RE-EMPOWERED

Renewable Energy EMPOWERing
European & InDian Communities

Deliverable 8.1: Report on the business models and financing tools (V1)

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R Document, report	**PU** Public
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

One of the main objectives of the RE-EMPOWERED project is the development and demonstration of new tools which can enable the energy transition in islanded or isolated communities and energy islands. Among the new technologies to be applied, renewable energy especially through small-scale projects, is one of the most relevant. Energy communities are in particular focus, as a key instrument for citizen's engagement and renewable energy development. The RE-EMPOWERED project deals with the development of a set of solutions, called "ecoToolset", which will foster the use of renewable energy in isolated islands and microgrids. The ecoToolset will also allow the development of new services (demand response, dynamic pricing) which will be based on the concept of the prosumer, and the participation of citizens in the energy transition, allowing them to become active players in the energy system. The ecoToolset will be tested in both European and Indian pilot sites, tailored for the requirements of each case.

However, to ensure the success of the project, it is not enough to develop technically feasible solutions. It is also necessary to design new business models which can guarantee that the ownership of the assets is the most appropriate, and that revenues are obtained, making the investment attractive. In some cases, benefits can be not only monetary, but other advantages can be offered and make the investment interesting for the local citizens.

In Work Package 8, the economic and financial feasibility of each ecoTool and demo site is analysed, considering if the suggested business model is profitable, and proposing different solutions. The main objective of the business models is to increase the citizen engagement, allowing to adapt demand to renewable energy production, in order to maximize the use of renewable energy in the demo sites.

Moreover, the different financial alternatives for each demo site are analysed, presenting the financial tool that has been chosen, and describing other alternatives, as well as advantages and disadvantages of each one.

This Deliverable includes the results of the work carried out in WP8 during the first 18 months of the project. However, the proposed business models and economic analyses must be refined as the RE-EMPOWERED project progresses, and for this reason, in Month 39, a new version of this Deliverable will be prepared, Deliverable 8.2 "Report on the business models and financing tools (V2)".

The results from this Deliverable and overall WP8, will provide key insights to Task 9.3. "Exploitation and commercialization analysis".

Keywords:

Smart Grids, Energy Communities, Business Models, Economic and Financial Models, Renewable Energies, Demand Response, Dynamic Pricing, District Heating System, Business Canvas, Financing Tools.

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Acronyms

Acronym	Description
€	Euro
₹	Rupee
°C	Degree Celsius
AC	Alternating current
Ah	Ampere hour
AMI	Advanced Metering Infrastructure
API	Application Programming Interface
B2B	Business to Business
B2C	Business to Consumers
BEPC	Board for Energy Planning and Control
BESS	Battery Energy Storage System
BMC	Business models
BMC	Business Model Canvas
BOO	Build-own-operate
BOOT	Build-own-operate-transfer
BRP	Balance Responsible Party
CCUS	Carbon capture, use and storage
CFD	Computational fluid dynamics
CfD	Contract for Difference
CHP	Combined heat and power
CO	Carbon monoxide
CO2	Carbon dioxide
CPP	Critical peak pricing
CRES	Centre for Renewable Energy Sources and Saving
CSA	Computational Structural Analysis
CSF	Community Support Framework
D	Deliverable
DBOOM	Design, Build, Operate, Own and Maintain
DC	Direct current
DCM	Distribution Charge Management
DH	District heating
DHN	District heating network
DK2	East Denmark grid
DKK	Danish Krone
DSO	Distribution System Operator
DSM	Demand side management
DST	Department of Science and Technology
EaaS	Energy-as-a-Service
EC	European Commission
EE	Energy efficiency
EEEF	European Energy Efficiency Fund
EIA	Environmental Impact Assessment

Acronym	Description
EMS	Energy Management System
EPC	Engineering, Procurement and Construction contract
ESCO	Energy Services Company
EU	European Union
EV	Electric Vehicle
FCR-D	Frequency containment reserve for disturbances
FIP	Feed-in premium
FIT	Feed-in tariff
GEDCOL	Green Energy Development Corporation of Orissa Ltd.
GRIDCO	Grid Corporation of Odisha Limited
GWh	Gigawatt-hour
GWhe	Gigawatt-hour electricity
GWhth	Gigawatt-hour thermal
h	Hour
HEDNO	Hellenic Electricity Distribution Network Operator
HETS	Hellenic Transmission System
HH	Household
HP	Horse power
HTSO	Hellenic Transmission System Operator
Hz	Hertz
ICT	Information and Communication Technology
IDCO	Odisha Industrial Infrastructure Development Corporation
ILC	Intelligent Load Controller
INR	Indian rupee
IoT	Internet of Things
IPP	Independent Power Producer
IPTO	Independent Power Transmission Operator
IRR	Internal rate of return
km	Kilometre
km2	Square kilometre
KPI	Key performance indicator
kV	Kilovolt
kVA	Kilovolt ampere
kW	Kilowatt
kWh	Kilowatt-hour
kWp	Kilowatt peak
LED	Light-Emitting-Diode
m3	Cubic meter
MaaS	Microgrid-as-a-Service
MAT	Minimum Alternate Tax
MEEC	Ministry for the Environment, Energy and Climate Change
MGCC	Microgrid central controller
MNRE	Ministry of New and Renewable Energy
MoU	Memorandum of Understanding
MW	Megawatt

Acronym	Description
MWh	Megawatt-hour
MWp	Megawatt peak
NECP	National Energy and Climate Plan
NGO	Non-Governmental Organization
NII	Non-Interconnected Island
NOC	No Objection Certificate
NOx	Nitrogen oxides
Nº	Number
NPV	Net present value
NREAP	National Renewable Energy Action Plan
NTUA	National Technical University of Athens
O&M	Operation and maintenance
OERC	Odisha Electricity Regulatory Commission
OPE	Operational Programme for Energy
OPEX	Operational expenditures
OREDA	Odisha Renewable Energy Development Agency
OREDF	Odisha Renewable Energy Development Fund
P2P	Peer-to-peer
P2X	Power-to-X
PaaS	Platform-as-a-Service
PAYG	Pay-as-you-go
PCB	Printed circuit board
PERC	Procurement of Energy from Renewable Sources and its Compliance
PJ	Peta joule
PM	Person-month
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
PSO	Public Service Obligation
PTR	Peak Time Rebate
PU	Public
PV	Photovoltaics
R	Report
RAE	Regulatory Authority of Energy
R&D	Research and Development
RE-EMPOWERED	Renewable Energy EMPOWERing European & InDian Communities
RES	Renewable Energy Sources
ROI	Return on Investment
RPO	Renewable Purchase Obligation
RPS	Renewable Portfolio Standard
RTP	Real Time Pricing
SaaS	Software-as-a-Service
SAIDI	System Average Interruption Duration Index

Acronym	Description
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory control and data acquisition
SME	Small and medium-sized enterprise
SMS	Short Message Service
SOx	Sulphur oxides
SSEC	Smart Sustainable Energy Community
toe	Tonnes of oil equivalent
TOU	Time of Use Program
TSO	Transmission System Operator
UC	Use case
ud.	Unit
UI	User interface
V	Version
V	Volt
VAT	Value added tax
VTMG	Vehicle-to-Microgrid
W	Watt
WBGEDCL	West Bengal Green Energy Development Corporation Limited
WBREDA	West Bengal Renewable Energy Development Agency
WBSEDCL	West Bengal State Electricity Distribution Company Limited
Wh	Watt-hour
WTP	Willingness-to-pay
WP	Work Package

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 (INR or ₹).

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 €= 83 INR, or 1 INR = 1 ₹ = 0.012 €.

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

1. Introduction

1.1 Purpose and scope of the document

The Work Package 8 of the RE-EMPOWERED project deals with the development of new business models to be applied to the energy systems of the demo sites, including the renewable energy technologies which are installed in the sites, as well as the ecoToolset which the RE-EMPOWERED initiative is developing.

The final objective is to test the technical, economic, and financial viability of the technologies and ecoToolset, and evaluate if they can also be used in other situations (for replication objectives). To ensure that the proposed technologies and ecoToolset are accepted by the different stakeholders (citizens, public administration, private organizations), it is necessary to ensure that such technologies bring to them economic profitability, additional to having a positive environmental impact, or that they contribute to the national and international energy objectives.

The RE-EMPOWERED project involves pilot sites from a large variety of energy islands. The project is developed in the Northern part of Europe (Bornholm Island), in the Mediterranean Sea (Kythnos Island and Gaidouromantra Microgrid), as well as two different zones of India: Keonjhar, in the State of Odisha and Ghoramara, in the State of West Bengal. Bornholm island is connected to the grid, while Kythnos is a non-interconnected island, and Keonjhar and Ghoramara are isolated villages/islands in rural areas.

This report includes a description of each demo site, focusing specially on the regulatory and economic aspects. Using this information and stemming from a complete understanding of the current situation, a business model is proposed for the use of the ecoToolset and the different technologies in each demo site. Besides, the use of alternative financing mechanisms is evaluated, focusing specially on new models specially designed for renewable energy and energy efficiency projects.

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.

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 during its lifetime: revenues (or energy savings), and operation and maintenance costs.

Section 3 includes a short description of the demo sites in Europe: Bornholm Island in Denmark, and Kythnos Island and Gaidouromantra Microgrid in Greece, focusing on the used technologies. For each demo site, a description of the energy system in the island and the demo site is included. An evaluation about the access to energy and the cost of this energy is also included. Then, the regulatory framework is described, focusing specially on renewable energies and energy efficiency. Next, the use of the ecoToolset in each demo site is explained. Based on the technologies and the ecoToolset, a business canvas and a business model are proposed. Finally, the use of financing tools is suggested, adapted to each specific demo site.

Section 4 is focused on the Indian demo sites: Keonjhar and Gaidouromantra. The same content used for Section 3 in the European demo sites is applied to the Indian demo sites.

Finally, Section 5 includes a summary of the main conclusions of Deliverable 8.1.

It should be noted that the results from Work Package 8, included in Deliverable 8.1, are in some cases preliminary, as the ecoTools are still under development and the demo-site installations are still ongoing (or not started at some cases). These will be refined as the ecoToolset is more developed, its application in the demo sites is carried out and, in general, the RE-EMPOWERED project progresses.

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

One of the main objectives of the RE-EMPOWERED project is to develop a set of solutions, called "ecoToolset", specially designed to allow the use of renewable energies at a large scale. Some ecoTools are based on demand flexibility and digitalization. The ecoToolset will allow to take advantage of synergies among different energy vectors. The solutions of the toolset are specially tailored to the specific needs of four pilot cases in the EU and India. However, since it is made up of 10 different systems, it can be adapted to other projects and situations, by creating specific packages of ecoTools.

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. ecoEMS considers energy storage facilities and offers advanced on-line security functions, both in preventive and corrective mode. 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 isolated electricity systems.

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.

The leaders in the development of this tool have provided information to prepare an economic model to evaluate the profitability of using this tool, as well as for 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 €30,000, for each island.

It is expected that during the first year, 3 islands will purchase the ecoEMS tool. This number will remain constant along the time.

This involves that the expected income for the ecoTool developer will amount to €90,000 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 €1,000 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.

- 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.

	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 (€)- New licences		90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €
Incomes (€)-Existing licences			3,000 €	6,000 €	9,000 €	12,000 €	15,000 €	18,000 €	21,000 €	24,000 €	27,000 €
Installation costs (€)		- 15,000 €	- 15,000 €	- 15,000 €	- 15,000 €	- 15,000 €	- 15,000 €	- 15,000 €	- 15,000 €	- 15,000 €	- 15,000 €
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 (€)		43,750 €	46,750 €	49,750 €	52,750 €	55,750 €	58,750 €	61,750 €	64,750 €	67,750 €	70,750 €
Deferred corporate taxes (€)		- 9,625 €	- 10,285 €	- 10,945 €	- 11,605 €	- 12,265 €	- 12,925 €	- 13,585 €	- 14,245 €	- 14,905 €	- 15,565 €
Net cash flow (€)	- 605,000 €	64,375 €	66,715 €	69,055 €	71,395 €	73,735 €	76,075 €	78,415 €	80,755 €	83,095 €	85,435 €
Accumulated net cash flows (€)	- 605,000 €	- 540,625 €	- 473,910 €	- 404,855 €	- 333,460 €	- 259,725 €	- 183,650 €	- 105,235 €	- 24,480 €	58,615 €	144,050 €

	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 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Design and development of the ecoTool	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Installation costs (€) of the ecoTool	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Incomes (€)	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €	90,000 €
Installation costs (€)	-15,000 €	-15,000 €	-15,000 €	-15,000 €	-15,000 €	-15,000 €	-15,000 €	-15,000 €	-15,000 €	-15,000 €
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 (€)	73,750 €	76,750 €	79,750 €	82,750 €	85,750 €	88,750 €	91,750 €	94,750 €	97,750 €	100,750 €
Deferred corporate taxes (€)	-16,225 €	-16,885 €	-17,545 €	-18,205 €	-18,865 €	-19,525 €	-20,185 €	-20,845 €	-21,505 €	-22,165 €
Net cash flow (€)	87,775 €	90,115 €	92,455 €	94,795 €	97,135 €	99,475 €	101,815 €	104,155 €	106,495 €	108,835 €
Accumulated net cash flows (€)	231,825 €	321,940 €	414,395 €	509,190 €	606,325 €	705,800 €	807,615 €	911,770 €	1,018,265 €	1,127,100 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	72,713
IRR (%)	11.548%
First positive accumulated cash flow	58,615
Payback (years)	Year 9

Table 1. Economic model for the ecoEMS Tool, including the cash flow mode and a profitability analysis.

The economic model shown before for ecoEMS shows that the net present value of the project, discounted with a discount rate of 10%, is €72,713, along 20 years. On the other hand, the IRR is 11.548%.

The payback period is 9 years.

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 €30,000 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, 35% of the production would be curtailed because of local grid limitations, this is 1,012 MWh.

  The ecoEMS software can avoid 10% of these curtailments, leading to an extra electricity production around 100 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 €10,000 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 €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 €30,000, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €1,500/year.
- The corporate taxes will 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 (€)	- 30,000 €										
Incomes (€)		10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €
Maintenance costs (€)		- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Depreciation and amortization (€)		- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €
Profit before taxes (€)	- 30,000 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €
Deferred corporate taxes (€)		- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €
Net cash flow (€)	- 30,000 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €
Accumulated net cash flows (€)	- 30,000 €	- 22,650 €	- 15,300 €	- 7,950 €	- 600 €	6,750 €	14,100 €	21,450 €	28,800 €	36,150 €	43,500 €

	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 (€)	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €	10,000 €
Maintenance costs (€)	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €	- 1,000 €
Depreciation and amortization (€)	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €	- 1,500 €
Profit before taxes (€)	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €	7,500 €
Deferred corporate taxes (€)	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €	- 1,650 €
Net cash flow (€)	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €	7,350 €
Accumulated net cash flows (€)	50,850 €	58,200 €	65,550 €	72,900 €	80,250 €	87,600 €	94,950 €	102,300 €	109,650 €	117,000 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	32,574.69 €
IRR (%)	24.178%
First positive accumulated cash flow	6,750
Payback (years)	Year 5

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

The results from the economic model show that, for a final user of ecoEMS, the net present value of using this tool will amount to €32,574.69, along 20 years, and the IRR is 24.178%. The payback period will be around 5 years.

