of installed capacity[26]

In May 2023, the law 5037/2023 made some changes related to energy communities:

- It differentiates between Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs), according to the EU regulation. Article 7 of the Law 4513/2018 on the establishment of energy communities is repealed, and no new energy communities according to this law can be created.
- Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs) are legal entities which are considered as civil cooperatives and are regulated by the Law 1667/1986.
- Renewable Energy Communities have as mission the production, consumption, storage, or trade of renewable energy. Their main objective is to benefit their members and their local communities in an environmental, economic, and social way.
- Citizen Energy Communities have the same characteristics that Renewable Energy Communities have, but may also be active in the supply, distribution, aggregation, balancing, and energy efficiency of electric vehicle charging services.
- Members of the Renewable Energy Communities should be near the area where the community has its activities. However, no proximity requirements are created for the members of Citizen Energy Communities.
- Virtual net-metering applications are forbidden for for-profit businesses.
- Net metering, which allows the consumer to offset the energy produced by the self-consumption project, and put it in the grid, with the energy consumed by the consumer, is limited to a maximum capacity of 10.8 kW for households and 100 kW for businesses. However, net metering is allowed, without any limit, to all types of energy communities and to agricultural loads.
- Net metering will be gradually replaced, by August 2024, by net billing.

In Kythnos, and specifically in the Gaidouromantra microgrid, there is not specific regulation apart from the general Greek regulation described before.

However, the feed-in premium scheme which is used for renewable energy projects in the rest of the Kythnos Island and Greece does not applies in Gaidouromantra microgrid.

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[26] Source: Energy Communities Repository. Greece. *Overview of the Policy Framework*. Published on 18/09/2023. Author: European Commission.

Appendix C- Review of the Regulatory framework for renewable energies and energy communities in India

The Government of India has ambitious renewable electricity targets for 2030. Specifically, the country has set as objective to reach 500 GW of renewable energy capacity by 2030. By March 2024, the country had a total renewable energy installed capacity of 190 GW, having reached the objective of 175 GW by 2022 that the country had set.

The first regulation related to renewable energy or environmental protection was the Environment Protection Rules, approved in 1986. These rules, enacted by the Ministry of Environment and Forests, created standards for maximum concentration of different pollutants, to limit their emission or discharge. Besides, companies have to obtain annual environmental statements. All gaseous emissions from oil facilities have to be flared, using elevated flares unless the crop production is affected.

In 1991, the Ministry of Power of the Government of India created the National Energy Conservation Awards, coordinated by the Bureau of Energy Efficiency. These awards are given to the industries and companies which take special efforts to reduce their energy consumption, using energy efficiency measures to maintain the same levels of production. These awards were given away on December 14th, 1991 for the first time. December 14th was declared the "National Energy Conservation Day". Considered sectors are classified in Large, Medium and Small scale, and include, for example: Industry Sector (Cement, Chlor-alkali, Glass, Tyres, etc.), Transport Sector (e.g., Railway Stations, Metro Railway Systems), Building Sector (Hotel, Hospitals, Airport, Shopping Mall), Institutions (State Agencies, Electrical Distribution Companies) and Appliances.

In 1994, the Government of India created an accelerated depreciation scheme for renewable energy projects, which reached a depreciation rate of 100%. This rate was reduced to 80% in 2002, and was withdrawn in 2012.

However, in 2014, this accelerated depreciation scheme was reinstated, at a rate of 80% until March 31st, 2017, for flat plate solar collectors, concentrating and pipe type solar collectors, solar PV systems, wind turbines, biogas plants and biogas engines, electric vehicles including battery powered or fuel-cell powered, and agriculture and municipal waste conversion devices producing energy.

In 2001, the Bureau of Energy Efficiency launched the Energy Conservation Act, 2001 No. 52 of 2001, of September 29th, 2001, with the objective of improving the energy intensity of the Indian economy. The act includes regulations for standards and labelling of equipment and appliances, energy conservation building codes for commercial buildings, and energy consumption regulations for energy intensive industries.

The Act also establishes the powers of Indian Central and State governments about energy efficiency and its conservation, as well as the penalties which can be imposed.

In 2010, this Act was amended, to include the issuance of Energy Savings Certificates by the Central Government, which are given to these consumers which use less energy than the prescribed standards. The Central Government can also define a minimum share of non-fossil fuel energy sources which have to be used by designated consumers.

The Electricity Act, No. 36 of 2003, of May 26th, 2003, consolidates the regulation related to generation, transmission, distribution, trading, and use of electricity. The objective of the Act is to support the electricity industry, protect electricity consumers, ensure that all areas receive electricity supply, assess the electricity tariffs, ensure transparency for subsidies, and promote environmental and climate policies. It describes that tariffs will be determined to promote co-generation and electricity distribution with renewable energy sources, and a National Electricity Policy and Plan will be designed to do so. State Electricity Regulatory Commissions (SERCs) will be established by each State, to promote renewable energies.

Following the Electricity Act, the Government of India launched on February 12th, 2005, the National Energy Policy. This Policy has as main objectives the following ones:

- Make electricity access available for all households in the following five years (this is, by 2010).
- Electricity demand had to be fully met by 2012. Energy and peaking shortages had to be overcome by that year, and adequate spinning reserve had to be created.
- Ensure supply of reliable and quality power of specified standards in an efficient manner and at reasonable rates.
- Per capita availability of electricity had to be increased to over 1,000 units by 2012.
- Minimum lifeline consumption of 1 unit/household/day as a merit good by year 2012.
- Financial turnaround and commercial viability of electricity sector.
- Protection of consumer's interest.

Besides, the Central Electricity Authority (CEA) has to prepare a National Electricity Plan each five years, and to review it periodically.

Regarding renewable energy sources, although the National Energy Policy focuses on Hydro Generation, Thermal Generation and Nuclear, it states that non-conventional energy sources, including small hydro, wind and biomass have to be exploited fully, and the participation of the private sector should be encouraged.

In January 2006, the Ministry of Power launched the Tariff Policy, related to the National Energy Policy of 2005.

It includes the obligation of central and state electricity regulatory commissions to purchase a minimum percentage of grid-based power from renewable energy sources. For example, solar PV should make at least 0.25% of power purchases by states by 2013, and 3% by 2022. The State Electricity Regulatory Commission (SERC) is the entity which has to define these minimum renewable energy purchase percentages, and had to do so before April 1st, 2006.

As it will take some time to make renewable energy sources competitive with conventional sources, procurement by distribution companies has to be done at preferential tariffs. However, the selection of projects and renewable electricity suppliers is done through competitive bidding processes, carried out separately for each technology.

On May 18th, 2006, the Bureau of Energy Efficiency (BEE) launched a Standards and Labelling (S&L) scheme, following the Energy Conservation Act of 2001. Energy labels are created for appliances, and offer information about the energy consumption for users. Labels are rated from one star, for the less efficient appliances, to five stars, for the most efficient. Besides, there are endorsement labels, which define appliances which meet the "Minimum Energy Performance Standards" (MEPS), and can be considered as efficient. Consumers are, so, encouraged to purchase the most efficient appliances. Although energy labels were initially voluntary, they have become mandatory for appliances such as refrigerators, electric water heaters, televisions, air conditioners, tubular fluorescent lamps, LED lamps, distribution transformers and ceiling fans.

In August 2006, the Planning Commission of the Government of India released the Integrated Energy Policy (IEP). This policy considers all aspects of energy in India, including energy security, access and availability, affordability and pricing, efficiency, and the environment.

The Integrated Energy Policy was designed to cover the energy demand of India, at the least cost, and in a technically efficient, economically viable, and environmentally sustainable way. It also considers the reduction of greenhouse gas emissions.

This policy regards renewable energies as a good way to maximize the domestic energy supply of India. They are also recognized to lead to many socio-economic benefits, and to reduce environmental impact. They can also improve the electricity supply, as they can generate electricity nearer the consumption.