2.2 ecoMicrogrid

ecoMicrogrid is an 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 state of charge, and to forecast the short-level development. An optimization procedure will define the required actions like load shedding, diesel generator start-up/shutdown and renewable energy power curtailment, according to the desired optimization goals.

Based on preliminary estimation of economic information it was possible to define an economic model and to evaluate the economic feasibility of the development and commercialization of this ecoTool. The model includes the estimation of the revenues, the operation and maintenance costs.

This model has been prepared using the following information:

- 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, with a PM cost for ICCS-NTUA of €5,000/PM, the total design cost will amount to €180,000.

This cost includes the personnel cost of the software development of ecoMicrogrid, as well as the energy management module, the load and solar PV production forecast, the outage detection tools, dynamic pricing for the residents and communal load scheduling.

It also covers the software development for the communication with the microgrid assets, data acquisition and storage in a database, as well as the communication with the 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 will be an industrial personal computer, with a total cost of around €4,000.

  On the other hand, a dedicated software for the data acquisition, industrial communication protocols and data storage will be needed. The total cost of this software (including personal cost) will amount to €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 €1,200 per user, including the ecoMicrogrid hardware and software.

  Supposing that, during the first year, there are 15 new clients, the incomes will amount to €18,000. The number of clients is expected to increase by 10% yearly, reaching 98 clients in the 20th year, with expected incomes of €117,600.

- Incomes for the project developer (existing clients): The yearly update of the license for an existing client will cost €200 for each license. This cost will be paid by all the clients which have a license, and includes the yearly update of the system.

  During the second year, there will be 15 clients, so the incomes will amount to €3,000. However, in year 20, the accumulated number of clients will be 89, and the incomes from renewal licenses will amount to €162,600.

- Estimated operation and maintenance costs: ecoMicrogrid is a software which will run on a dedicated software on site. The operating costs will be the electricity consumption of the hardware (with a power of around 400 W), which are negligible (similar to the cost of a conventional PC).

  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 20-years period. This cost will amount to €4,000.

  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 €1,880,000, and a lifetime of 20 years, then the depreciation and amortization will amount to €9,400/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 (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Salaries of the professionals in charge of developing the ecoTool	- 180,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Hardware	- 4,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Software licences	- 4,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€) of new clients (installation cost)	- €	18,000 €	20,400 €	22,800 €	25,200 €	27,600 €	30,000 €	33,600 €	37,200 €	40,800 €	44,400 €
Incomes (€) of existing clients (licence for the system)	- €	- €	3,000 €	6,400 €	10,200 €	14,400 €	19,000 €	24,000 €	29,600 €	35,800 €	42,600 €
Operation and maintenance costs (€)	- €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €
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 €
Renewal of the hardware	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Depreciation and amortization (€)	- €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €
Profit before taxes (€)	- €	- 26,400 €	- 21,000 €	- 15,200 €	- 9,000 €	- 2,400 €	4,600 €	13,200 €	22,400 €	32,200 €	42,600 €
Deferred corporate taxes (€)	- €	5,808 €	4,620 €	3,344 €	1,980 €	528 €	- 1,012 €	- 2,904 €	- 4,928 €	- 7,084 €	- 9,372 €
Net cash flow (€)	- 188,000 €	- 11,192 €	- 6,980 €	- 2,456 €	2,380 €	7,528 €	12,988 €	19,696 €	26,872 €	34,516 €	42,628 €
Accumulated net cash flows (€)	- 188,000 €	-199,192 €	-206,172 €	-208,628 €	-206,248 €	-198,720 €	-185,732 €	-166,036 €	-139,164 €	- 104,648 €	- 62,020 €

	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	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Software licences	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€) of new clients (installation cost)	49,200 €	54,000 €	60,000 €	66,000 €	73,200 €	80,400 €	88,800 €	97,200 €	106,800 €	117,600 €
Incomes (€) of existing clients (licence for the system)	50,000 €	58,200 €	67,200 €	77,200 €	88,200 €	100,400 €	113,800 €	128,600 €	144,800 €	162,600 €
Operation and maintenance costs (€)	- 39,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €	- 35,000 €
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 €
Renewal of the hardware	- 4,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Depreciation and amortization (€)	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €	- 9,400 €
Profit before taxes (€)	50,800 €	67,800 €	82,800 €	98,800 €	117,000 €	136,400 €	158,200 €	181,400 €	207,200 €	235,800 €
Deferred corporate taxes (€)	- 11,176 €	- 14,916 €	- 18,216 €	- 21,736 €	- 25,740 €	- 30,008 €	- 34,804 €	- 39,908 €	- 45,584 €	- 51,876 €
Net cash flow (€)	49,024 €	62,284 €	73,984 €	86,464 €	100,660 €	115,792 €	132,796 €	150,892 €	171,016 €	193,324 €
Accumulated net cash flows (€)	- 12,996 €	49,288 €	123,272 €	209,736 €	310,396 €	426,188 €	558,984 €	709,876 €	880,892 €	1,074,216 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	102,194.56 €
IRR (%)	13.260%
First positive accumulated cash flow	49,288
Payback (years)	Year 12

Table 3. Economic model for the ecoMicrogrid Tool, including the cash flow mode and a profitability analysis.

The aforementioned economic model for the ecoMicrogrid tool has the following results: the net present value of the project amounts to €102,194.56, with a discount rate of 10%, along 20 years. The payback period is 12 years, and the internal rate of return is 13.260%.

2.3 ecoPlanning

ecoPlanning is a tool developed by the Electric Energy Systems Laboratories of the National Technical University of Athens (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.

Using the information provided by the ecoTool leader, an economic model to evaluate the economic feasibility of the ecoPlanning tool has been developed. This model considers the investment cost, the operation and maintenance costs, and the estimated revenues expected from the sale of ecoPlanning to the final clients.

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

- Investment cost: The total investment cost to develop the ecoPlanning consists of two parts:
  - Design of the tool through research and private contracts is expected to amount 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, 3 islands will purchase the ecoPlanning tool, the incomes for the tool developer will amount to €150,000. Since the number of potential clients is limited, it is supposed that the incomes will remain constant along the 20 years of lifetime, €150,000 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.

	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 (€)		150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €
Installation costs (€)		- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €	- 6,000 €
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 (€)		130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €
Deferred corporate taxes (€)		- 28,688 €	- 28,688 €	- 28,688 €	- 28,688 €	- 28,688 €	- 28,688 €	- 28,688 €	- 28,688 €	- 28,688 €	- 28,688 €
Net cash flow (€)	- 252,000 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €
Accumulated net cash flows (€)	- 252,000 €	- 137,688 €	- 23,376 €	90,936 €	205,248 €	319,560 €	433,872 €	548,184 €	662,496 €	776,808 €	891,120 €

	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 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Design and development of the ecoTo	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Installation costs (€) of the ecoTool	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Incomes (€)	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €	150,000 €
Installation costs (€)	-6,000 €	-6,000 €	-6,000 €	-6,000 €	-6,000 €	-6,000 €	-6,000 €	-6,000 €	-6,000 €	-6,000 €
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 (€)	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €	130,400 €
Deferred corporate taxes (€)	-28,688 €	-28,688 €	-28,688 €	-28,688 €	-28,688 €	-28,688 €	-28,688 €	-28,688 €	-28,688 €	-28,688 €
Net cash flow (€)	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €	114,312 €
Accumulated net cash flows (€)	1,005,432 €	1,119,744 €	1,234,056 €	1,348,368 €	1,462,680 €	1,576,992 €	1,691,304 €	1,805,616 €	1,919,928 €	2,034,240 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	721,202
IRR (%)	45.336%
First positive accumulated cash flow	90,936
Payback (years)	Year 3

Table 4. Economic model for the ecoPlanning Tool, including the cash flow mode 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 €721,202, along 20 years. On the other hand, the IRR is 45.34%.

The payback period is 3 years.

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.

An economic model, with the expected cash flows for the ecoDR ecoTool has been developed, in order to analyse if the project is economically profitable. The ecoDR leader has provided some information about investment costs, operation and maintenance costs, and expected incomes.

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

- 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 INR 24,000, equivalent to €289.16[1].
    - Development of the ecoDR ecoTool: During the development phase, it is expected that three iterations will be needed. The total development costs is expected to reach INR 300,000, equivalent to €3,614.46.

      This cost includes all the consumables, components, development boards, PCBs, etc.

  The total investment cost for ecoDR amounts to INR 324,000, this is, €3,903.61.

- Incomes for the project: These incomes will come from the sale of the developed ecoDR tool to new users. Since the commercialization plan has not been developed yet, in this model some assumptions are going to be used:
    - An installation price for the final clients of INR 10,000, this is, €120.48. This is referred to the labour cost.
    - For each client, it is necessary to purchase and install a smart meter, worth INR 6,000, or €72.29.
    - 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.

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[1] Note: In all the document, an exchange rate of 1 €= 83 INR will be used. It is an average exchange rate considering its evolution during the evolution of the exchange rate along the last year.

Thus, the expected income for the first year will be €2,409.64 (20 clients x €120.48), while in the year 20, the incomes will amount to €14,698.80 (122 clients x €120.48).

Besides, as the expected useful time of the smart meters is 10 years, the cost of the smart meter and its installation will be charged to the existing clients in the 11th year of use.

- 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 ecoToolset: The installation cost for each smart meter is around INR 6,000, this is, €72.29.

      Apart from the cost of the smart meter itself, the labour cost to install it amounts to INR 500, this is, €6.02.

      In year 1, with 20 clients, the total installation cost will amount to €1,566.
    - Operation and maintenance costs: They are considered to be negligible along the useful time of the ecoToolset.

      In this model, the hypothesis is that the expected useful lifetime of each smart meter will be around 10 years. Thus, in the year 10, the smart meters of the demo site will be replaced for new ones. The cost of this replacement will be INR 24,000 (€289.16).

      However, at the 10th year, it is expected that the smart meters will have to be replaced for new ones. For this reason, in year 10, the investment cost for the demo site is repeated. The cost will be INR 6,000 (€72.3) for each smart meter.

      Besides, since the 11th year, the smart meter of the first clients will have to be changed, at a price of INR 6,000 for each device and INR 500 (€6.02) for each existing smart meter.
- 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 €3,904, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €195/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 (€)	0	0	0	0	0	0	0	0	0	0	0
Smart meters (x 4 units)	-289 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Development of the ecoTool	-3,614 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Incomes (€)	0 €	2,410 €	2,651 €	2,892 €	3,133 €	3,494 €	3,855 €	4,217 €	4,699 €	5,181 €	5,663 €
Incomes from existing clients (€)											
Installation costs (€)	0 €	-1,566 €	-1,723 €	-1,880 €	-2,036 €	-2,271 €	-2,506 €	-2,741 €	-3,054 €	-3,367 €	-3,681 €
Smart meters		-1,446 €	-1,590 €	-1,735 €	-1,880 €	-2,096 €	-2,313 €	-2,530 €	-2,819 €	-3,108 €	-3,398 €
Labour costs		-120 €	-133 €	-145 €	-157 €	-175 €	-193 €	-211 €	-235 €	-259 €	-283 €
Operation and maintenance costs (€)	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	-289 €
Depreciation and amortization (€)	0 €	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €
Profit before taxes (€)	0 €	648 €	733 €	817 €	901 €	1,028 €	1,154 €	1,281 €	1,449 €	1,618 €	1,498 €
Deferred corporate taxes (€)	0 €	-143 €	-161 €	-180 €	-198 €	-226 €	-254 €	-282 €	-319 €	-356 €	-329 €
Net cash flow (€)	-3,904 €	701 €	767 €	832 €	898 €	997 €	1,095 €	1,194 €	1,326 €	1,457 €	1,363 €
Accumulated net cash flows (€)	-3,904 €	-3,203 €	-2,436 €	-1,604 €	-706 €	291 €	1,386 €	2,581 €	3,906 €	5,364 €	6,727 €

	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	0	0	0	0	0	0	0	0	0
Smart meters (x 4 units)	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Development of the ecoTool	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Incomes (€)	6,265 €	6,867 €	7,590 €	8,313 €	9,157 €	10,120 €	11,084 €	12,169 €	13,373 €	14,699 €
Incomes (€)	2,410 €	2,651 €	2,892 €	3,133 €	3,494 €	3,855 €	4,217 €	4,699 €	5,181 €	5,663 €
Installation costs (€)	-4,072 €	-4,464 €	-4,934 €	-5,404 €	-5,952 €	-6,578 €	-7,205 €	-7,910 €	-8,693 €	-9,554 €
Smart meters	-3,759 €	-4,120 €	-4,554 €	-4,988 €	-5,494 €	-6,072 €	-6,651 €	-7,301 €	-8,024 €	-8,819 €
Labour costs	-313 €	-343 €	-380 €	-416 €	-458 €	-506 €	-554 €	-608 €	-669 €	-735 €
Operation and maintenance costs (€)	-1,566 €	-1,723 €	-1,880 €	-2,036 €	-2,271 €	-2,506 €	-2,741 €	-3,054 €	-3,367 €	-3,681 €
Depreciation and amortization (€)	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €	-195 €
Profit before taxes (€)	431 €	486 €	582 €	678 €	739 €	841 €	943 €	1,010 €	1,118 €	1,269 €
Deferred corporate taxes (€)	-95 €	-107 €	-128 €	-149 €	-162 €	-185 €	-208 €	-222 €	-246 €	-279 €
Net cash flow (€)	532 €	574 €	649 €	724 €	771 €	851 €	931 €	983 €	1,067 €	1,185 €
Accumulated net cash flows (€)	7,258 €	7,832 €	8,481 €	9,206 €	9,977 €	10,828 €	11,759 €	12,742 €	13,809 €	14,994 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	4,047 €
IRR (%)	22.8%
First positive accumulated cash flow	291 €
Payback (years)	Year 5

Table 5. Economic model for the ecoDR ecoTool, including the cash flow mode and a profitability analysis.

According to the model provided before, the business model proposed for the ecoDR ecoTool: the net present value of the project (with a discount rate of 10%) amounts to €4,047.26 along 20 years, and the IRR is 22.8%.

On the other hand, the payback period is 5 years.

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.

Using information about the expected investment cost, operation and maintenance costs, and future revenues of the ecoPlatform, an economic model has been prepared:

- Investment cost: The following investment cost is expected for the ecoPlatform tool:

- Development of the ecoPlatform: €150,000, including the design of ecoPlatform, its installation in the Bornholm demo site, the SCADA and the engineering needed.
- 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 €160,000.

- Incomes for the project: First of all, the ecoPlatform will reduce the losses of the solar PV plant of Bornholm.
    - It has been estimated that the reduction in 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.
    - On the other hand, the financial model takes into account the commercialization of the ecoPlatform tool to new users. Since the commercialization plan has not been developed yet, so some assumptions are used in the model:
        - An installation price for the final clients of €500 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 €2,500 (5 clients x €500), and in the year 20, the income will amount to €18,500.
    - It has been supposed that each client will need to renew its license yearly, at a price of €50 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 €250, while in the year 20, it will be €15,400.
- 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 of updating the application: It is estimated that 0.1 professionals will be needed per year (around 1.2 months).

Considering a personnel cost of €6,000 per PM, then this cost will amount to €7,200 per year.

  - Cloud server as cloud database storage: It has been taken into account that a cloud server will be needed, with a cost of €75 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 €160,000, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €8,000/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 (€)	- 150,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Campaign to increase the citizen involvement	- 10,000 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
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 €
Incomes (€) of new clients (installation cost)	- €	2,500 €	3,000 €	3,500 €	4,000 €	4,500 €	5,000 €	5,500 €	6,000 €	6,500 €	7,000 €
Incomes (€) of existing clients (licence for the system)	- €	- €	250 €	550 €	900 €	1,300 €	1,750 €	2,250 €	2,800 €	3,400 €	4,050 €
Operation and maintenance costs (€)	- €	- 12,275 €	- 12,275 €	- 12,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €
Operation and maintenance and demo purchase of electricity	- €	- 5,000 €	- 5,000 €	- 5,000 €	- €	- €	- €	- €	- €	- €	- €
Professional cost of updating the application	- €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €
Cloud server as cloud database storage	- €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €
Depreciation and amortization (€)	- €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €
Profit before taxes (€)	- €	37,225 €	37,975 €	38,775 €	44,625 €	45,525 €	46,475 €	47,475 €	48,525 €	49,625 €	50,775 €
Deferred corporate taxes (€)	- €	- 8,190 €	- 8,355 €	- 8,531 €	- 9,818 €	- 10,016 €	- 10,225 €	- 10,445 €	- 10,676 €	- 10,918 €	- 11,171 €
Net cash flow (€)	- 160,000 €	37,036 €	37,621 €	38,245 €	42,808 €	43,510 €	44,251 €	45,031 €	45,850 €	46,708 €	47,605 €
Accumulated net cash flows (€)	- 160,000 €	- 122,965 €	- 85,344 €	- 47,100 €	- 4,292 €	39,218 €	83,468 €	128,499 €	174,348 €	221,056 €	268,660 €

	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 (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Campaign to increase the citizen involvement	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
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 €
Incomes (€) of new clients (installation cost)	7,500 €	8,500 €	9,500 €	10,500 €	11,500 €	12,500 €	14,000 €	15,500 €	17,000 €	18,500 €
Incomes (€) of existing clients (licence for the system)	4,750 €	5,500 €	6,350 €	7,300 €	8,350 €	9,500 €	10,750 €	12,150 €	13,700 €	15,400 €
Operation and maintenance costs (€)	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €	- 7,275 €
Operation and maintenance and demo purchase of electricity	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Professional cost of updating the application	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €	- 7,200 €
Cloud server as cloud database storage	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €	- 75 €
Depreciation and amortization (€)	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €	- 8,000 €
Profit before taxes (€)	51,975 €	53,725 €	55,575 €	57,525 €	59,575 €	61,725 €	64,475 €	67,375 €	70,425 €	73,625 €
Deferred corporate taxes (€)	- 11,435 €	- 11,820 €	- 12,227 €	- 12,656 €	- 13,107 €	- 13,580 €	- 14,185 €	- 14,823 €	- 15,494 €	- 16,198 €
Net cash flow (€)	48,541 €	49,906 €	51,349 €	52,870 €	54,469 €	56,146 €	58,291 €	60,553 €	62,932 €	65,428 €
Accumulated net cash flows (€)	317,201 €	367,106 €	418,455 €	471,324 €	525,793 €	581,938 €	640,229 €	700,781 €	763,713 €	829,140 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	226,792.35
IRR (%)	25.818%
First positive accumulated cash flow	39,218
Payback (years)	Year 5

Table 6. Economic model for the ecoPlatform Tool, including the cash flow mode and a profitability analysis.

The previously described model shows that the development of the ecoPlatform tool will lead to a net present value of €226,792.35, with an Internal Rate of Return of 25.82%, and a payback period of 5 years.

2.6 ecoMonitor

ecoMonitor is a tool to develop a portable digital control platform, with multiple sensors to monitor real-time different ambient air quality parameters, such as the concentration of CO, NOx, SOx, 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.

The tool is designed to be low-power, portable, and low-cost. 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.

According to the information provided by the ecoMonitor leader, an economic model including the expected investment cost, operation and maintenance costs, and the future revenues of the toolset has been prepared.

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:
    - Installation of 3 air quality monitoring systems at three demo sites (one in the demo site of Ghoramara, India, and the other two in Kythnos and Bornholm, in the European Union). The total investment cost for the three systems is estimated to be INR 180,000, equivalent to €2,168.67.
    - Installation of a solar powered water purification plant (commercially available) in the Ghoramara demo site. The investment cost of this plant will be around INR 150,000, this is, €1,807.23.
    - Development of the ecoMonitor ecoTool: During the development phase, it is expected that three iterations will be needed. The total development costs will reach INR 300,000, equivalent to €3,614.46.

      This cost includes all the consumables, components, development boards, PCBs, etc.

  The total investment cost for ecoMonitor amounts to INR 630,000, this is, €7,590.36.

- Incomes for the project: The financial model considers the commercialization of the developed ecoTool to new users. The commercialization plan has not been developed yet, so some assumptions are used in the model:
    - An installation price for the final clients of INR 7,000, this is, €84.34 will be used. This includes the equipment cost and the labour cost.

- It is expected that during the first year, 10 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 61 new clients.

  Thus, the expected income for the first year will be €843.37 (10 clients x €84.33), while in the year 20, the income will amount to €5,144.58 (61 clients x €84.33).

- 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 ecoMonitor tool: The installation cost for ecoMonitor is around INR 500 per unit, this is, €6.02/ud.

    In year 1, with 10 clients, the total installation cost will amount to €60, while in year 20, with 60 clients, the total installation cost will be €5,144.58.
  - Operation and maintenance costs: It is expected that a one-time replacement cost in the ecoMonitor tool will be needed each 10 years, with a cost of INR 60,000, this is, €722.89.
- 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 €7,590.36, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €198.80/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 (€)											
Air quality monitoring system	- 2,169 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Solar powered water purification plant in Ghoramara demo site	- 1,807 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Development of the ecoTool	- 3,614 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€)	- €	843 €	928 €	1,012 €	1,096 €	1,181 €	1,265 €	1,434 €	1,602 €	1,771 €	1,940 €
Operation and maintenance cost (INR)		- €	- €	- €	- €	- €	- €	- €	- €	- €	- 723 €
Installation costs (€)	- €	- 60 €	- 66 €	- 72 €	- 78 €	- 84 €	- 90 €	- 102 €	- 114 €	- 127 €	- 139 €
Depreciation and amortization (€)	- €	- 199 €	- 199 €	- 199 €	- 199 €	- 199 €	- 199 €	- 199 €	- 199 €	- 199 €	- 199 €
Profit before taxes (€)	- €	584 €	663 €	741 €	819 €	898 €	976 €	1,133 €	1,289 €	1,446 €	880 €
Deferred corporate taxes (€)	- €	- 129 €	- 146 €	- 163 €	- 180 €	- 197 €	- 215 €	- 249 €	- 284 €	- 318 €	- 193 €
Net cash flow (€)	- 7,590 €	655 €	716 €	777 €	838 €	899 €	960 €	1,082 €	1,204 €	1,327 €	885 €
Accumulated net cash flows (€)	- 7,590 €	- 6,936 €	- 6,220 €	- 5,443 €	- 4,606 €	- 3,707 €	- 2,747 €	- 1,664 €	- 460 €	866 €	1,751 €

	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 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Air quality monitoring system	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Solar powered water purification plant in Ghoramara demo site	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Development of the ecoTool	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Incomes (€)	2,108 €	2,361 €	2,614 €	2,867 €	3,120 €	3,458 €	3,795 €	4,217 €	4,639 €	5,145 €
Operation and maintenance cost (INR)	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €	0 €
Installation costs (€)	-151 €	-169 €	-187 €	-205 €	-223 €	-247 €	-271 €	-301 €	-331 €	-367 €
Depreciation and amortization (€)	-199 €	-199 €	-199 €	-199 €	-199 €	-199 €	-199 €	-199 €	-199 €	-199 €
Profit before taxes (€)	1,759 €	1,994 €	2,229 €	2,464 €	2,699 €	3,012 €	3,325 €	3,717 €	4,108 €	4,578 €
Deferred corporate taxes (€)	-387 €	-439 €	-490 €	-542 €	-594 €	-663 €	-732 €	-818 €	-904 €	-1,007 €
Net cash flow (€)	1,571 €	1,754 €	1,937 €	2,121 €	2,304 €	2,548 €	2,793 €	3,098 €	3,403 €	3,770 €
Accumulated net cash flows (€)	3,322 €	5,076 €	7,013 €	9,134 €	11,438 €	13,986 €	16,779 €	19,877 €	23,280 €	27,050 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	3,435
IRR (%)	14.282%
First positive accumulated cash flow	866
Payback (years)	Year 9

Table 7. Economic model for the ecoMonitor Tool, including the cash flow mode and a profitability analysis.

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 €3,435 along 20 years, and the IRR is 14.28%.

On the other hand, the payback period is 9 years.

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. 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. ecoCommunity contains advanced functionalities and is tailored to the special requirement of energy-disadvantaged communities.

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.

Based on the preliminary information about investment and operation and maintenance costs, and future revenues provided by the ecoCommunity leader, an economic model for the development and commercialization of the tool has been estimated, considering the sale of the ecoTool to the final clients.

First, an economic model for the ecoCommunity from the point of view of the ecoTool developer has been prepared, 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.
- 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. The standard cost of a cloud server depends on the storage and the computational requirements, but 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.

- 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.

	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 (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Salaries of the professionals in charge of developing the ecoTool	- 12,500 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
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 (€) 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 8. Economic model for the ecoCommunity Tool, including the cash flow mode and a profitability analysis.

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.

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. Considering 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.

	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 (%)	495.000%
First positive accumulated cash flow	3,950
Payback (years)	Year 1

Table 9. Economic model for the ecoCommunity Tool, including the cash flow mode and a profitability analysis, for the final client.

As it can be seen, the preliminary 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.

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 will optimize the design of solar PV facilities to minimize the aerodynamic wind loads through numerical simulations, wind tunnel testing, and field tests. In the case of wind turbines, cyclone resistive hybrid structures will be designed to withstand extreme weather conditions. Different turbine heights will be tested using numerical simulations and field tests. Small wind turbines will be manufactured locally, with the support of local technicians and community members using the available resources of the regions. This will also allow to carry out the maintenance locally, which will ensure a quick response, reduced downtime, and increased resilience.

To calculate an economic model for the ecoResilience tool, the expected investment cost, the operation and maintenance costs, and the future revenues expected from the sale of the ecoTool have been considered.

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

- Investment cost: The total investment cost to develop the ecoResilience ecoTool is expected to amount to INR 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 (INR)	Cost for a plant with ecoResilience (INR)	Note
Foundation (civil works, sand filling, reinforcement, and shuttering)	8,000	10,000	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	60,000	60,000	There are not differences
Material cost (galvanized to resist rusting)	22,000	32,000	A box structure is used rather than angles to withstand cyclonic loads.

Components	Cost for conventional plant (INR)	Cost for a plant with ecoResilience (INR)	Note
			Concave and convex structures are used at the ends.
Labour cost	5,000	10,000	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 INR 170,000

Table 10. 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 INR 170,000, this is, €2,048.19.

It is expected that during the first year, 10 clients will purchase the ecoResilience 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 61 new clients.

Thus, the expected income for the first year will be €20,481.93 (10 clients x €2,048.19), while in the year 20, the income will amount to €124,939.76. (61 clients x €2,048.19).

- Estimated operation and maintenance costs: The ecoResilience tool will not have, itself, any operation and maintenance costs.

  The installation cost of the ecoResilience tool to the final client will be around INR85,000 per unit, this is, €1,024.10.

  For the final client, the operation and maintenance cost of the solar PV plant will be doubled, due to the need to check the lubrication of movable parts of the ecoResilience tool.

- 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.

	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 €	20,481.93 €	22,530.12 €	24,578.31 €	26,626.51 €	28,674.70 €	30,722.89 €	34,819.28 €	38,915.66 €	43,012.05 €	47,108.43 €
Installation costs (€)	0.00 €	-10,240.96 €	-11,265.06 €	-12,289.16 €	-13,313.25 €	-14,337.35 €	-15,361.45 €	-17,409.64 €	-19,457.83 €	-21,506.02 €	-23,554.22 €
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 €	7,440.96 €	8,465.06 €	9,489.16 €	10,513.25 €	11,537.35 €	12,561.45 €	14,609.64 €	16,657.83 €	18,706.02 €	20,754.22 €
Deferred corporate taxes (€)	0.00 €	-1,637.01 €	-1,862.31 €	-2,087.61 €	-2,312.92 €	-2,538.22 €	-2,763.52 €	-3,214.12 €	-3,664.72 €	-4,115.33 €	-4,565.93 €
Net cash flow (€)	-56,000.00 €	8,603.95 €	9,402.75 €	10,201.54 €	11,000.34 €	11,799.13 €	12,597.93 €	14,195.52 €	15,793.11 €	17,390.70 €	18,988.29 €
Accumulated net cash flows (€)	-56,000.00 €	-47,396.05 €	-37,993.30 €	-27,791.76 €	-16,791.42 €	-4,992.29 €	7,605.64 €	21,801.16 €	37,594.27 €	54,984.96 €	73,973.25 €

	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 (€)	51,204.82 €	57,349.40 €	63,493.98 €	69,638.55 €	75,783.13 €	83,975.90 €	92,168.67 €	102,409.64 €	112,650.60 €	124,939.76 €
Installation costs (€)	-25,602.41 €	-28,674.70 €	-31,746.99 €	-34,819.28 €	-37,891.57 €	-41,987.95 €	-46,084.34 €	-51,204.82 €	-56,325.30 €	-62,469.88 €
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 (€)	22,802.41 €	25,874.70 €	28,946.99 €	32,019.28 €	35,091.57 €	39,187.95 €	43,284.34 €	48,404.82 €	53,525.30 €	59,669.88 €
Deferred corporate taxes (€)	-5,016.53 €	-5,692.43 €	-6,368.34 €	-7,044.24 €	-7,720.14 €	-8,621.35 €	-9,522.55 €	-10,649.06 €	-11,775.57 €	-13,127.37 €
Net cash flow (€)	20,585.88 €	22,982.27 €	25,378.65 €	27,775.04 €	30,171.42 €	33,366.60 €	36,561.78 €	40,555.76 €	44,549.73 €	49,342.51 €
Accumulated net cash flows (€)	94,559.13 €	117,541.40 €	142,920.05 €	170,695.08 €	200,866.51 €	234,233.11 €	270,794.89 €	311,350.65 €	355,900.39 €	405,242.89 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	405,242.89 €
IRR (%)	20.986%
First positive accumulated cash flow	7,606
Payback (years)	Year 6

Table 11. Economic model for the ecoResilience Tool, including the cash flow mode and a profitability analysis.