However, subsidies offered to renewable energy project developers have to be limited, and the period when they are offered has to be also reduced. They should be linked to energy generation, and not to capacity installed. For example, they can be offered as a Tradable Tax Rebate Certificate (TTRC), based on the electricity generated. Power regulators are asked to analyse alternative incentive structures, such as mandated feed-in laws or differential tariffs, to promote the integration of renewable energies in energy systems, by utilities.

Besides, specific renewable energy alternatives should be encouraged, such as fuel wood plantations, biogas plants, wood gasifiers based power plants, solar thermal, solar water heaters, solar PV, biodiesel and ethanol.

In 2007, the National Programme on Energy Efficiency and Technology Up gradation of SMEs carried out 35 technology gap assessment studies in 25 Energy intensive SME clusters of 12 sectors. As a result, energy efficient technologies were demonstrated in 4 clusters for further replication of the technologies. Dissemination and awareness creation workshops were held in 51 SME clusters. The Bureau of Energy Efficiency carried out more than 150 detailed energy audits, focused on 15 Micro, Small and Medium Enterprises (MSME).

Similar to this, the Agricultural Demand Side Management (AgDSM) scheme was focused on the analysis of the energy intensity of the agriculture pumping sector in India. In general terms, agriculture pumps are not energy efficient, due to the low cost of electricity for agriculture consumers. The use of Energy Efficient Star Labelled Pump Sets can save about 30-40% energy. For this reason, 11 Detailed Project Reports were prepared in 8 states (Maharashtra, Haryana, Punjab, Rajasthan, Gujarat, Andhra Pradesh, Madhya Pradesh, and Karnataka), which were agriculturally intensive, covering 20,000 pumps. AgDSM pilot programmes were developed in Mangalwedha Sub-division of Solapur District in Maharashtra (replacing 2,209 pumps, and saving around 6.1 million kWh), followed by a second program in Karnataka, with 590 pumps. The investment cost of new pumps is free for agriculture consumers, as well as maintenance costs during the first 5 years.

In January 2008, the central government created generation-based incentives for solar power plants, to promote the development of these projects. The subsidy consisted of 12 rupees (€ 0.30)/kWh, for solar PV power, and 10 rupees (€ 0.25)/kWh for solar thermal power supplied to the grid. For each Indian state, the subsidized power capacity was limited to 10 MW, with a maximum of 5 MW for each developer. The incentives can last for a period of 10 years.

On June 30th, 2008, India launched its first National Action Plan on Climate Change (NAPCC), which includes the existing and future policies related to climate change mitigation and adaptation. The plan includes eight "national missions", which had to be achieved until 2017. These missions are:

- National Solar Mission: Development and use of solar energy for power generation and other uses, trying to make solar energy competitive with fossil fuels. It focuses on increasing the penetration of solar thermal technologies in urban areas, industry, and commercial establishment. There is a target to increase the production of solar PV to 1,000 MW/year, and to deploy at least 1,000 MW of solar thermal generation. Besides, a solar research centre has to be created, as well as increase the international collaboration on technology development, the domestic manufacturing capacity, and the government funding and international support.

- National Mission for Enhanced Energy Efficiency: Recommendations about compulsory energy consumption decreases in large energy-consumption industries, including a mechanism to trade energy efficiency certificates, financing for public-private partnership to reduce energy consumption through demand-side management programs, and energy incentives, such as reduced taxes on energy-efficient appliances.

- National Mission on Sustainable Habitat: Energy efficiency has to be a core component of urban planning, extending the existing Energy Conservation Building Code, strengthening the automotive fuel economy standards, and using pricing mechanisms to promote the purchase of efficient vehicles. Incentives to use public transport are also created.

- National Water Mission: Its objective is to reach a 20% improvement of water use efficiency in India, using pricing mechanisms and other measures.

- National Mission for Sustaining the Himalayan Ecosystem: The objective of the mission is to prevent melting of the Himalayan glaciers and protect the biodiversity of the Himalayan region.

- Green India Mission: Afforestation of 6 million hectares of degraded forest lands and expansion of the forest cover from 23 to 33% of the India's territory.

- National Mission for Sustainable Agriculture: Support for climate adaptation in agriculture, developing climate-resilient crops, expanding weather insurance mechanisms, and using agricultural practices.

- National Mission on Strategic Knowledge for Climate Change: Improve the understanding of climate science, impacts, and challenges. A new Climate Science Research Fund has to be created, climate modelling is improved, and increased international collaboration is fostered. Besides, private sector initiatives are encouraged.

There are other initiatives, including:

- Power generation: Compulsory close of inefficient coal-fired power plants, and support to the research and development of Integrated Gasification Combined Cycle (IGCC) and supercritical technologies.
- Renewable energy: According to the Electricity Act 2003 and the National Tariff Policy 2006, the central and the state electricity regulatory commissions have to purchase a minimum percentage of electricity from renewable energy sources.
- Energy efficiency: According to the Energy Conservation Act 2001, large energy-consuming industries have to carry out energy audits. Besides an energy-labelling programme for appliances is created.
- Health sector: This includes two components: provision of enhanced public health care services and assessment of increased burden of diseases, due to the climate change.
- Implementation: Ministries which are responsible for each of the Missions have to develop specific objectives, implementation strategies, timelines and monitoring and evaluation criteria. They have to review and periodically report the progress of each mission.

In July 2008, the generation-based incentive for solar PV projects was replicated for wind energy projects, by the Ministry of New and Renewable Energy (MNRE), trying to promote the development of new and large independent wind energy projects. Projects had to have at least 5 MW, and be commissioned on or before March 31st, 2012. The incentive was set at 0.50 rupees/kWh (US$ 0.01/kWh) of grid-connected electricity, for a minimum of 4 years and a maximum of 10 years, and up to a maximum of 6.2 million rupees/MW (US$ 140,000/MW). The scheme had as objective to install up to 4,000 MW.

In 2009, the National Tariff Policy created the obligation for each State Electricity Regulatory Commission (SERC) to specify a renewable energy purchase obligation (RPO), trying to reach at least 10% of the power purchased from renewable energy sources.

On September 16th, 2009, the Central Electricity Regulatory Commission (CERC) developed guidelines about which projects can be given feed-in tariffs, and how feed-in tariffs are calculated. They depend on the investment cost and operation and maintenance costs, as well as useful lives: 13 years for most renewable energies, 25 years for solar PV and thermal and 35 years for small hydro. Return on equity, depreciation, and interest on working capital are also considered.

Feed-in tariffs depend on the technology and different factors, for example, the wind density in W/m^2 for wind energy. Besides, feed-in tariffs established in 2008 for solar PV and wind energy continued being operating. Finally, each state can also create its own feed-in tariff scheme for renewable energy sources.

On January 11th, 2010, the Government of India and the State Governments launched the Jawaharlal Nehru National Solar Mission (JNNSM), or the National Solar Mission, with the objective of promoting the solar energy in India. This policy was included in the National Action Plan on Climate Change, and was inaugurated on January 11th, 2010.

It has had three different phases:

- Phase I (2010-2013):
  - Target for grid-connected solar PV (including rooftop): 1,000- 2,000 MW.
  - Target for off-grid solar PV applications: 200 MW.
  - Target for solar collectors: 7 million square meters.
- Phase II (2014-2017)
  - Cumulative target for grid-connected solar PV (including rooftop): 4,000- 10,000 MW.
  - Cumulative target for off-grid solar PV applications: 1,000 MW.
  - Target for solar collectors: 15 million square meters.
  - Besides, a scheme for at least 25 solar parks and the Ultra Mega Solar Power Projects were approved, to target 40,000 MW of solar PV.
- Phase III (2017-2022)
  - Cumulative target for grid-connected solar PV (including rooftop): 100,000 MW, including 40,000 MW of rooftop solar.
  - Cumulative target for off-grid solar PV applications: 2,000 MW.
  - Target for solar collectors: 20 million square meters.