According to the model provided before, the business model proposed for the ecoResilience eco tool: the net present value of the project (with a discount rate of 10%) amounts to €405,242.89 along 20 years, and the IRR is 20.99%.

On the other hand, the payback period is 6 years.

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 20-kW solar PV plant with the tool, and without it. From Table 10, it is obtained that the extra cost of ecoResilience is INR 170,000, this is, €2,048.19.
- 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 it, 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 60% of the investment cost. From Table 10, the total investment cost of the plant is INR 950,000, so the damage would be INR 570,000 (€6,867.47). 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 INR 10,000, for a 20-kW solar PV plant (€120.48) 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 €2,048.19, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €102.41/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 (€)	- 2,048 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Additional foundation costs	- 241 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Additional solar panel costs	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Additional material costs	- 1,205 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Additional labour costs	- 602 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	6,867 €
Maintenance costs (€)	- €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €
Depreciation and amortization (€)	- €	- 102.41 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €
Profit before taxes (€)	- €	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	6,645 €
Deferred corporate taxes (€)	- €	49 €	49 €	49 €	49 €	49 €	49 €	49 €	49 €	49 €	- 1,462 €
Net cash flow (€)	- 2,048 €	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	5,285 €
Accumulated net cash flows (€)	- 2,048 €	- 2,120 €	- 2,191 €	- 2,263 €	- 2,334 €	- 2,405 €	- 2,477 €	- 2,548 €	- 2,620 €	- 2,691 €	2,594 €

	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 (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	6,867 €
Maintenance costs (€)	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €	- 120 €
Depreciation and amortization (€)	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €	- 102 €
Profit before taxes (€)	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	- 223 €	6,645 €
Deferred corporate taxes (€)	49 €	49 €	49 €	49 €	49 €	49 €	49 €	49 €	49 €	- 1,462 €
Net cash flow (€)	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	- 71 €	5,285 €
Accumulated net cash flows (€)	2,523 €	2,451 €	2,380 €	2,308 €	2,237 €	2,165 €	2,094 €	2,022 €	1,951 €	7,236 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	204.99 €
IRR (%)	10.742%
First positive accumulated cash flow	2,594
Payback (years)	Year 10

Table 12. Economic model for the ecoResilience Tool, including the cash flow mode 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 €204.99, along 20 years, and the IRR is 10.742%. The payback period will be around 10 years.

2.9 ecoConverter

ecoConverter is the tool related to the development of power electronic converters and their control, for DC/AC 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. 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. The converter will be modular, plug-and-play, reliable and compact with functions like built-in communication, protection, remote control, and display options.

The following information has been used to prepare an economic model for ecoConverter:

- Investment cost: The ecoTool leader, VNIT, is developing two different converters:
    - 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 will amount to INR 200,000, equivalent to €2,409.64.
    - Development of a power electronic converter interface to integrate a wind turbine of 5 kW. The total cost for developing this tool will be approximately INR 150,000, this is, €1,807.23.

  The total investment cost for ecoConverter amounts to INR 350,000, this is, €4,217.87.

- Incomes for the project: The financial model considers the commercialization of the developed ecoTool to new users. The commercialization plan has not been developed yet, so some assumptions are used in the model:
    - An installation price for the final clients of INR 500, this is, €6.02 will be used. 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 €602.41 (10 clients x €6.02), while in the year 20, the income will amount to €3,710.84 (616 clients x €6.02).

- 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, INR 35,000, or €421.67/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 €4,216.87, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €210.84/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 (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Development of 10 kW high power DC-DC converter to integrate batteries of 100 kWh	- 2,410 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Development of power electronic converter interface to integrate wind turbine of 5 kW	- 1,807 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (€)	- €	602 €	663 €	729 €	801 €	880 €	970 €	1,066 €	1,175 €	1,295 €	1,428 €
Operation and maintenance costs (€)	- €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €
Depreciation and amortization (€)	- €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €
Profit before taxes (€)	- €	- 30 €	30 €	96 €	169 €	247 €	337 €	434 €	542 €	663 €	795 €
Deferred corporate taxes (€)	- €	7 €	- 7 €	- 21 €	- 37 €	- 54 €	- 74 €	- 95 €	- 119 €	- 146 €	- 175 €
Net cash flow (€)	- 4,216.87 €	187 €	234 €	286 €	342 €	403 €	474 €	549 €	634 €	728 €	831 €
Accumulated net cash flows (€)	- 4,217 €	- 4,030 €	- 3,795 €	- 3,509 €	- 3,167 €	- 2,763 €	- 2,289 €	- 1,740 €	- 1,106 €	- 379 €	452 €

	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 (€)	1,572 €	1,729 €	1,904 €	2,096 €	2,307 €	2,536 €	2,789 €	3,066 €	3,373 €	3,711 €
Operation and maintenance costs (€)	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €	- 422 €
Depreciation and amortization (€)	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €	- 211 €
Profit before taxes (€)	940 €	1,096 €	1,271 €	1,464 €	1,675 €	1,904 €	2,157 €	2,434 €	2,741 €	3,078 €
Deferred corporate taxes (€)	- 207 €	- 241 €	- 280 €	- 322 €	- 368 €	- 419 €	- 474 €	- 535 €	- 603 €	- 677 €
Net cash flow (€)	944 €	1,066 €	1,202 €	1,353 €	1,517 €	1,696 €	1,893 €	2,109 €	2,349 €	2,612 €
Accumulated net cash flows (€)	1,396 €	2,462 €	3,665 €	5,017 €	6,534 €	8,230 €	10,123 €	12,232 €	14,581 €	17,193 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	1,953.77 €
IRR (%)	13.814%
First positive accumulated cash flow	452
Payback (years)	Year 10

Table 13. Economic model for the ecoConverter Tool, including the cash flow mode and a profitability analysis.

From the analysis described before, it is possible to obtain a net present value for the ecoConverter tool of €1,953.77 (with a discount rate of 10%), and an IRR of 13.814%.

The payback period is 10 years.

2.10 ecoVehicle

ecoVehicle is the tool related to the development and deployment of power electronics and drive systems for electric wheelers and boats. ecoVehicle tool will be only developed in two demo sites: Ghoramara and Keonjhar, which are the two Indian demo sites.

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.

The electric system of the electric boat will include three subsystems: supply system, traction system and control & monitoring system. The charging stations will receive the energy from solar PV facilities in a microgrid. 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.

In order to prepare an economic model for the ecoVehicle tool, preliminary information about ecoVehicle were collected. Using this information, three economic models including the expected investment cost, operation and maintenance costs, and the future revenues of the ecoVehicle have been prepared. The first model is designed for the Keonjhar demo site, the second one for the Ghoramara island, and the third one, is a combination of both.

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 INR 200,000, which is equivalent to €2,409.64.
  - Modification of the seating of the electric rickshaws and installation of the ecoVehicle tool set. INR 40,000, equivalent to €481.93.
  - Installation of one charging point for the electric rickshaws. INR 70,000. (€843.37)
  - Another charging point has already developed by VNIT, with a power of 1.5 kW, and a cost of INR 35,000 (€421.69).

  The total investment cost for ecoVehicle in Keonjhar amounts to INR 545,000, this is, €6,566.27.
- Incomes from the project: The business model for ecoVehicle involves the leasing of electric rickshaws by local users, for 1-day periods.

The leasing of an electric rickshaw will have a cost, per day, of INR 800 (9.64). However, from this amount, INR 400 (€4.82) will be the retribution for the electric rickshaw operator, while the other INR 400, will be the retribution for the RE-EMPOWERED project.

Assuming that each electric rickshaw is used 300 days per year, then the income from the project will amount to INR 240,000 (€2,891.57), considering that there are two electric rickshaws.

- 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 INR 100.

      Supposing that the electric rickshaws are used 300 days per year, then the total operation cost for these vehicles will amount to INR 30,000, this is, €361.45.
    - Maintenance cost for the battery of the electric rickshaws: The batteries have to be replaced each 4-5 years, with a total cost of INR 70,000 for each electric rickshaw.

      This involves that, each 5 years, the cost of replacing the batteries in Keonjhar will amount to €1,686.75.
    - 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 INR 10,000, this is, €120.48. Since there are two electric rickshaws, then, in the year 10, there will be an expenditure of INR 20,000 (€240.96) 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 €6,566.27, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to €328.31/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 (€)	- 6,566 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric rickshaw (2 units)	- 4,819 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Modification of seating of electric rickshaw and installation of the ecoTool set (2 units)	- 482 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
One charger for electric vehicle	- 843 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Developed charger of 1.5 kW	- 422 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes - Electric rickshaw (€)	- €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €
Operation and maintenance costs - Electric rickshaw electricity (€)	- €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €
Operation and maintenance costs- Rickshaw battery replacement (€)	- €	- €	- €	- €	- €	- 1,687 €	- €	- €	- €	- €	- 1,687 €
Operation and maintenance costs- Rikshaw motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- 241 €
Depreciation and amortization (€)	- €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €
Profit before taxes (€)	- 6,566 €	2,202 €	2,202 €	2,202 €	2,202 €	515 €	2,202 €	2,202 €	2,202 €	2,202 €	274 €
Deferred corporate taxes (€)	- €	- 484 €	- 484 €	- 484 €	- 484 €	- 113 €	- 484 €	- 484 €	- 484 €	- 484 €	- 60 €
Net cash flow (€)	- 6,566 €	2,046 €	2,046 €	2,046 €	2,046 €	730 €	2,046 €	2,046 €	2,046 €	2,046 €	542 €
Accumulated net cash flows (€)	- 6,566 €	- 4,521 €	- 2,475 €	- 429 €	1,617 €	2,347 €	4,392 €	6,438 €	8,484 €	10,530 €	11,072 €

	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 (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Operation and maintenance costs - Electric rickshaw electricity (€)	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €
Operation and maintenance costs- Rickshaw battery replacement (€)	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €
Operation and maintenance costs- Rikshaw motor controller replacement (€)	- €	- €	- €	- €	- 1,687 €	- €	- €	- €	- €	- 1,687 €
Depreciation and amortization (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Profit before taxes (€)	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €	- 328 €
Deferred corporate taxes (€)	2,202 €	2,202 €	2,202 €	2,202 €	515 €	2,202 €	2,202 €	2,202 €	2,202 €	515 €
Net cash flow (€)	- 484 €	- 484 €	- 484 €	- 484 €	- 113 €	- 484 €	- 484 €	- 484 €	- 484 €	- 113 €
Accumulated net cash flows (€)	2,046 €	2,046 €	2,046 €	2,046 €	730 €	2,046 €	2,046 €	2,046 €	2,046 €	730 €
Accumulated net cash flows (€)	13,117 €	15,163 €	17,209 €	19,255 €	19,985 €	22,030 €	24,076 €	26,122 €	28,168 €	28,898 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	8,942.97 €
IRR (%)	28.626%
First positive accumulated cash flow	1,617
Payback (years)	Year 4

Table 14. Economic model for the ecoVehicle Tool in the Keonjhar demo site, including the cash flow mode 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 €8,942.97, along 20 years, while the IRR will be 28.626%.

Additionally, the payback period is 4 years.

Once the financial model for ecoVehicle in Keonjhar has been defined, it is possible to define it 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: INR 400,000, this is, €4,819.28.
  - Modification of the seating of the electric rickshaws and installation of the ecoVehicle tool set. INR 40,000, equivalent to €481.93.
  - Purchase of electric boat: INR 4,000,000, this is, €48,193.
  - 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 INR 140,000, this is, €1,686.75.
  - Installation of three charging points for the electric rickshaws and electric boat. INR 200,000. (€2,409.64).
  - Another charging point has already developed by VNIT, with a power of 1.5 kW, and a cost of INR 35,000 (€421.69).

  The total investment cost for ecoVehicle in Ghoramara amounts to INR 4,815,000, this is, €58,012.05.

- 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 that the use of electric rickshaws will be the same as described in the demo site of Keonjhar, the total incomes from the project will amount to INR 240,000 (€2,891.57), for two electric rickshaws.

  In the case of the electric boat, it will be leased by a company which will use it to offer two round trips per day to Sagar Island. The boat operator, this is, the company which will offer this service, is expected to earn INR 1,200 per day. Out of this, INR 700 per day will be paid to RE-EMPOWERED, as payment for the use of the electric boat.

  Supposing that the electric boat is used all days of the year, then the total incomes for RE-EMPOWERED will amount to INR 255,500, this is, €3,078.31.

  Thus, the total incomes from the project for the demo site of Ghoramara will be INR 495,000 per year, or €5,969.88.

- 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 INR 30,000, this, is €361.45 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 INR 70,000 for each electric rickshaw, this is, a total of €1,686.75.

   - 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 INR 20,000 (€240.96), 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 INR 120,000, this is, €1,445.78.
   - 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 INR 50,000, this is, €602.41
   - Operation and maintenance cost of the solar PV plant: This cost will be of INR 41,667 (INR 125,000 for the first 3 years), this is, €502.01 per year.

- Similarly to other financial and economic models, the depreciation and amortization cost is linear.

  Since the total investment cost is €58,012.05, and a lifetime of 20 years is considered, then the depreciation and amortization will amount to 2,900.60€/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 (€)	- 58,012.05 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric rickshaw (2 units)	- 4,819 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Modification of seating of electric rickshaw and installation of the ecoTool set (2 units)	- 481.93 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric boat	- 48,193 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Solar PV plant (12 kWp), battery storage (72 kWh), inverter (12.5 kVA)	- 1,687 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Three chargers for electric vehicle	- 2,409.64 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Developed charger of 1.5 kW	- 422 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes- Electric boat (€)	- €	3,078.31 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €
Incomes-Electric rickshaw (€)	- €	2,891.57 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €
Operation and maintenance costs - Electric rickshaw (€)	- €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €
Operation and maintenance costs- Boat battery replacement (€)	- €	- €	- €	- €	- €	- 1,446 €	- €	- €	- €	- €	- 1,446 €
Operation and maintenance costs- Boat motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- 602.41 €
Operation and maintenance costs- Rickshaw battery replacement (€)	- €	- €	- €	- €	- €	- 1,687 €	- €	- €	- €	- €	- 1,687 €
Operation and maintenance costs- Rickshaw motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- 241 €
Operation and maintenance solar PV plant	- €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €
Depreciation and amortization (€)	- €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €
Profit before taxes (€)	- €	2,206 €	2,206 €	2,206 €	2,206 €	- 927 €	2,206 €	2,206 €	2,206 €	2,206 €	- 1,770 €
Deferred corporate taxes (€)	- €	- 485 €	- 485 €	- 485 €	- 485 €	204 €	- 485 €	- 485 €	- 485 €	- 485 €	389 €
Net cash flow (€)	- 58,012 €	4,621 €	4,621 €	4,621 €	4,621 €	2,178 €	4,621 €	4,621 €	4,621 €	4,621 €	1,520 €
Accumulated net cash flows (€)	- 58,012 €	- 53,391 €	- 48,770 €	- 44,149 €	- 39,527 €	- 37,350 €	- 32,729 €	- 28,107 €	- 23,486 €	- 18,865 €	- 17,345 €

	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- Electric boat (€)	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €
Incomes-Electric rickshaw (€)	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €	2,892 €
Operation and maintenance costs - Electric rickshaw (€)	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €	- 361 €
Operation and maintenance costs- Boat battery replacement (€)	- €	- €	- €	- €	- 1,446 €	- €	- €	- €	- €	- 1,446 €
Operation and maintenance costs- Boat motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Operation and maintenance costs- Rickshaw battery replacement (€)	- €	- €	- €	- €	- 1,687 €	- €	- €	- €	- €	- 1,687 €
Operation and maintenance costs- Rickshaw motor controller replacement (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Operation and maintenance solar PV plant	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €
Depreciation and amortization (€)	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €	- 2,901 €
Profit before taxes (€)	2,206 €	2,206 €	2,206 €	2,206 €	- 927 €	2,206 €	2,206 €	2,206 €	2,206 €	- 927 €
Deferred corporate taxes (€)	- 485 €	- 485 €	- 485 €	- 485 €	204 €	- 485 €	- 485 €	- 485 €	- 485 €	204 €
Net cash flow (€)	4,621 €	4,621 €	4,621 €	4,621 €	2,178 €	4,621 €	4,621 €	4,621 €	4,621 €	2,178 €
Accumulated net cash flows (€)	- 12,724 €	- 8,103 €	- 3,482 €	1,139 €	3,317 €	7,938 €	12,559 €	17,181 €	21,802 €	23,980 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	-22,330.55 €
IRR (%)	3.641%
First positive accumulated cash flow	1,139
Payback (years)	Year 14

Table 15. Economic model for the ecoVehicle Tool in the Ghoramara demo site, including the cash flow mode and a profitability analysis.

The economic model of Ghoramara is not profitable, as the model for Keonjhar is, since it has a net present value (with a discount rate of 10%) of €-22,330.55, along 20 years. On the other hand, the IRR is 3.641%, and the payback period 14 years.

The combined economic model for Ghoramara and Keonjhar has been calculated (considering the incomes, investment and operation and maintenance costs of both pilot sites), to evaluate if the profitability of the Keonjhar demo site can outbalance the lack of profitability of the Ghoramara demo site.

This combined economic model is shown in the following table:

	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 (€)	- 64,578 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric rickshaw (2 units)	- 9,639 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Modification of seating of electric rickshaw and installation of the ecoTool set (2 units)	- 964 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Electric boat	- 48,193 €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Chargers for electric vehicles											
Incomes (INR)- Electric boat	- €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €
Incomes (INR)- Electric rickshaw	- €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €
Operation and maintenance costs (INR)- Electric rickshaw	- €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €
Operation and maintenance costs- Boat battery replacement (INR)		- €	- €	- €	- €	- 1,446 €	- €	- €	- €	- €	- 1,446 €
Operation and maintenance costs- Boat motor controller replacement (INR)		- €	- €	- €	- €	- €	- €	- €	- €	- €	- 602 €
Operation and maintenance costs- Rickshaw battery replacement (INR)	- €	- €	- €	- €	- €	- 3,373 €	- €	- €	- €	- €	- 3,373 €
Operation and maintenance costs- Rikshaw motor controller replacement (INR)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- 482 €
Operation and maintenance solar PV plant	- €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €
Depreciation and amortization (€)	- €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €
Profit before taxes (€)	- 64,578 €	4,408 €	4,408 €	4,408 €	4,408 €	- 412 €	4,408 €	4,408 €	4,408 €	4,408 €	- 1,496 €
Deferred corporate taxes (€)	- €	- 970 €	- 970 €	- 970 €	- 970 €	91 €	- 970 €	- 970 €	- 970 €	- 970 €	329 €
Net cash flow (€)	- 64,578 €	6,667 €	6,667 €	6,667 €	6,667 €	2,908 €	6,667 €	6,667 €	6,667 €	6,667 €	2,062 €
Accumulated net cash flows (€)	- 64,578 €	- 57,911 €	- 51,245 €	- 44,578 €	- 37,911 €	- 35,003 €	- 28,336 €	- 21,669 €	- 15,002 €	- 8,336 €	- 6,273 €

	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	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Incomes (INR)- Electric boat	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €	3,078 €
Incomes (INR)- Electric rickshaw	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €	5,783 €
Operation and maintenance costs (INR)- Electric rickshaw	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €	- 723 €
Operation and maintenance costs- Boat battery replacement (INR)	- €	- €	- €	- €	- 1,446 €	- €	- €	- €	- €	- 1,446 €
Operation and maintenance costs- Boat motor controller replacement (INR)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Operation and maintenance costs- Rickshaw battery replacement (INR)	- €	- €	- €	- €	- 3,373 €	- €	- €	- €	- €	- 3,373 €
Operation and maintenance costs- Rikshaw motor controller replacement (INR)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
Operation and maintenance solar PV plant	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €	- 502 €
Depreciation and amortization (€)	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €	- 3,229 €
Profit before taxes (€)	4,408 €	4,408 €	4,408 €	4,408 €	- 412 €	4,408 €	4,408 €	4,408 €	4,408 €	- 412 €
Deferred corporate taxes (€)	- 970 €	- 970 €	- 970 €	- 970 €	91 €	- 970 €	- 970 €	- 970 €	- 970 €	91 €
Net cash flow (€)	6,667 €	6,667 €	6,667 €	6,667 €	2,908 €	6,667 €	6,667 €	6,667 €	6,667 €	2,908 €
Accumulated net cash flows (€)	393 €	7,060 €	13,727 €	20,394 €	23,302 €	29,969 €	36,636 €	43,302 €	49,969 €	52,877 €

Corporate taxes	22%

Discount rate (%)	10%

NPV	-13,387.58 €
IRR (%)	6.731%
First positive accumulated cash flow	393
Payback (years)	Year 11

Table 16. Economic model for the ecoVehicle Tool in the Ghoramara and Keonjhar demo sites, including the cash flow mode and a profitability analysis.

The combined economic model has a net present value of €-13,387.58 (with a discount rate of 10%), during a lifetime of 10 years, and an IRR of 6.731%.

2.11 Deployment of ecoTools at the demo sites

The following figure includes an overview of the deployment of the ecoTools at each demo site.

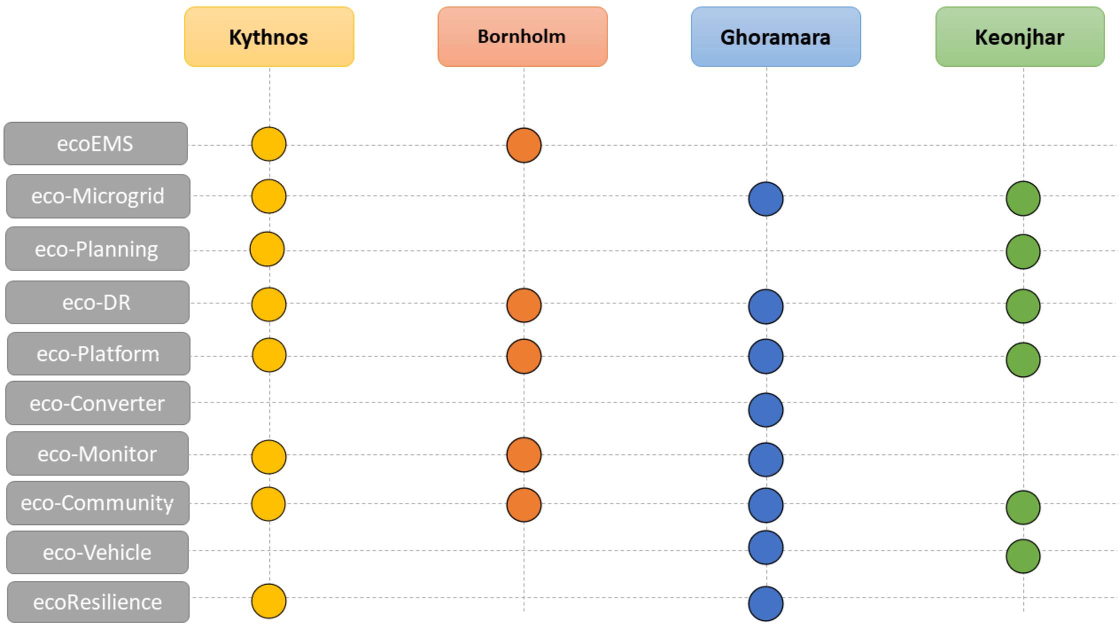

Figure 1. Assignment of ecoTools to be demonstrated at each of the four demo sites in RE-EMPOWERED

3. Energy system and Business models applied in EU

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.

Figure 2. Bornholm Island. Source: Google Maps

The geology of the island is mostly granitic, except for the southern coast. The northern part of the island is made of granite formations, sloping down with pine and deciduous forests, while in the middle part of the island there are farms, and in the south, sandy beaches.

Bornholm has a total population of 39,545 inhabitants in 2022[2], and a surface of 588.36 km^2. 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.

To compare with these data, the total population of Denmark is 5.840 million people[3] in 2021.

The whole population can read and write, and 88.24% of the population lived in urban zones in 2021[4]. On the other hand, 96.55% of the population had access to the Internet in 2020[4]. These data are for all the country. In Bornholm, and the demo site of Østerlars, Østermarie and Gudhjem, the percentage of population which live in urban zones is, presumably, lower.

The electricity access rate is 100%. As for the level of wealth of the population, in 2020, the average disposable income in the Bornholm Island reached DKK 218,783 (€29,338.80[5]), while

[2] Source: Statistics Denmark
[3] Source: World Economic Outlook: October 2022. International Monetary Fund.
[4] Source: The World Bank Data.
[5] Average Exchange rate for 2020: 1 DKK= 0.1341 €.

for the whole country of Denmark, the average income was DKK 254,455 (€34,122.42). This means that the income in Bornholm was around 86% of the average income in the country.

It can be also mentioned that Bornholm has the fifth lower average income per family in Denmark, with DKK 483,994[2] (€64,903.60) in 2021, while the average income for all Denmark was DKK 589,233 (€79,016.15), this is, the figure of Bornholm is 82% of the average for the whole country.

Differences between men and women in Bornholm are as follows: the average disposable income for men reached DKK 234,671[2] (€31,469.38) in 2020, while for women, it was DKK 203,425[2] (€27,279.29) (around 86.7% of the men incomes). It is interesting to compare this with the whole Denmark: the average income for men was DKK 280,053[2] (€37,5551.11), and for women, DKK 229,507[2] (€30,776.89) (around 81.95%).

The following table includes the breakdown of employees in Bornholm, according to the economic sector[2:]

	Men	Women	Total
A Agriculture, forestry and fishing	714	116	**830**
B Mining and quarrying	16	1	**17**
CA Manufacture of food products, beverages, and tobacco	410	235	**645**
CB Textiles and leather products	1	11	**12**
CC Wood and paper products and printing	66	13	**79**
CD Oil refinery etc.	-	-	**-**
CE Manufacture of chemicals	1	2	**3**
CF Pharmaceuticals	-	-	**-**
CG Manufacture of plastic, glass, and concrete	188	73	**261**
CH Basic metals and fabricated metal products	70	13	**83**
CI Manufacture of electronic components	-	-	**-**
CJ Electrical equipment	1	-	**1**
CK Manufacture of machinery	323	44	**367**
CL Transport equipment	26	4	**30**
CM Manufacture of furniture and other manufacturing	71	23	**94**
D Electricity, gas, steam, and air conditioning supply	14	5	**19**
E Water supply, sewerage, and waste management	106	16	**122**
F Construction	1,016	80	**1,096**
G Wholesale and retail trade	1,205	1,024	**2,229**
H Transportation	537	145	**682**
I Accommodation and food service activities	439	519	**958**
JA Publishing, television, and radio broadcasting	229	140	**369**
JB Telecommunications	23	1	**24**

	Men	Women	Total
JC IT and information service activities	57	10	**67**
K Financial and insurance	79	76	**155**
L Real estate activities	174	132	**306**
MA Consultancy etc.	256	152	**408**
MB Scientific research and development	7	10	**17**
MC Advertising and other business services	64	73	**137**
N Travel agent, cleaning, and other operational services	421	308	**729**
O Public administration, defence, and compulsory social security	753	548	**1,301**
P Education	408	685	**1,093**
QA Human health activities	258	1,265	**1,523**
QB Residential care	390	1,870	**2,260**
R Arts, entertainment, and recreation activities	164	150	**314**
S Other service activities etc.	184	239	**423**
X Activity not stated	2	10	**12**
Total	**8,673**	**7,993**	**16,666**

Table 17. Number of employees in the region of Bornholm (data from November 2020).

As it can be seen in the table before, the most important economic sectors regarding the number of employees, are Residential care (14%) and Wholesale and retail trade (13%).

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

The Danish Island of Bornholm has been interested in energy transition since long time ago. The island has adopted the green agenda for over 30 years, with the objective of becoming a CO_2 neutral island in 2025, and a zero-emissions and climate-friendly community by 2035. The island has received the 1st Prize of RESponsible Island[6].

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.

[6] Source: Bornholms Varme A/S.

Local electricity production is based on biomass, wind, and solar PV. In 2019, the local generation covered around 70% of the whole electricity consumption[6].

The power generation mix consists of the following power plants[6]:

- 37 MW of wind energy, from 35 wind turbines, both public and private.
- 23 MW of solar PV:
  - 8 MW from approximately 1,000 rooftop solar PV plants.
  - 15 MW from two private solar PV plants.
- 3 MW of biogas plant.
- 58 MW of fossil fuel plants.
- 60 MW can be exported or imported through the submarine cable.