Energy Efficiency Services Limited (EESL) is a Super Energy Service Company (ESCO) founded in 2009, and promoted by the Ministry of Power of the Republic of India, as a Joint Venture of four public-sector undertakings: NTPC Limited, Power Finance Corporation Limited, REC Limited and Powergrid Corporation of India Limited.

This company is developing different energy efficiency solutions in India, in sectors such as lighting, buildings, industry electric mobility, smart metering or agriculture. It has achieved to save over 47 billion kWh per year, and reduced 36.5 million tonnes of CO2 emissions[27].

Some of the programmes developed by EESL are:

- Super-Efficient Air Conditioning programme (2017), to provide super-efficient air conditioner (which consume 750 kWh/year, 40% less than the conventional equipment) to

[27] Source: Energy Efficiency Services Limited website: www.//eeslindia.org/en/about-us/

customers of BSES Rajdhani Power Limited (an electricity distribution company of India), with a discount.

- Smart Meter National Programme (2017), with the objective of replace 250 million conventional meters, for smart meters, using the bulk procurement Build-Own-Operate-Transfer (BOOT) model, where EESL is charged with all the investment and operation and maintenance costs, without any investment from states and utilities. EESL receives the Internal Rate of Return mutually agreed.
- National Energy Efficient Buildings Programme (2017). This programme has as objective to retrofit 20,000 large public and private buildings with mode efficient appliances by 2020. Buildings are equipped with advanced energy management systems, to know power consumption in real time, and identify options to reduce energy waste.

In 2010, the Ministry of New and Renewable Energy (MNRE) of India launched the Indian Solar Cities Programme[28]. The objective of the programme is to support 60 cities in the development of energy efficiency and renewable energy projects, trying to reduce the energy demand by 10% in 2013, compared to 2008.

Each selected city had to develop a Master Plan, with detailed projections for energy demand and supply for five and ten years periods (for 2013 and 2018). It also includes annual targets for energy savings, renewable energy, and reduction of greenhouse gas emissions.

At least one city in each state, with a maximum of five cities per state, have been supported. The programme had five objectives:

- To enable urban local governments to address energy challenges at a city-level.
- To offer a framework and support to prepare a Master Plan.
- To create capacity in the urban local bodies, as well as awareness in all sectors of the civil society.
- To involve different stakeholders in the planning process.
- To manage the implementation of sustainable energy projects, using public-private partnerships.

The support of the Ministry of New and Renewable Energy includes:

- Preparation of the Master Plan, and management of its implementation.
- Setting up a solar cell in each city. The solar cell involves the city council to provide support for project planning and implementation, including the senior administrator and city engineers. Besides, it also implicates the senior administrator and city engineers.

[28] Source: National Renewable Energy Laboratory (NREL). KANDT, Alicen. *Indian Solar Cities Programme: An Overview of Major Activities and Accomplishments*. May 2022.

- Organization of promotional activities, such as training programs, workshops, business meetings, and awareness campaigns for stakeholders.

In 2011, the Indian government created a Renewable Energy Certificate system, to try to increase the penetration of renewable energies in the country. Renewable Energy Certificates are created to help states and utilities to reach their Renewable Portfolio Obligation Targets, defined by the National Energy Policy. In 2010, the objective was to reach 5% of the total energy generated with renewable energy sources, to be increased to 6% in 2011, 7% in 2012, 8% in 2013, 9% in 2014 and 10% in 2015.

As some states could easily fulfil this obligation, while others could not, a system to purchase Renewable Energy Certificates to the states which exceeded the objective was created.

In 2012, the Government of India launched its Twelfth Five-Year Plan. Economy in India has been led by Five-Year Plans, developed, carried out, and monitored by the Planning Commission (1951-2014) and the NITI Aayog (2015-2017). They are centralized and integrated national economic programs, based on the ones designed in the Soviet Union since 1928.

The Twelfth Five-Year Plan was designed for the period 2012-2017, and is important because it includes some objectives related to renewable energy penetration. It deems as necessary to use low-carbon technologies to ensure the growth of Indian economy, while this growth is sustainable. It focuses on increasing productivity, to reduce energy consumption without affecting the economy and poverty reduction.

Some energy-specific objectives are:

- To reduce the emission intensity of GDP between 20% and 25% by 2020, compared to 2005.
- To add 30,000 MW of renewable energy capacity during 2012-2017.
- Renewable Energy Certificates and Feed-in tariffs, which were implemented previously, are mentioned as instruments to increase the penetration of renewable energies in India.

During these years, there has been a number of policies related to energy efficiency. Among them, it is possible to mention:

- Super Efficient Equipment Programme (SEEP), 2012. It is designed to transform the Indian market using “super efficient” appliances. To do this, financial stimuli are given at critical points of intervention. The first appliance which was supported was the ceiling fan.
- Domestic Lighting Replacement Programme (UJALA), 2015. The EESL’s Unnat Jyoti by Affordable LEDs for All (UJALA) is the world’s largest domestic lighting replacement programme in the world, and had as objective to replace 770 million old lamps for LED lamps, and 35 million street lights for LED lamps. It is a joint programme of the Government of India’s Public Sector Undertakings, the Union Ministry of Power’s Energy Efficiency Services Limited (EESL) and DISCOM.
- In 2013, the Ministry of Finance, along with the Ministry of Power and the Bureau of Energy Efficiency (BEE) launched a regulation creating minimum energy efficiency criteria for the

purchases made by all ministries, departments, and public offices. The objective of this measure was to save 250 MW.

- In 2015, the Government of India launched the Street Lighting National Programme, with the objective of replacing 35 million inefficient light bulbs used in street lighting in 100 Indian cities, for LED technology. The programme finances the up-front cost, recovered with the financial savings obtained due to the lower electricity bills.

In 2013-2014, the Ministry of New and Renewable Energy launched the Biogas Power (Off-grid) Programme, which offered subsidies for decentralized power generation plants and thermal applications based on biogas. Subsidies were offered per each kW, and were double for power generation than for thermal applications. Additionally, the subsidy per kW was lower as the plant size increases. Subsidies range from rupees 15,000/kW for thermal plants with a power capacity ranging from 100 kW to 250 kW, and rupees 40,000/kW for power generation with a power capacity between 3 and 20 kW.

In 2014, the Ministry of New and Renewable Energy launched a National Biogas and Organic Manure Management Programme. This programme offered subsidies for biogas plants, according to the type of organic matter used: cattle dung, human excreta, and other organic matter, through the process digestion.

In that year, the Prime Minister of India launched the Make in India initiative. It had as objective to enhance the manufacturing capacities of India, transforming the country in a worldwide leader. This would improve the economic growth of the country. Its objective was to increase the share of manufacturing as a proportion of the gross domestic product from 16% to 25% by 2022, creating 100 million additional jobs in industry.

Related to renewable energy, the Make in India programme focused on solar PV, lithium batteries, solar charging infrastructure, and other technologies, such as cooling, electric mobility, smart grids, and advanced biofuels. The plan included the objective of reaching 450 GW of renewable energy capacity by 2030.

In 2015, the Government of India defined a renewable energy penetration target, to be achieved in 2022. It included the development of 175 GW of renewable energy, divided into 100 GW of solar energy, 60 GW of wind energy, 10 GW of biomass and 5 GW of hydropower.

As commented before, the Make in India initiative has proposed as objective to reach 450 GW of renewable energy installed by 2030.

Besides, in 2015, the Government of India launched the National Policy on Biofuels, to ensure that a minimum level of biofuels is available in the market, covering the demand at any time. There is a blending target of 20% biofuels in biodiesel and bio-ethanol, to 2030.

The World Bank, Small Industries Development Bank of India (SIDBI) and Energy Efficiency Services Limited created in 2015 the Partial Risk Sharing Facility for Energy Efficiency (PRSF) Project, which involves the mobilization of commercial finance and the participation of energy services companies. The programme offered sub-guarantees to sub-financiers, managed by the Small Industries Development Bank of India, and tried to develop energy efficiency markets, using end-to-end solutions and measurement and verification (M&V) activities.

Besides, it offered technical assistance, capacity building and operations support. The total budget of the program reached US$ 43 million, from which US$ 27 million were allocated to the Partial Risk Sharing Facility for Energy Efficiency, and US$ 6 million to the development of technical assistance.

In 2015, the Government of India prepared a Draft National Renewable Energy Act, and launched it to the public consultation in July. It had the objective of promoting the use of renewable energies to produce energy, to reduce the dependence on fossil fuels, ensure supply security and reduce CO_2 and other greenhouse gas emissions.

The law included the development of a National Renewable Energy Fund, to support the objectives of the law, including the R&D, resource assessment, demonstration and pilot projects, the low-cost financing, infrastructure development, or support to renewable energy technology manufacturing. Besides, the operators of the transmission and distribution system would be obliged to connect the renewable energy projects to the grid.

In 2015, the Government of India published its Intended Nationally Determined Contribution (INDC), for the period 2015-2030, to the United Nations. India has committed to reducing the emission intensity of the economy by 33 to 35% by 2030, compared to 2005 level.

Besides, India will increase the share of non-fossil fuels-based electricity to 40% by 2030, and will restore the forest cover, creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 through additional forests by 2030.

The objective of reaching 450 GW of renewable energy capacity installed in India by 2030 is expected to create up to 3 million jobs in India. However, these professionals need to be trained and highly qualified. For this reason, in 2015, the India's Ministry of Skill Development and Entrepreneurship created the Skill Council for Green Jobs (SCGJ), with the support of the Ministry of New and Renewable Energy and the Confederation of Indian Industry.

The Skill Council for Green Jobs is a non-profit, independent, industry-led organisation, with the objective of identifying skilling needs in green job sectors, and to design training plans for capacity building. It is also trying to promote green jobs in schools, universities, and engineering institutions. If focuses on three fields: renewable energy; environment, forestry and climate change; and sustainable development, and has developed 44 nationally approved qualifications.

It has a network of over 400 affiliated centres, with over 4,000 trainers in all the country, specialized in different green fields. The objective of the Skill Council for Green Jobs is to create 30-35 million additional jobs by 2047. The sectors which would have the highest potential are green hydrogen, energy storage, hybrid renewable systems, biomass and biofuels, electric vehicle charging, pollution control, e-waste management, and decarbonisation of energy intensive industries.

In 2015, the Bureau of Energy Efficiency (BEE) and the United Nations Industrial Development Organization (UNIDO) launched the Facility for Low Carbon Technology Deployment (FLCTD), supported by the Global Environment Facility (GEF). FLCTD is a 5-year project, with the objective of supporting the innovation in low-carbon technologies, and their development in industrial and other related sectors of India. Each year, an "Innovation Challenge" competition is celebrated, to identify low carbon technologies focused on energy efficiency, including waste heat recovery, space cooling, and pumps and pumping systems.

Another interesting initiative related to the energy efficiency in India is the Energy Efficiency Financing Platform (EEFP), launched in 2015 by the National Mission for Enhanced Energy Efficiency. It is a platform where financial institutions and project developers can interact to promote energy efficiency projects. For example, different training programmes have been celebrated for capacity building for financial institutions, related to energy efficiency.

In 2016, the Ministry of Power, Coal and New & Renewable Energy launched the Ujwal Bharat programme. This programme has as objective to ensure 24 x 7 affordable and environmentally friendly power for all by 2019, connecting the unconnected villages.

The programme includes solar massive capacity additions, and other measures such as:

- Create a transparent Coal Allocation Monitoring System (CAMS) to provide information about coal price, availability, and use for small and medium-scale consumers.
- Increase the hydroelectricity power, by building the 1,200 MW Teesta Hydro Project.
- Install up to 11,717 MW of regasified liquid natural gas power plants.
- Double coal India's production to 1 billion tonnes/year by 2020.
- Increase the renewable energy capacity to 175,000 MW by 2022.
- Increase the power generation by 50% by 2020.
- Energy savings of 10% of current consumption.
- Transparent procurement systems to reduce price of LED lamps by 82%.

The Municipal Energy Efficient Programme (MEEP) was launched in 2016, under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT). It has as objective to deploy more efficient pumps in 500 cities, replacing inefficient pumps in public water works and sewerage systems. The programme covers the investment cost and the maintenance costs during seven years, receiving a part of the energy cost savings obtained by the users.

In 2016, there were two relevant programmes with the objective of promoting renewable energy sources:

1) Comprehensive policy on Decentralized (Off-grid) Energy Generation Projects based on New and Renewable Energy (Non-Conventional) Energy Sources.

   This programme included a Draft National Policy on Mini and Micro-grids, with the objective of deploying at least 10,000 renewable energy-based micro and mini grids with a minimum capacity of 500 MW up to 2021, in under-served and un-served locations. However, the development of this Policy has been delayed.

2) Grid Connected Solar Power Rooftop Programme: It has as objective to install grid-connected rooftop solar PV (GRPV) projects, reducing greenhouse gas emissions by replacing the use of thermal energy for electricity.

In 2017, the Tree-Year Action Agenda 2017-2018 to 2019-2020 included some new objectives related to the installation of renewable energies, such as:

- Add 61.6 GW of electricity generation capacity with conventional sources, 6.9 GW of large hydro projects, 15.8 GW of wind power and 53 GW of solar PV.
- Reach a target of 100 GW of renewable energy by 2019-2020, with the objective of 175 GW by 2022.
- Install 20 GW of off-grid solar PV energy by 2019-2020, with the final aim of reaching 40 GW for 2022. Off-grid solar PV energy will be installed in the residential, commercial, industrial and agricultural sectors.
- The Solar Energy Corporation of India Limited (SECI) should develop energy storage solutions within the next three years, to reduce energy prices through demand aggregation of both household and grid scale batteries.
- By 2019-2020, a robust market for renewable power should be created by the effective implementation of Renewable Purchase Obligations (RPOs).
- A target of 5,000 MW of Small Hydro Power by 2022, which should be advanced to 2019-2020 through viability gap funding and tariff support.

The Venture Capital Fund for Energy Efficiency (VCFEE) was established in 2017 by the Bureau of Energy Efficiency (BEE), under the framework for Energy Efficient Economic Development of National Mission for Enhanced Energy Efficiency (NMEEE). It offers risk capital support to energy efficiency investments in new technologies, goods, and services. The main beneficiaries are energy service companies (ESCOs) and companies that plan to carry out energy efficiency projects, using energy performance contracts. The total budget of the fund is rupees 2.1 billion.

Between 2016 and 2017, the Ministry of New and Renewable Energy (MNRE) developed a reverse auction mechanism for onshore wind energy projects. The objective of this mechanism was to make onshore wind prices transparent and to discover prices, to help states fulfil with the non-solar Renewable Purchase Obligations (RPO).

The first auction was carried out in February 2017, when 1,000 MW of onshore wind capacity were awarded to four companies, at a price of rupees 3.46/kWh.

The second auction took place in October 2017, reaching prices 24% lower than in the first auction. The lowest bid reached rupees 2.64/kWh for 500 MW, and rupees 2.65/kWh for other 500 MW. There were 12 bids, with an accumulated capacity of 2,900 MW.

In 2018, there were three auctions, with prices of rupees 2.44/kWh, rupees 2.51/kWh and rupees 2.76/kWh, while in 2019, in the three corresponding auctions, prices ranged between 2.79 and 2.83/kWh[29].