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 diagram shows the 60-kV net diagram in the Bornholm Island:

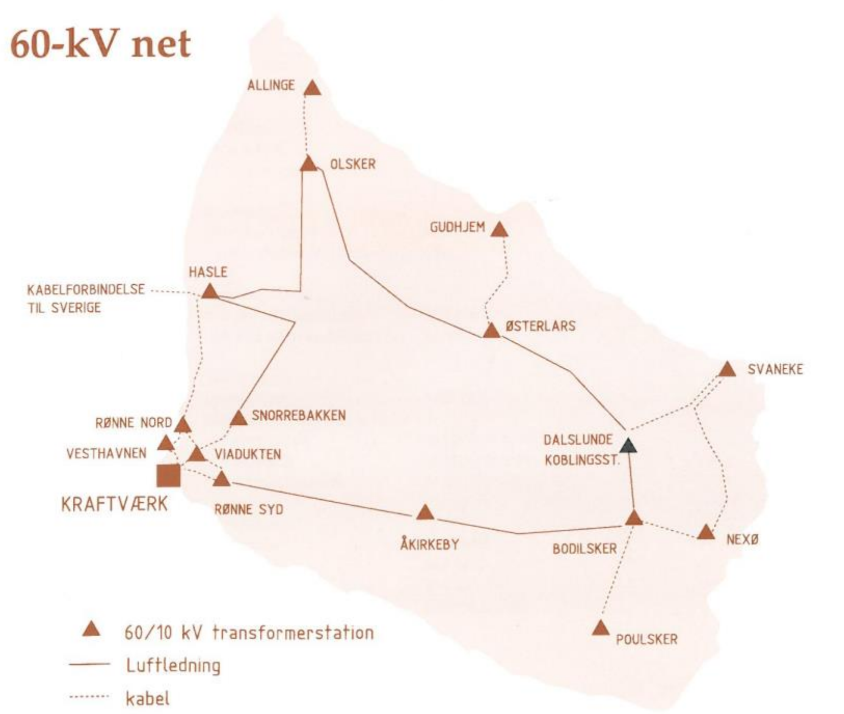

Figure 3. Bornholm Island 60-kV net diagram[6]

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.

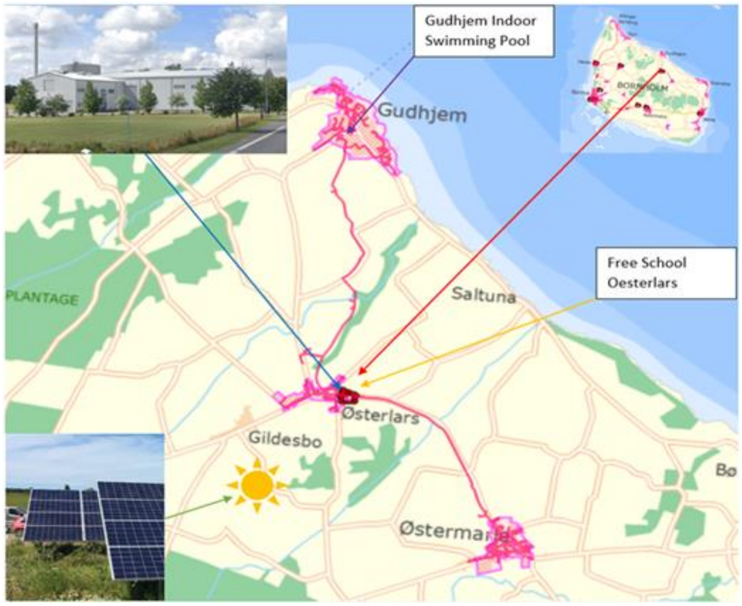

Figure 4. Bornholm Island demo site diagram[6]

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.

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.

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

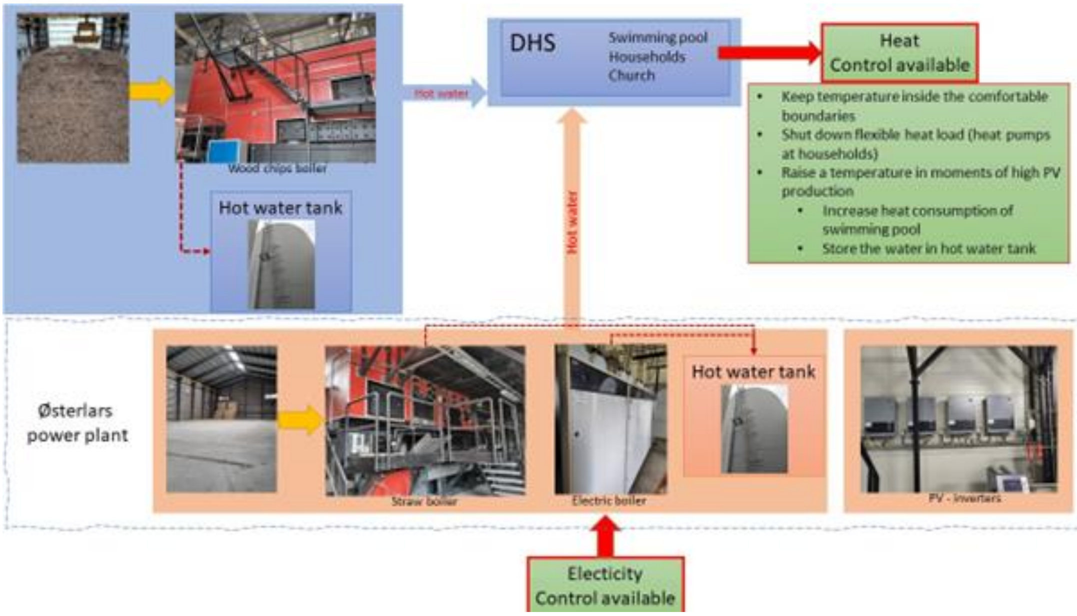

Figure 5. Heat production and storage units in Østerlars heat plant

Figure 6. Top view of the Østerlars heat plant

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 ºC, 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.
- A 20 MW_{DC} (15 MW_{AC}) solar PV plant near Østerlars, in Aakirkeby, connected to the grid.
- 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 3,000 kWh/year. The Østerlars district heating network supplies around 600 consumers, which are mostly households, but also business, public buildings (such as schools) and a swimming pool.

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.
- 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 Bornholm Energi & Forsyning, 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.

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 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

In Bornholm, access to energy is not a problem, since 100% of the population benefits from continuous access to electricity and heat. Besides, the electricity supply is quite stable. Despite being an island, the 60 kV AC submarine cable which connects the Bornholm Island with the Scandinavian grid ensures that in case of limited local energy production (for example, due to a reduced wind or solar PV resource), the sea cable can increase the electricity supply to Bornholm from Sweden.

On the other hand, the Bornholm Island can also work in “island mode”, which means that, if there is any breakdown in the sea cable, the local energy production units in Bornholm can increase their power generation to avoid power shortages.

However, it is expected that the use of higher amounts of renewable energies in Bornholm will lead to more difficulties in forecasting the production, and matching generation and consumption. This is why the RE-EMPOWERED project proposes the installation of the ecoTool set, as described in the following chapters.

As for electricity prices, the electricity market in Denmark and particularly in Bornholm is totally liberalized. For this reason, the electricity tariff for consumers depends on the supplier and the contract chosen. For instance, the price can depend on the hourly spot price, or be a fixed average price. There is not any subsidization of electricity prices in the country.

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.

The following figure shows the evolution of the prices for domestic consumers in Denmark, and in the European Union, Germany, and Sweden (neighbouring countries to Denmark) since 2007 to 2022. The comparison has been carried out for consumers with a band of consumption between 2,500 and 5,000 kWh per year.

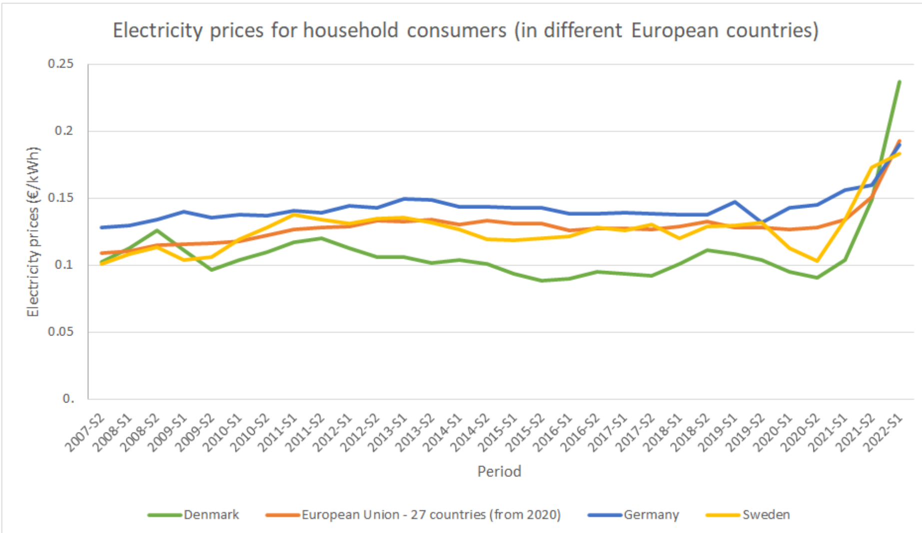

Figure 7. Evolution of the electricity prices for household consumers in Denmark and other European countries (Eurostat, 2022).

As can be seen, prices in Denmark have been historically lower than in the rest of the European Union. They have been in general less stable than prices in other countries. Although the average price has been around €0.10/kWh, in the second half of 2021 it reached a record of €0.1485/kWh, followed by a new record of €0.2371/kWh in the first half of 2022.

In the first semester of 2022, Denmark had one the highest electricity prices of all the European Union. 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:

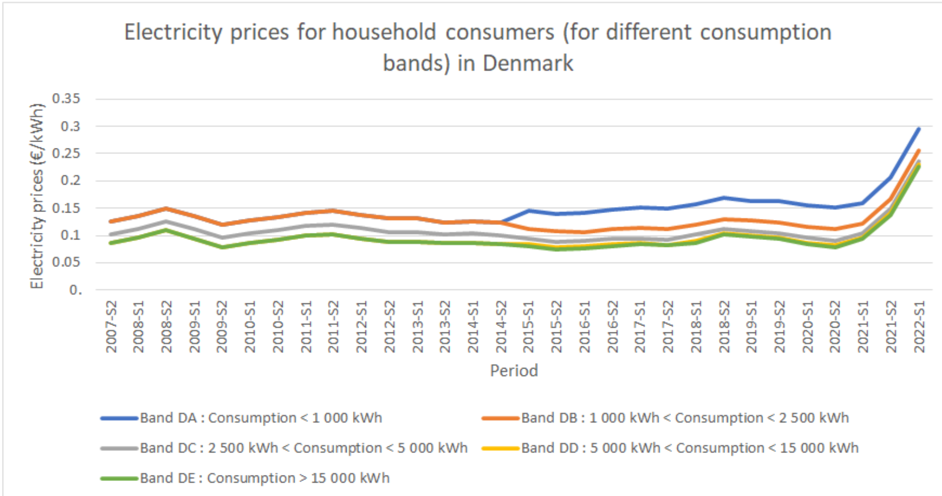

Figure 8. Evolution of the electricity prices for different consumption bands of household consumers in Denmark[7] (Eurostat, 2022).

In Denmark, prices for all consumption bands evolve in similar ways, depending on the changes of the wholesale market. Prices are considerably higher for smaller consumers (below 1,000 kWh/year), while prices for the band above 5,000 kWh/year are approximately €6-7 cents/kWh lower than those for smaller consumers (price per kWh are usually lower for the consumers who use more electricity). Since the second half of 2021, prices have increased very sharply, more than doubling in some cases. It is remarkable that the increase in the price is higher for bigger consumers (with an increase of 141.7% in the case of the band of consumption higher than 15,000 kWh/year, this is, €0.2265/kWh), than for the clients with the lowest consumption (only an increase of 84.6% in the case of consumption lower than 1,000 kWh/year, with €0.2944/kWh). In absolute terms, the increase for the electricity price in all consumption bands has been around €0.133/kWh.

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.

If the analysis is focused on evolution of the electricity prices for industrial consumers in different countries, a graph like Figure 6 can be obtained. The graph has been elaborated for industrial consumers with a level of consumption between 20,000 and 70,000 kWh/year.

[7] 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.

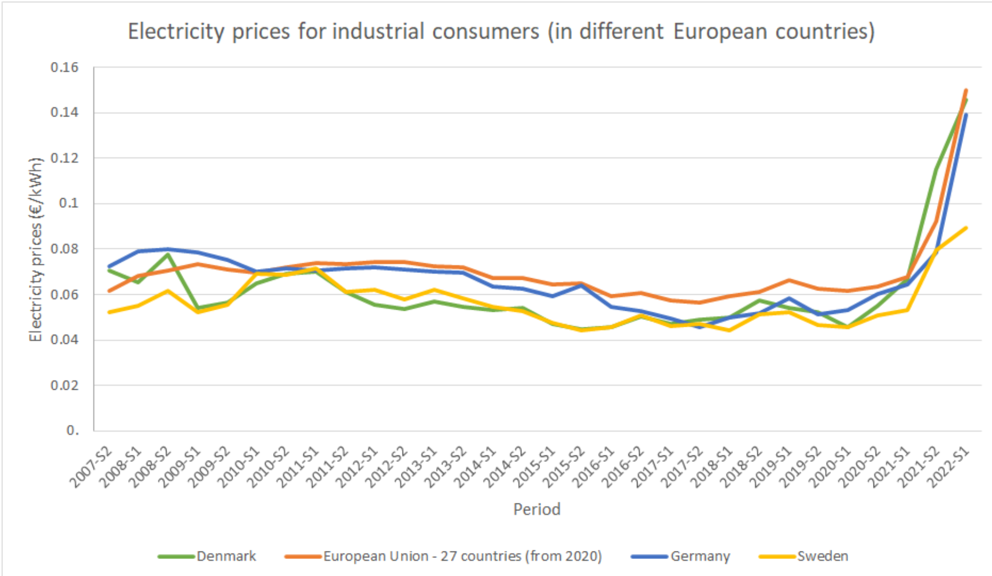

Figure 9. Evolution of the electricity prices for industrial consumers in Denmark and other European countries (Eurostat, 2022).

It is interesting to see that, while historically the electricity price in Denmark has been lower than the average for the European Union (specially between 2011 and 2021), with an average difference of €0.012/kWh, in the second semester of 2021, the Danish electricity price went up to €0.1154/kWh, being among the highest in the European Union. In the first semester of 2022, the difference has been much lower, only €0.039/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. However, the level of prices is considerably lower. In this case, except for specific years, prices have been below €0.10/kWh until the end of 2021. In the case of the biggest consumers, prices have even been around €0.04/kWh in 2020.

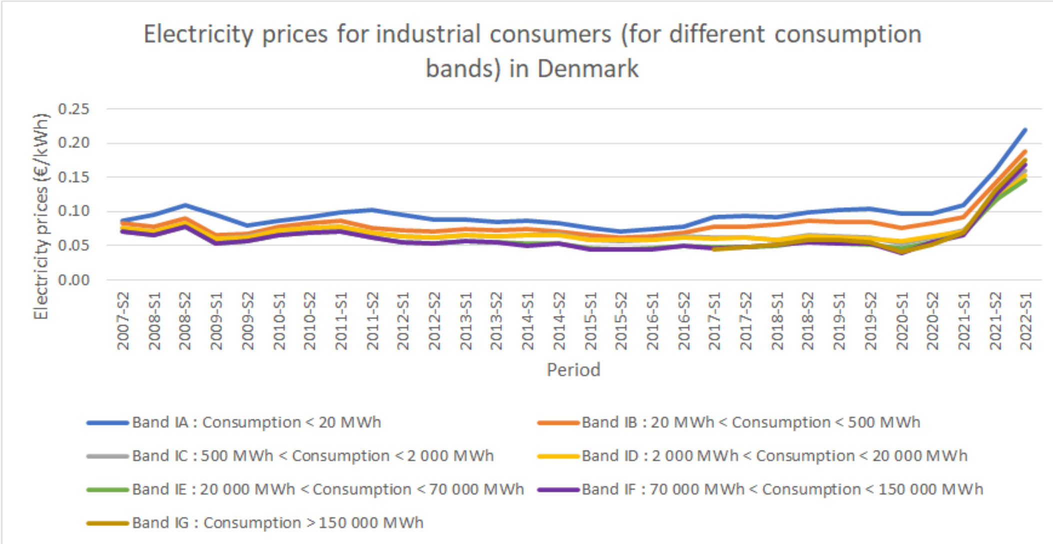

Figure 10. Evolution of the electricity prices for different consumption bands of industrial consumers in Denmark (Eurostat, 2022).