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[29] Source: Global Wind Energy Council (GWEC) India, 2022. *Accelerating onshore wind capacity addition in India to achieve 2030 target*. Chennai, India.

In these auctions, developers are free to choose locations for their projects. The offtaker is the Solar Energy Corporation of India Limited (SECI), which signs power purchase agreements with the developers, for 25 years.

In 2017, there was also an auction for the 500 MW Bhadla Phase-III Solar Park, launched by the SECI. The result of this auction was as follows:

- 200 MW were awarded to Acme Solar, with a price of rupees 2.44/kWh.
- 300 MW were awarded to SBG Cleantech, with a price of rupees 2.45/kWh.

Besides, the 250 MW Bhadla Phase-IV Solar Park was also auctioned in May 2017, with prices of rupees 2.62/kWh for 150 MW and 2.63/kWh for the remaining 100 MW.

In July 2017, the NITI Aayog launched the Draft National Energy Policy, with the goal of carrying out the planning related to energy in India.

The objectives of the Draft National Energy Policy are as follows:

- Improvement of the energy security of the country, reducing the dependency on imports, especially oil and gas. To do so, renewable energy sources like solar and wind energy will be promoted. The sources of imports will be diversified.
- Ensuring energy access at an affordable cost for all households, by electrifying all houses by 2022, 24x7, along with access to clean cooking fuel.
- Increase of the share of manufacturing in GDP to 25% in 2022, compared to 16% in 2017.
- According to the Nationally Determined Contributions committed by the Republic of India to the United Nations, the emissions intensity of the Indian economy will be reduced by 33%-35% by 2030, compared to 2005.
- Promote economic growth, with competitive pricing to ensure that energy intensive sectors in India can compete at a worldwide level, and to promote domestic energy production.
- Generate at least 175 GW of energy from renewable energy sources by 2022.
- Increase the share of non-fossil fuel-based capacity in the electricity mix above 40% by 2030.
- Propose higher taxes on sport utility vehicles (SUVs) and promote the use of public transport like metro and buses.

In 2017, the Global Environment Facility (GEF), along with the Asian Development Bank and Energy Efficiency Services Limited (EESL) launched a project to expand the market for LED domestic and street lighting, and to support other energy efficiency technologies such as ceiling fans, tri-generation technologies, and smart meters.

During the period from May 2018 to March 2020, the Government of India launched a Scheme to Support the Promotion of Biomass-Based Cogeneration in Sugar Mills and Other Industries in the Country. This program offers a Central Financial Assistance (CFA) for projects which use biomass like bagasse, agro-based industrial residues, crop residues, wood produced through energy plantations, weeds, and wood waste from industry. The subsidy provided is rupees 25 Lakh/MW for bagasse cogeneration projects, and rupees 50 Lakh/MW for non-bagasse cogeneration projects. It is given when the project is commissioned, and the energy generation begins.

In January 2018, the Central Electricity Authority of India launched the Third National Electricity Plan (NEP), for two five-years period: 2017-2022 and 2023-2027.

The main targets included in this plan are:

- Reach a cumulative renewable energy power capacity of 175 GW by 2022, including 100 GW of solar, 60 GW of wind, 10 GW of biomass and 5 GW of small hydro.
- Increase the coal-fired power capacity by 46 GW between 2022 and 2027.
- Increase the share of non-fossil fuel based installed capacity (Nuclear + Hydro + Renewables) to 46.8% by 2021-2022 and to 56.5% by the end of 2026-2027.
- Increase the renewable energy generation share to 20% by 2022 and to 24% by 2027.

On May 14th, 2018, the Ministry of New & Renewable Energy (MNRE) of India launched the National Wind-Solar Hybrid Policy, with the objective of creating a framework to promote large-scale hybrid solar and wind projects. The use of both technologies can use more efficiently the transmission grid and the land, and reduce the variability of renewable energy electricity generation. To be recognized as a hybrid project, the installed capacity of one technology has to be at least 25% of the installed capacity of the other technology.

An existing wind or solar project can be hybridized with a higher transmission capacity than the sanctioned one, if there is transmission capacity in the system available. A transparent bidding process to sell electricity to the system is called by the government. Energy battery storage is allowed in these projects to optimize the input.

In 2018, the Government of India launched a new National Biofuel Policy[30], to incentivize biofuel generation from excess crop production. Some of the measures included in this policy are:

- Biofuels are categorized into “Basic Biofuels” or First Generation (1G) bioethanol and biodiesel, and “Advanced Biofuels” or Second Generation (2G) ethanol, Municipal Solid Waste (MSW) to drop-in fuels, Third Generation (3G) biofuels, including bio-compressed natural gas.
- The type of raw materials which can be used to produce ethanol is expanded, including sugarcane juice, sugar containing materials such as sugar beet, sweet sorghum, starch containing materials like corn, cassava, damaged food grains like wheat, broken rice, rotten potatoes which cannot be used for human consumption.
- Surplus food grains can be used for ethanol production, with the approval of National Biofuel Coordination Committee.

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[30] Source: National Policy on Biofuels- 2018. https://lms.indianeconomy.net/economy-news/national-policy-biofuels-2018.html/

- Viability Gap Funding: A viability gap funding scheme for 2G ethanol bio refineries with rupees 5,000 crore in 6 years is proposed. Besides, additional tax incentives and higher purchase prices as compared to 1G biofuels are given to 2G ethanol generation.
- Development of the supply chain for biodiesel production, for non-edible oil seeds, used cooking oil, short gestation crops, etc.

On February 26th, 2018, the Ministry of New & Renewable Energy (MNRE) of India launched an Order to extend capital grants support for Concentrated Solar Thermal (CST) applications until 2020. The level of subsidy was 30% of the benchmark or the actual investment cost in the fiscal year 2018-2019, while it was reduced to 20% in year 2019-2020. The total budget of the programme is rupees 70 million. It is focused on community cooking, solar process heat and solar cooling.

In 2019, different plans and roadmaps were developed by the Government of India:

- Roadmap of Sustainable and Holistic Approach to National Energy Efficiency (ROSHANEE): It is the evolution of the National Mission for Enhanced Energy Efficiency (NMEEE) and includes the current and potential areas of energy efficiency, for each sector.
- Energy Storage System Roadmap for India: 2019-2032: Developed by the India Smart Grid Forum (ISGF), with the support of MacArthur Foundation and the Indian Energy Storage Alliance (IESA), it considers the energy storage systems requirements to integrate rooftop solar PV in the distribution grid, using these systems. It proposes different scenarios and calculates the needed energy storage capacity, and develops policies and tariff schemes to promote the development of this technology.
- India Cooling Action Plan (ICAP): It offers a 20-years plan to provide access to sustainable cooling. As main targets, it is possible to mention a reduction of cooling demand in all sectors by 20% to 25% by year 2037-2038; the reduction of refrigerant demand by 25% to 30% by year 2037-2038; the reduction of cooling energy requirements by 25%-40% by year 2037-2038; and the training and certification of 100,000 sector technicians by 2022-2023.

In 2019, the Pradhan Mantri Kisan Urka Suraksha evam Utthaan Majabhiyan (PM-KUSUM) scheme was approved by the Government of India, with the objective of providing energy security to farmers, adding up to 30,800 MW of solar capacity to farmers, reducing the use of diesel.

The scheme had three components:

- Component A: Support for adding solar capacity of 10,000 MW through small solar PV plants installation. To do so, individual farmers, group of farmers, cooperatives, panchayats, farmer producer organizations (FPO) or water user associations (WUA) will be able to develop renewable energy-based power plants, with capacities ranging between 500 kW and 2 MW.

  The level of subsidy is 40 paise/kWh or rupees 660,000/MW/year, whichever is less, for the first five years.

- Component B: Installation of 1,750,000 stand-alone solar-powered agriculture pumps. Individual farmers can install stand-alone solar PV agriculture pumps with a capacity up to 7.5 HP replacing existing diesel pumps in off-grid areas. Pumps with a capacity higher than 7.5 HP can be also installed, although the support is offered only to 7.5 HP.

- Component C: Support to farmers in making 1 million existing grid-connected agriculture pumps be powered with solar PV panels. The farmer can use the generated solar power to meet the irrigation demand, and use the excess solar power to distribution companies (DISCOMs), at a pre-fixed tariff.

  The level of subsidy in component B and C includes a Central Financial Assistance (CFA) for the 30% or 50%, a state government subsidy of 30%, and the remaining 20% or 40% to be covered by the farmer.

In August 2020, the Indian Ministry of Power (MoP) exempted all solar and wind energy projects commissioned before June 30th, 2023 from the inter-state transmission system (ISTS) charges and losses. In June 2021, this waiver was extended until June 30th, 2025.

The waiver applies not only to renewable energy projects, but also to pumped hydro storage and battery energy storage systems (BESS), whenever at least 70% of the annual electricity requirement for pumping or charging is through solar and/or wind power.

In November 2020, in the framework of the Atmanirbhar Bharat ("Self-Reliant India"), Programme, Production-Linked Incentives (PLI) were created to enhance the Indian manufacturers' competitiveness, to attract investments in cutting-edge technology, create efficiencies and economies of scale and enhance exports. Among the 10 selected sectors, the manufacturing of solar PV modules and advanced chemistry cell (ACC) batteries are included.

In 2021, during the World Leaders Summit at UNFCCC COP26 in Glasgow (United Kingdom), the Indian Prime Minister Modi announced that the Nationally Determined Contributions for India, under the Paris Agreement, were increased as follows, until 2030:

- To promote a healthy and sustainable way of life, based on traditions and values of conservation and moderation.

- To adopt a climate friendly and a cleaner path than the typical path followed by countries with a similar level of economic development.

- To reduce the emissions intensity of Indian economy by 45% by 2030, compared to 2005.

- To reach 50% of cumulative electric power installed capacity, based on non-fossil fuel energy resources by 2030. To do so, India counts with the help of technology transfer, and low-cost international finance provided by the Green Climate Fund (GCF).

- To increase non-fossil fuel capacity in power generation to 500 GW by 2030, compared to a previous target of 450 GW.

- To reduce emissions by 1 billion tonnes by 2030.

- To create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent, with additional forest and tree cover by 2030.

- To better adapt to climate change, enhancing investments in development programmes in sectors which are vulnerable to climate change, such as agriculture, water resources, the Himalayan region, coastal regions, health and disaster management.
- To mobilize domestic and new funds from developed countries, to support the before described actions.
- To build capacities, create domestic framework and international architecture for the diffusion of innovative climate technology in India.

As part of the Union's 2021-2022 Budget, the Government of India announced two relevant investments[31]:

- Rupees 10 billion to the Solar Energy Corporation of India (SECI), to tender 15,000 MW of new solar energy generation capacity per year. This can attract annual investment of more than rupees 600 billion, generating employment of 45,000 job years, and reduce emissions by 28.5 million tonnes of CO_2 per year.
- Rupees 15 billion to the Indian Renewable Energy Development Agency (IREDA) to support an extension of their loan facility of rupees 120 billion to support renewable energy. This involves financial support to around 4,500 MW of renewable energy projects, with total investments of rupees 180-190 billion, creating employment for 13,500 job-years, and reducing emissions by 8.55 million tonnes of CO_2 per year.

Besides, this Budget includes the launch of a National Hydrogen Mission, announced on India's 75th Independence Day, this is, on August 15th, 2021, to generate hydrogen from green power sources. Its objective is to make India a global hub for hydrogen and fuel cells manufacturing.

To do so, there is a target of five million tonnes per year of green hydrogen production by 2030, more than 80% of the current hydrogen demand of the country.

On January 4th, 2022, the National Hydrogen Mission was approved by the Union Cabinet[32]. It has as objective to develop a green hydrogen roadmap, with a budget of rupees 19,744 crore (197,440 million), divided into:

- Rupees 17,490 crore (174,900 million) for the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme, which offers financial incentive mechanisms for domestic manufacturing of electrolysers and production of green hydrogen.
- Rupees 1,466 crore (14,660 million) for Pilot Projects in emerging end-use sectors and production pathways.

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[31] Source: Ministry of New and Renewable Energy. *Budget 2021-22 augments Capital of SECI and IREDA to promote development of RE sector. National Hydrogen Mission proposed*. https://pib.gov.in/PressReleasePage.aspx?PRID=1696498

[32] Source: National Hydrogen Mission. Decarbonising India, Achieving Net-Zero Vision. Ministry of New & Renewable Energy. March 21st, 2022, updated on January 10th, 2023.

- Rupees 400 crore (4,000 million) for Research and Development, including a Public-Private Partnership framework for R&D.
- Rupees 388 crore (3,880 million) for other Mission components, especially skill development.

By 2030, the National Hydrogen Mission should have achieved the following objectives:

- Development of a hydrogen production capacity of 5 million metric tonnes per year, as well as renewable energy capacity addition of about 125 GW.
- Over Rupees 8 trillion in total investments.
- Creation of over 600,000 jobs.
- Cumulative reduction of rupees 1 lakh crore of fossil fuel imports (rupees 1 trillion).
- Reduction of nearly 50 million tonnes of annual greenhouse gas emissions.

The National Hydrogen Mission will be coordinated with other previous programmes, such as the "Make in India" or the "Atmanirbhar Bharat". Hydrogen demand will be created by the Government of India in selected sectors, by creating mandates to use hydrogen in fertilizer, steel, or petrochemical manufacturing. A Production-Linked Incentive (PLI) was also announced, and the government will promote the demonstration of the technologies in niche applications.

Finally, the budget includes nearly rupees 197 lakh crore (197 trillion) to manufacture high efficiency solar PV modules, to create global champions in this sector, and generate jobs for youth. New gigawatt scale solar PV manufacturing facilities will be developed in India.

This objective is supported by imposing a custom duty on solar cells and modules manufactured out of India. Since April 1st, 2022, imports of solar PV modules are charged a 40%, while solar PV cells are charged a 25%.

In 2022, the Indian Government also developed the National Electricity Plan, which plans to add solar PV capacity up to 333 GW and wind energy up to 134 GW by 2031-2032.

In that year, the Indian Government also defined an Energy Storage Obligation (ESO), specifying that energy storage should be set at 1% in the 2023-2024 and gradually rise to 4% by 2029-2030, considering the total energy consumed from solar and wind.

Besides, the Renewable Purchase Obligation (RPO) programme was extended until 2029-2030, including an increase from 24.61% in 2022-2023, to 43.33% by 2029-2030.

In 2022, the National Policy on Biofuels of 2018 was amended, to include the following changes:

- The deadline to reach a blending target of 20% of bioethanol in petrol was advanced from 2030 to 2025-2026.
- Additional feedstocks were made eligible for the production of biofuels.

Related to the previous policy, the Ministry of New and Renewable Energy (MNRE) of India launched in 2022 the National Bioenergy Programme 2022, and extended it to 2025-2026. This Programme includes:

- A Waste to Energy Programme, which supports the installation of large biogas, bio compressed natural gas and power plants.
- A Biomass Programme, focused on the use of pellets and briquettes for power generation.
- A Biogas Programme to support the installation of family and medium size biogas installations in rural areas.

<u>Regional policies</u>

Until 2022, the renewable energy policy of the State of West Bengal was defined in the Policy on Co-Generation and Generation of Electricity from Renewable Sources of Energy, published in 2012 by the Department of Power % Nonconventional Energy Sources of West Bengal.