Between 2021 and 2022, prices for industrial consumers have doubled or have been multiplied by 2.5. The consumption bands which have risen the least are those with the lowest consumption, for example, the consumption band <20 MWh/year has seen a price increase of 100%, from €0.1098/kWh in the first semester of 2021 to €0.2198/kWh in the first semester of 2022. However, the increase in the consumption band >150,000 MWh has been of 256%, from €0.0689/kWh to €0.1762/kWh in the same period.

3.1.3. Regulatory background, renewable energy targets and energy efficiency in Bornholm Island

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. 984 of 12 May 2021). 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.

Similar to the Electricity Supply Act, the Natural Gas Supply Act was enacted in May 1979, and it is regularly updated. The last version is the Consolidated Act No. 126 of 6 February 2020. 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 and 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. Similar to 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.

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 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 have changed along the time, considering the advances in each technology, as described hereinafter.

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 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.

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 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 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.

The subsidies to replace old wind turbines were replaced 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.

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).

- 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.
- 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 2021, the European Commission approved that Denmark created state aids for €400 million to develop electricity production from renewable energies. These subsidies will be awarded by means of competitive bidding processes, organized until 2024. The bids will be focused on different technologies, such as onshore and offshore wind, hydroelectric and wave energy, as well as solar PV. However, the tenders will be 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 will receive €1.55 billion in grants, from which 59% will be 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 will be 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.

- 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.

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. The objective is to reduce 70% of CO_2 emissions by 2030.
- 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.

Energy Agreements

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.

In February 2011, the government published the Energy Strategy 2050. Its goals include:

- To achieve independence from coal, oil, and gas by 2050, with an intermediate objective of reducing the consumption of fossil fuels by 33% by 2020.
- 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.
- 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.

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 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).

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 hearing or to the natural gas grid. Other subsidies are offered to refurbish public buildings, and for information activities about energy efficiency measures.

It can be also mentioned that Denmark and the Netherlands set a joint cooperation in 2021 to develop the green transition in the pandemic crisis. The cooperation includes activities in the following fields:

1. Policies to facilitate the decarbonization of the heating sector.
2. Organization of heat distribution system.
3. Development of the offshore wind energy, including offshore energy infrastructure and potential offshore hubs in the North Sea.
4. Technical pathways through the decarbonization of the natural gas system.
5. Clean fuel developments, including Power-to-X and biofuels.
6. Development and deployment of CCUS-technologies for industrial decarbonization, including waste-to-energy.
7. Collaborate to increase the European climate ambitions.

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.

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 wind turbine offshore, 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 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.

3.1.4. 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.

The following figure shows the new ecoTools, and the way they interact with the rest of equipment of the Bornholm demo site:

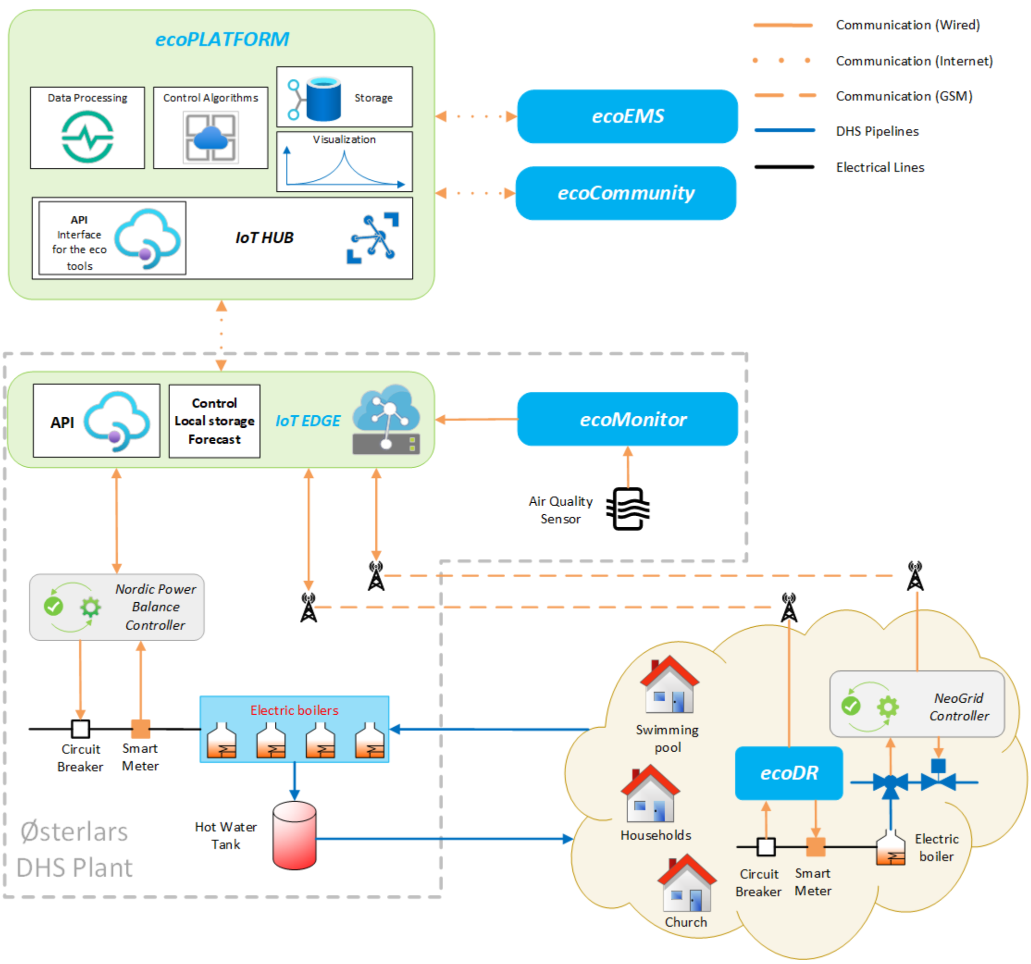

Figure 11. Key components of the Bornholm demo site.

In Bornholm, the following ecoTools will be installed:

- ecoEMS: The ecoEMS tool is an energy management system (EMS) which will be used to optimize the operation of the demo site, while the cost is minimized. It is linked to ecoDR to determine if the electric heaters are switched on or off. It will be hosted at NTUA premises, and will communicate with the Bornholm demo-site using the ecoPlatform.

  The objectives of ecoEMS are the determination of the best strategy to combine the solar PV production, the use of electric boilers and the production of heat with the district heating system. It will ensure that the electric production from the solar PV plant is used to heat water with the electric boilers in these moments when the electricity demand is lower. It includes the day ahead scheduling of the electric boiler.

- ecoDR: ecoDR tool is used to control non-critical electrical loads (<3 kW), to be able to use demand response in the power grid. In Bornholm demo-site, the ecoDR tool will be only installed for a small electric load, such as an electric heater at a consumer site.

  Based on the electricity consumption and production of the Bornholm demo site, it can control the moment when the electric heater is switched on or switched off, to introduce demand response.

- ecoPlatform: The ecoPlatform tool is a cloud-based platform, which connects all the other ecoTools. It gathers information from different sources across the Bornholm demo site, controlling the communication and interface with the rest of ecoTools. It can be also used to manage consumer and production-side flexibility, controlling demand and the operation of the electric boilers, according to the forecast solar PV production.

  It ensures the interoperability of all ecoTools, and stores the data in a cloud platform.

- ecoMonitor: The ecoMonitor tool is used to measure the air quality in real time at the Østerlars heat plant, considering that the use of straw in the boiler causes higher emissions of SO_x and NO_x, while the use of the solar PV production to generate heat at the boilers reduces such emissions. ecoMonitor is hosted at the Østerlars site and can communicate with the ecoPlatform through the IoT edge device called Raspberry Pi.

  ecoMonitor can measure the following parameters: CO_2, NO_x, SO_x, PM2.5 and PM10 microparticles, temperature and humidity.

- ecoCommunity: The ecoCommunity tool increases the participation of citizens and contributes to the use of the ecoToolset by the community, to reach the general demo site objectives. ecoCommunity is hosted in the cloud and communicates through the ecoPlatform.

  ecoCommunity allows the members of the community to use forums for communication, to provide feedback and to report problems using portals.

  It will also offer the members of the Bornholm community some training materials and guides. It also includes a display screen to show different thermal variables, associated to the local heating system and the district heating consumers.

Mapping UCs and, ecoTools in Bornholm Island

The following table includes a summary of the Use Cases which have been developed in WP2, associated with each ecoTool, for demonstration and deployment.

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	Demo sites Bornholm Island
ecoEMS	EMS_1UC1	Real time monitoring and system data visualization	EMS_2UC1.1	Real time system monitoring and data acquisition and visualization	▲
			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	▲
ecoDR	DR_1UC1	Increased energy monitoring at demand side	DR_2UC1.1	Real time monitoring of energy consumption	▲
ecoPlatform	PT_1UC1	Microgrid data acquisition	PT_2UC1.1	Connect to sensors and acquire data through designated communication networks and protocols	▲
			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	▲
			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 18. Association of ecoTools and UCs in the Bornholm Island Demo Site: RE-EMPOWERED

3.1.5. 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 will analyse 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 will be developed in the demo site is the installation of the Neogrid IoT devices, which will be installed at each demo participating in the RE-EMPOWERED project. These systems will be 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.

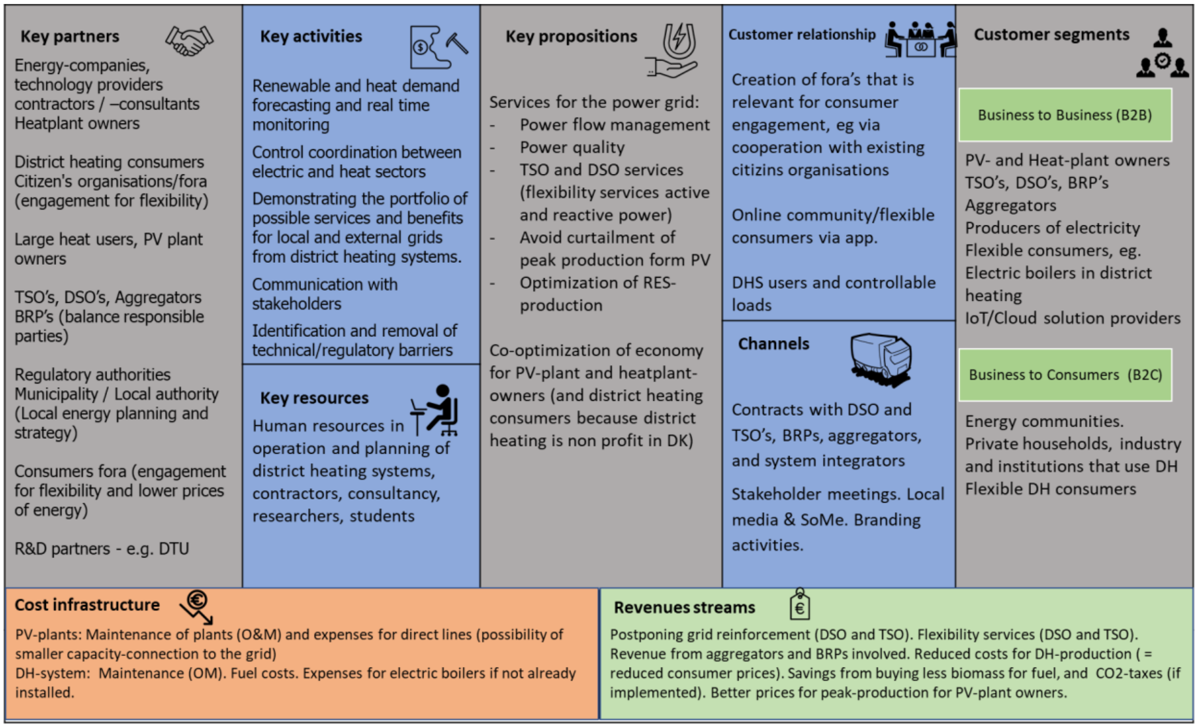

Figure 12. Proposed business canvas to Bornholm demo site

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 19. 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 systems 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 will begin 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 will be 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 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.

- 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).

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.

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. 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 income water to the household radiator system. This also ensures to keep pipe dimensions as reduced as possible.

In the demo site tests, some consumers will be engaged for the demonstration, and the already installed Danfoss ECL computer will be upgraded with remote controls, using the Neogrid IoT devices which will be installed in the future, 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 stakeholders 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:

- Energy companies (European Energy A/S).
- Technology providers and contractors.
- Consultants.
- Bornholm Varme A/S, owner of the district heating plant.
- 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.
- 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.

3.1.6. Financing tools applicable to the demo site

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[8] million, equivalent to €3,671,600.
  - 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:

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

- 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/year, 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 (€)	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €	- €
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)	- €	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)	- €	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)	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)	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 20. Economic model for the Bornholm Demo Site, including the cash flow mode 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.

Financing tools for Bornholm 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.

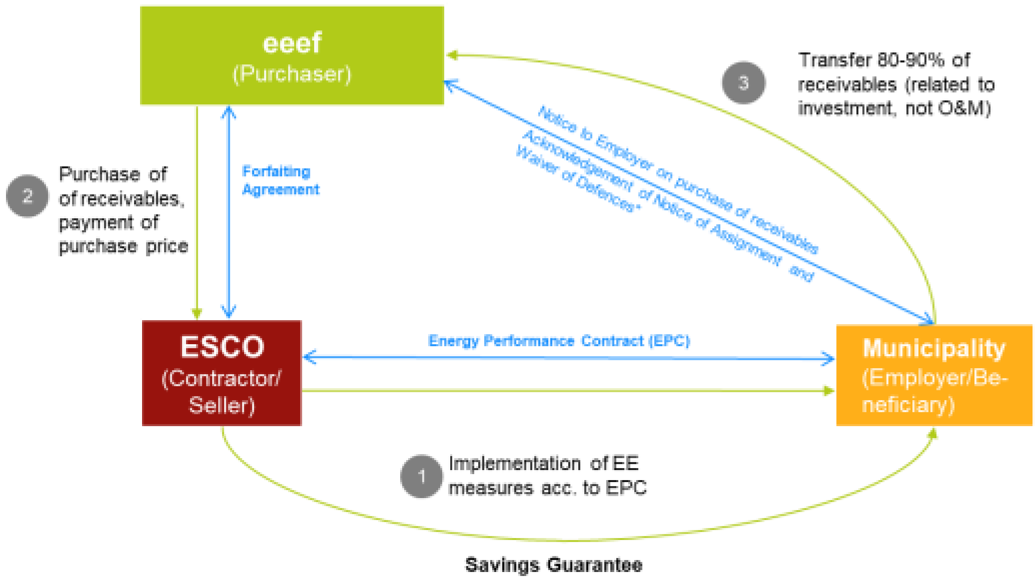

Figure 13. Structure of a forfaiting contract[9]

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.