This Policy had as objective the promotion and facilitation of the growth of electricity generation from renewable energy sources, optimizing the use of renewable energy in the West Bengal State. Besides, it tried to remove constraints to the development of these projects.

There were 9 objectives, which can be divided into long-term and short-term objectives:

- Long-term objectives:
    - Facilitating enhanced contribution of electricity generation from renewable energy sources.
    - Facilitating and sustaining private sector investment in the development of renewable energy.
    - Adopting/evolving renewable energy technologies and facilitating commercial development of these energies.
- Short-term objectives:
    - Identifying technology-wise thrust areas and strategies for renewable energies in the State.
    - Developing a Roadmap for each of the renewable energy technologies.
    - Facilitating renewable energy investments in the public as well as the private sector.
    - Charting an energy-mix and framing a timeline in synch with the renewable purchasing obligations (RPOs).
    - Developing future renewable energy technologies via pilot projects.
    - Framing the basic building blocks to develop necessary regulatory, administrative, infrastructural and institutional mechanisms.

According to this document, the State of West Bengal has an estimated potential of generating electricity using renewable energy sources which amounts to 2,206 MW, excluding solar PV.

The West Bengal Electricity Regulatory Commission (WBERC) established, by 2012-2013, a minimum of 4% of electricity purchased from renewable energy sources.

The targets in terms of renewable energy installed capacity, established in the Policy on Co-Generation and Generation of Electricity from Renewable Sources of Energy, were as follows:

Renewable Energy Source	Potential (MW)	Existing installed capacity in 2012 (MW)	Target Cumulative Capacity (in MW)	
			2017	2022
Wind power	450	2	75	450
Mini & Small Hydro	394	97	220	395
Co-generation	6,001	69	355	600
Biomass	662	16	240	662
Waste to energy	100	7	50	100
Solar	Under preparation	2	100	500
Total	2,206	193	1,040	2,706

Table 42. Renewable energy targets in the State of West Bengal, according to the Policy on Co-Generation and Generation of Electricity from Renewable Sources of Energy.

Besides, the Draft National Energy Policy, defined for all the country, included specific objectives for the West Bengal State of 5,336 MW of solar PV power plants, considering both large scale grid connected projects and rooftop projects. Later, the target was reviewed to 4,500 MW. Additionally, 50 MW of mini and small hydro should be developed.

The West Bengal State Electricity Distribution Company Limited (WBSEDCL) procures renewable energy from other sources, to fulfil with its Renewable Energy Purchase Obligations, as mandated in "Cogeneration and Generation of Electricity from Renewable Sources of Energy Regulations", notified in 2013.

In 2022, the target of renewable energy penetration in the West Bengal state was reviewed to 20% by 2030.

Besides, on June 3rd, 2021, the State of West Bengal launched the Electric Vehicle Policy 2021, whose vision is to leverage on the history of electric mobility transportation ecosystem implementation in West Bengal to lead India's future of electric mobility.

The objectives of this policy are as follows:

- Promote innovation actively through grants and venture funds to research organizations, incubators, and start-ups working on next generation battery technology, fuel cells technologies, EV power trains and EV electronics.
- Enable investment into charging/battery swapping infrastructure and hydrogen generation and fuelling station development.
- Promote usage of EVs to enable transition to environmentally friendly cities.

Besides, the following targets have been developed:

- The State of West Bengal aims at being amongst the top three best states in India in terms of electric mobility penetration by 2022, and being the best State in electric mobility penetration by 2030.
- The target is to reach 1,000,000 electric vehicles, considering all segment of vehicles, during policy implementation.
- Another target is to reach 100,000 public and semi public charging stations during policy implementation.
- The ratio electric vehicle/public charging point should reach 8 by the implementation of the policy, creating robust infrastructure for electric vehicles including adequate power supply and network of charging points with favourable power tariff.
- Recycle and reuse used batteries and dispose the rejected batteries in an environment friendly manner to avoid pollution.

Finally, on December 5th, 2023, the State of West Bengal launched the West Bengal Green Hydrogen Policy, 2023, based on the National Hydrogen Mission.

West Bengal is considered to have the potential to become a hub for green hydrogen production, as it has steel, sponge iron, fertilizer industries and refineries.

The vision of the policy is to transform West Bengal into a prominent player in the green hydrogen/ammonia economy of India.

The mission of the policy includes:

- To facilitate the identification of green hydrogen demand centres by GIS mapping.
- To enable investment for setting up green hydrogen/ammonia production as well as green hydrogen-based products manufacturing units.
- To establish a State Centre of Excellence (SCoE) to conduct research and development as well as techno-economic innovation to not just provide the state an advantage in terms of green hydrogen technology, but also to guide other states in India in terms of the same.
- To formulate and execute green hydrogen procurement and trade strategies to establish efficient and effective mechanisms for acquiring and exchanging green hydrogen/ammonia resources.
- To create employment by leveraging green hydrogen/ammonia development.

In the State of Odisha, the Odisha Renewable Energy Development Agency (OREDA) is the agency which is in charge of the promotion of renewable energies, and was founded in 1984. It has set the objective of providing minimum illumination to all remote un-electrified villages/hamlets by 2015, and to increase the share of renewable energy to 10% of the total power mix by 2020.

According to a report carried out in 2018 by the Ministry of New and Renewable Energy (MNRE) of India, Odisha has a potential to produce up to 25.78 GW of solar power. However, the

International Forum on Environment, Sustainability and Technology (iFOREST), a New Delhi environmental group, estimated that the potential of this state was much larger, up to 170 GW[33].

On the other hand, Odisha Electricity Regulatory Commission (OERC) has issued PERC (Procurement of Energy from Renewable Sources and its Compliance) Regulations 2015 for purchase of electricity, making it mandatory for obligated entities to source certain percentage of their power purchase form RE sources. According to the OERC, the Renewable Purchase Obligation (RPO) should reach:

- 7.25% of RPO coming from solar PV, 0.18% from hydro, and 5.82% from other renewable energy sources by 2021-2022. A total of 13.25% of electricity should be produced with renewable energy sources.
- 8.00% of RPO coming from solar PV, 0.35% from hydro, and 6.15% from other renewable energy sources by 2022-2023. A total of 14.50% of electricity should be produced with renewable energy sources.
- 8.75% of RPO coming from solar PV, 0.66% from hydro, and 6.59% from other renewable energy sources by 2023-2024. A total of 16.00% of electricity should be produced with renewable energy sources.
- 9.75% of RPO coming from solar PV, 1.08% from hydro, and 7.17% from other renewable energy sources by 2024-2025. A total of 18.00% of electricity should be produced with renewable energy sources.

However, the State of Odisha has not been able to meet these targets with its own renewable energy power plants. It is purchasing electricity from renewable energy sources from neighbouring states.

The State of Odisha has issued two renewable energy policies, one in 2016, which covered the period 2016-2022, and another in 2022, for the period 2023-2030.

The Odisha Renewable Energy Policy 2016 had as mission to provide a long-term sustainable solution for meeting energy needs, and reducing energy dependency on conventional sources of power, while seeking to achieve the Renewable Purchase Obligation targets, and also fulfilling the objectives of the State Action Plan for Climate Change.

The Policy had five main objectives:

- Contribute to long-term energy security of the State as well as ecological security by reduction in carbon emissions.
- Create an environment conducive to public/private/community participation and investment in Renewable Energy Projects.

[33] Source: International Forum for Environment, Sustainability and Technology (Iforest). Singh, Mandvi; Ray Chaudhuri, Ritwik; Mukherjee, Arpo. *Odisha Renewable Energy Potential Re-assessment: Focus on Solar, Wind and Biomass*. New Delhi, India. February 2023..

- Create skilled and semi-skilled manpower resources through promotion of technical and other related training facilities.
- Enhance the contribution of Renewable Energy Projects in the total installed capacity of the State through private participation.
- Facilitate development of manufacturing units and Research & Development in the Renewable energy sector.

The targets in terms of renewable energy installed capacity, by year 2022, were as follows:

- Solar: 2,200 MW.
- Wind: 200 MW.
- Small hydro: 150 MW.
- Biomass: 180 MW.
- Waste-to-energy: 20 MW.
- Total: 2,750 MW.

In order to achieve targeted capacity in the State, solar capacity will be added mainly through four means:

- Land based solar projects: Odisha Industrial Infrastructure Development Corporation (IDCO) has identified patches of land under its Land Bank Scheme to set up solar plants and projects. The project developer may utilize energy generated for self-consumption or selling power within / outside State.
- Utilizing water bodies: Areas over lakes, reservoirs, canals, and ponds can be considered for solar projects development by mounting solar PV panels or floating technologies. Grid Corporation of Odisha Limited (GRIDCO) in co-ordination with concerned departments notify tenders for power procurement through competitive bidding.
- Consumer side of meter: These projects are a decentralized mode for promoting small scale solar PV projects on consumer side of meter. Investors/ consumers develop rooftop PV by connecting to the grid at either 33 kV/11 kV or 440/ 220 V phase depending on the system size. Odisha Renewable Energy Development Agency (OREDA) shall be nodal agency for projects below 1 MW capacity and higher than that will be implemented by Green Energy Development Corporation of Orissa Ltd. (GEDCOL). Net metering facility to be extended to all project developers and follow guidelines.
- Solar parks: They are dedicated zones for development of solar power generation projects, solar manufacturing projects and R&D.

For small hydro, the Engineer-in-Chief (EIC) is the nodal agency, while for wind energy and biomass, OREDA is the nodal agency.

Decentralized renewable energy projects are also encouraged, in on-grid, off-grid and hybrid modes. Specifically, the following projects are included in the policy:

- RE based Mini/Micro Grid: Mini grids have a capacity of 10 kW and above, and micro grids a capacity of less than 10 kW. Both operate isolated from the grid, or can be connected to the grid to exchange power.
- Rooftop Solar Projects.
- Solar Water Pumping for Irrigation, Drinking Water Supply, etc.
- Wind-Solar Hybrid Projects.
- Micro-Pico Hydro Projects.
- Biomass Gasifiers for Power Generation and Thermal Applications.
- Solar Thermal Projects.
- Biogas-Based Projects for Domestic Application & Power Generation.
- Improved Cook Stoves.
- All New and Innovative Energy Options.

All new renewable energy projects can receive different incentives, among them, the exemption from paying Electricity Duty for self-consumption for a period of 5 years, from the date of entering into operation.

The Odisha Renewable Energy Policy 2022, which applies from 2023 to 2030, is the update of the before described policy, and was enacted on November 30th, 2022 by the Department of Energy of the Government of Odisha.

The vision of this Policy is to harness the renewable energy potential of Odisha, and accelerate investment in the renewable energy sector for ensuring energy security, promoting socio-economic growth and protecting the environment.

It has four main objectives:

- To accelerate the adoption of clean energy alternatives and decarbonize the energy sector which includes both grid-based electricity consumption and captive consumption of industrial consumers in the state.
- To harness the clean energy potential of the State and make best use of the available resources by facilitating development of green energy projects in the State.
- To attract investment in the clean energy sector, create job opportunities and develop the State economy.
- To facilitate R&D and promote new initiatives & emerging renewable energy technologies in the State.

OREDA continues being the Nodal Agency, which is a single window facility which has to approve all the renewable energy projects in the State, in a time-bound manner, and will help project developers to obtain these consents.

The targets in terms of renewable energy installed capacity, by year 2030, in the Odisha State, are as follows:

- Wind: 3,500 MW.
- Hydro: 1,200 MW.
- Other renewable energies: 17,000 MW.
- Total renewable energies: 21,700 MW.

On the other hand, the RPO trajectory is as follows:

Renewable Energy Source	2022-2023	2023-2024	2024-2025	2025-2026	2026-2027	2027-2028	2028-2029	2029-2030
Wind Power Obligation	0.81%	1.6%	2.5%	3.4%	4.3%	5.2%	6.2%	6.9%
Hydro Purchase Obligation	0.35%	0.7%	1.1%	1.5%	1.8%	2.2%	2.5%	2.8%
Other Renewable Energy Obligation	23.44%	24.8%	26.4%	28.2%	29.9%	31.4%	32.7%	33.6%
Total	24.60%	27.07%	29.91%	33.01%	35.95%	38.81%	41.36%	43.33%

Table 43. Trajectory of Renewable Purchase Obligations for the period 2022-2030, according to the Odisha Renewable Energy Policy 2022, in the State of Odisha.

The Renewable Energy Policy 2022 also includes the promotion of pilot renewable energy projects and research and development activities to demonstrate new renewable energy technologies, including round the clock and hybrid renewable power projects and renewable energy power projects with storage systems, and green micro grids. The manufacturing of renewable energy equipment manufacturing, and electric vehicle and associated infrastructure is also encouraged.

Virtual Net Metering Framework shall be applicable for consumers under “Domestic” and “Specified Public Purpose” category as per OERC Distribution (Conditions of Supply) Code, 2019 and also for the offices of Government/ local authorities. The capacity of the Renewable Energy System under Group Net Metering or Virtual Net Metering framework to be installed by any Renewable Energy Generator shall not be less than 5 kW and more than 500 kW.

Regulation related to energy communities in India

The regulation about energy communities in India is not as developed as in the European Union, although there have been some measures aimed at promoting the electrification of isolated zones, by means of microgrids and energy communities.

The first regulation in India which includes some reference to energy community microgrids was the Remote Village Electrification Programme (RVEP), developed by the Ministry of New and

Renewable Energy (MNRE). This programme was launched in 2003-2004, and complemented the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) programme (whose main objective was to create decentralised distribution-generation systems).

The RVEP had as objective to electrify all unelectrified census villages and remote villages, using solar PV home-lighting systems. These systems were installed on a cost-sharing basis. The central government covered 90% of the total costs, while the state government paid for the remaining 10%. Out of this 10%, 5% is expected to be charged to the final user from charges, or from other welfare schemes at the state level.

The objective of RVEP was to electrify all the remote villages by 2007, using off grid renewable energy systems, such as small hydro, biomass gasification, or solar PV. However, the success of RVEP and RGGVY was limited, due to the higher costs of plants and the needs for large infrastructure[34].

On the other hand, although the RVEP offered solar PV home-lighting systems, community power plants was installed in few projects.

As the objective of electrifying all villages in India had not been fulfilled, in 2014, the Indian Government launched the DeenDayal Upadhyaya Gram Jyoti Yojana (DDUGJY) rural electrification programme, focused on providing electricity supply to villages, using conventional or renewable energy sources. Its objective was to electrify 18,452 unelectrified villages within 1,000 days, by May 1st, 2018.

To reach this objective, three main projects can be subsidized:

- Separation of agriculture and non-agriculture feeders, making easy to restore the supply to agricultural and non-agricultural consumers in rural areas.
- Strengthen and increase the sub-transmission and distribution infrastructures in rural areas, including metering of distribution transformers, feeders, and consumers.
- Complete the micro grid and off-grid distribution network and rural electrification projects already sanctioned.

The programme offered subsidies for up to 90% of the project cost, including cost of spare parts during 5 years.

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[34] Source: National Council of Applied Economic Research (NCAER). April 2011. *The Remote Village Electrification Programme in India. Assessment of Experience in Odisha, Madhya Pradesh and Chhattisgarh.* Authors: BIDHE, Shashanka; BURAGOHAIN, Tarujyoti; LANDGE, R.S.; BISWAL, Chinmayee; SACHEDEVA, Praveen; SRIVASTAVA, Rakesh Kumar.