[9] 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 14. Kythnos island

Kythnos has a total surface of 100.187 km^2, and a coastline of about 22 km. Kythnos has only one municipality, Kythnos, and two main cities, the village of Chora of Kythnos or Messaria and the village of Dryopsis or Dryopida.

Both villages have windy and stepped streets, and do not have traffic since they are too narrow.

There are also some settlements in the coast, which are growing thanks to the tourism. Among them, it is possible to mention Kanala (or Panagia Kanala), at the east side of the island, and Aghios Dimitrios, at the southern part of the island. In the northern part of the island, the city of Loutra is known for the thermal springs, which are said to have curative properties. Loutra is also the port of Chora of Kythnos.

At the Western part of the island, the port town called Merichas has a fluctuating population, depending on the season.

The total population of the island of Kythnos is around 1,608 inhabitants, 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 10.679 million people[10] in 2021.

In Greece, 97.936% of the total adult (aged >15 year) can read and write, while this figure goes up to 99.16% of the young adults (aged between 15 and 24 years)[11]. It can be also mentioned that 80.038% of the population lived in urban zones in 2021[11].

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[10] Source: World Economic Outlook: October 2022. International Monetary Fund.
[11] Source: The World Bank Data.

The electricity access rate is 100%. 78.116% of the Greek population used Internet in 2020[11].

The economy of Kythnos is mainly focused on tourism. It takes profit of 125 beaches, from which around 60 are easily accessible.

The geology of the island of Kythnos mostly consists of schists and marbles of the Cycladic Blueschist Nappe. Most of the island is covered by a complex water system, with springs and small waterfalls.

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. 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.

For these reasons, Kythnos has been used as a live testbed for different smart grid technologies, and has the main player 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.

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 peak load of the island reaches 3.118 MW (2020).

On the other hand, there are 3,353 electricity customers at the low voltage side, including both end consumers and producers.

The total yearly energy production and the total yearly energy consumption, measured in 2020 reaches:

Total yearly local energy production (MWh)	Total yearly energy consumption (MWh)
10,058.75	9,166.75

Table 21. Summary of the total yearly energy consumption and production in Kythnos (2020).

The split of the electricity production between the plants is as follows:

- Diesel generators: 9,656.83 MWh/year (96.0%).
- Solar PV power plants: 396.52 MWh/year (3.9%).
- Solar PV rooftop installations: 5.4 MWh/year (0.1%).

Although there are plenty of renewable energy resources in Kythnos island, the seasonality of the demand, the lack of storage systems, and technical restrictions due to the variability of wind and solar plants lead to a reduced penetration of renewable energy. As for today, solar PV only produces 4% of the electricity in the island, and to ensure that the system keeps stable, no more solar PV projects are allowed to be developed in the island.

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.

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 (Distribution System Operator): HEDNO S.A. (Hellenic Electricity Distribution Network Operator), in Greek “Διαχειριστής Ελληνικού Δικτύου Διανομής Ηλεκτρικής Ενέργειας”, or ΔΕΔΔΗΕ.
- TSO (Transmission System Operator): 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 operation of the electricity market.

As in all the European Union, the operation of the power system in Kythnos Island is based on three main pillars:

- To produce electricity at an affordable cost.
- To increase the security of energy supply, reducing the dependency on imports from other countries.
- To maximize the electricity generation using renewable energy sources.

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

In Kythnos, 100% of the population have access to electricity, and there are 3,353 low-voltage customers. However, there are some problems with stability of the energy supply. In peak hours, the high power demand can exceed the generation capacity of the island, leading to voltage and frequency variations, which can cause blackouts and be harmful for the operating devices.

At the moment, there are not load controllers. In summer, when the population increases to 8-10 times the existing number of inhabitants in winter, there can be issues in all the Kythnos grid. This extra power which is needed in summer is covered with diesel generators which are moved from an island to another.

There are issues with power outages and voltage drops, especially at the edges of the electricity network. For this reason, the island has the objective to improve the SAIDI (System Average Interruption Duration Index) and the SAIFI (System Average Interruption Frequency Index). Besides, it is necessary to develop protection systems against extreme weather conditions and better load and weather forecasts.

Regarding energy prices, the cost of electricity in Kythnos is partially subsidized. The objective is that the consumers of the island can pay the same prices than the rest of the Greek citizens.

In Greece, the energy cost of all non-interconnected islands is subsidized. As a result, the consumer only pays a proportion of the energy cost. In general, island systems rely more on thermal power plants, which produce electricity at higher costs than the continental power system, which allows for using more renewable energy. 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.

In the following figure, it is possible to find the evolution of the prices for Greece, the European Union as a whole, and some countries comparable to Greece: 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.

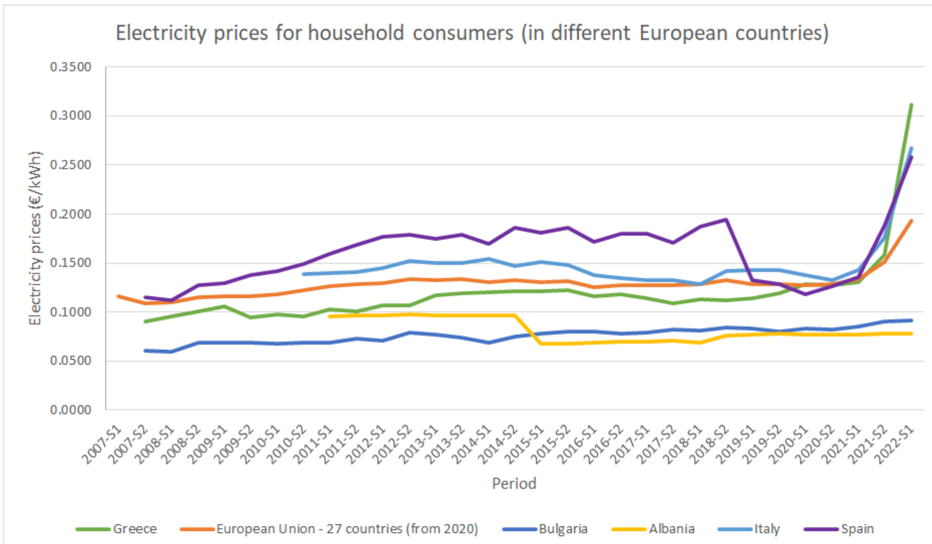

Figure 15. Evolution of the electricity prices for household consumers in Greece and other European countries (Eurostat, 2022).

Prices in Greece have been historically lower than that of the European Union. In the period 2013-2016, they went up quicklier than the European Union prices. In 2020, 2021 and 2022, prices in Greece have become similar to that of the European Union, or have been even higher. The record price in Greece was reached in the first semester of 2022, with €0.3118/kWh. Indeed, in this semester, the price for domestic consumers in Greece has been the highest of all the European Union.

These prices have been considerably higher than that of the neighbour countries, and this difference has gone up with the years. For example, the difference between Greece and Bulgaria was on average €0.035/kWh until 2019, and in the first semester of 2022 it reached a record of €0.2207/kWh.

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

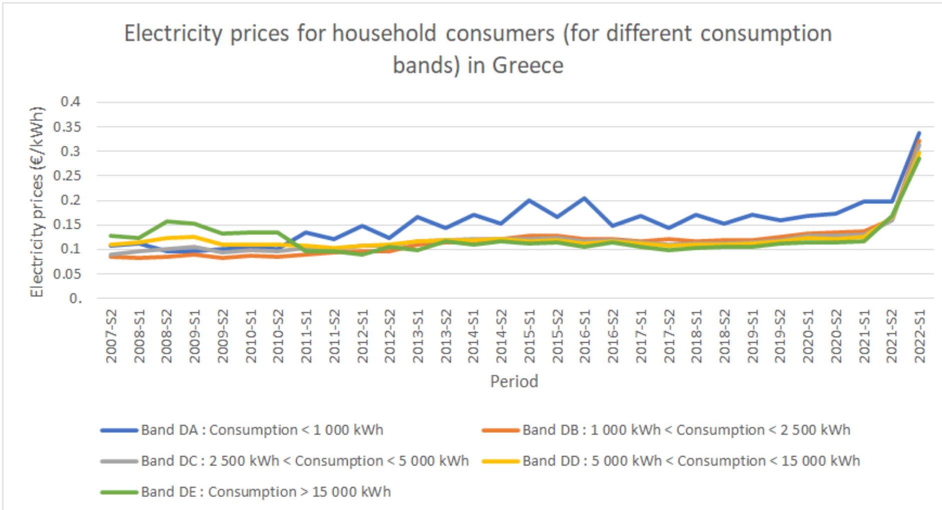

Figure 16. Evolution of the electricity prices for different consumption bands of household consumers in Greece (Eurostat, 2022).

The graph shows that until 2011, prices for the highest consumers, above 15,000 kWh/year, have been the highest, around €0.05/kWh higher than that of the lowest consumption clients. However, this changed in 2011, when the prices for highest consumers went down, while prices for clients with a consumption lower than 1,000 kWh/year went up by 35%.

Since then, it can be remarked that prices for low consumption clients have varied very much, ranging between €0.15/kWh and €0.20/kWh. The increase in prices in the second semester of 2021 was higher for those clients with the highest consumption, while prices had increased before for clients with a consumption lower than 1,000 kWh/year. In the first semester of 2022, all tariffs have increased by 70%-100%, compared to the second semester of 2021.

A comparison of the evolution of the prices for industrial consumers, in a consumption band between 20,000 and 70,000 kWh/year has been also carried out.

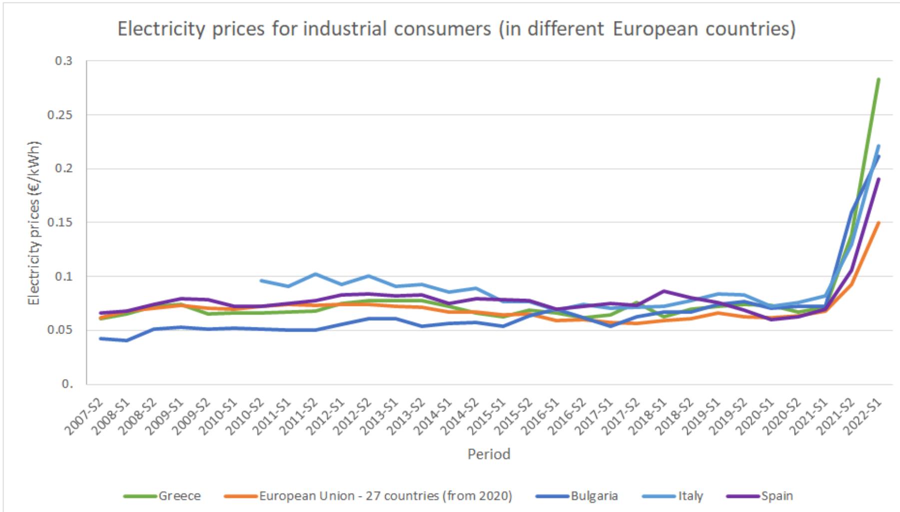

Figure 17. Evolution of the electricity prices for different consumption bands of household consumers in Greece (Eurostat, 2022)

Prices for industrial consumers vary more than that of householders. The highest price of the series was reached in the first semester of 2021, with a record level of €0.2832/kWh in Greece, doubling the price of the second semester of 2021, and almost 4 times higher than the price of the first semester of 2021. It can be also mentioned that until 2017, prices in Greece and in the European Union were similar, with differences below €0.01/kWh. Since then, the prices in Greece have always been higher, with a record difference reached in the first semester of 2022.

The following graph includes the evolution of the electricity prices for industrial consumers in Greece, for different consumption bands. In general, the consumers with a lower consumption level have higher price, specially these which need less than 20 MWh/year. As described for industrial prices in all the European Union, all consumption levels have seen a sharp increase in prices in 2021 and 2022. Consumers with the highest level of consumption (more than 500 MWh/year) have seen an increase of prices of around 400% in this year.

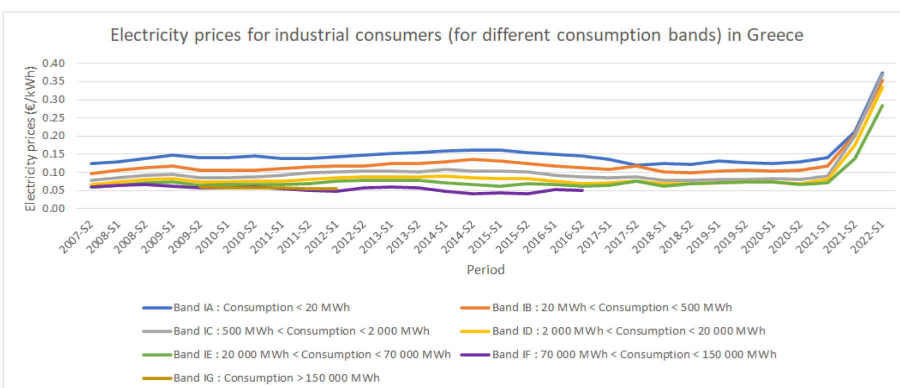

Figure 18. Evolution of the electricity prices for different consumption bands of industrial consumers in Greece (Eurostat, 2022).

In general, in all Greece, consumers are very worried and dissatisfied with the electricity price increase during the last 18 months.

3.2.3. Regulatory background, renewable energy targets and energy efficiency in Kythnos Island

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.

Additionally, 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.

In 1987, Law 2689/87 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 was 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%. 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 managing 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 has 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.

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 promotion 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.

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 change included ambitious renewable energy targets, which are defined as follows:

- The share of renewable energy will be 20% of the gross final energy consumption by 2020.
- The share of renewable electric energy will be 40% of the gross electrical energy consumption by 2020.
- The share of renewable energy in heating and cooling will be at least 20% of the final energy consumption for heating and cooling by 2020.
- The share of renewable electric energy in transport will 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.

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.

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 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 60% of the gross final electricity consumption by 2030.
- The share of renewable energy in heating and cooling needs to exceed 40% 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 will be 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.

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 will receive €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, improve energy efficiency in houses and businesses and reduce 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.

The Greek Republic has recently approved 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.

In Kythnos, there is not specific regulation apart from the general Greek regulation described before.

3.2.4. 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 price 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 to introduce 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 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. Kythnos will be an example which will be replicated in other non-interconnected islands in Greece.

The following figure shows how the existing infrastructure and the new ecoTools will interact in the Kythnos demo site:

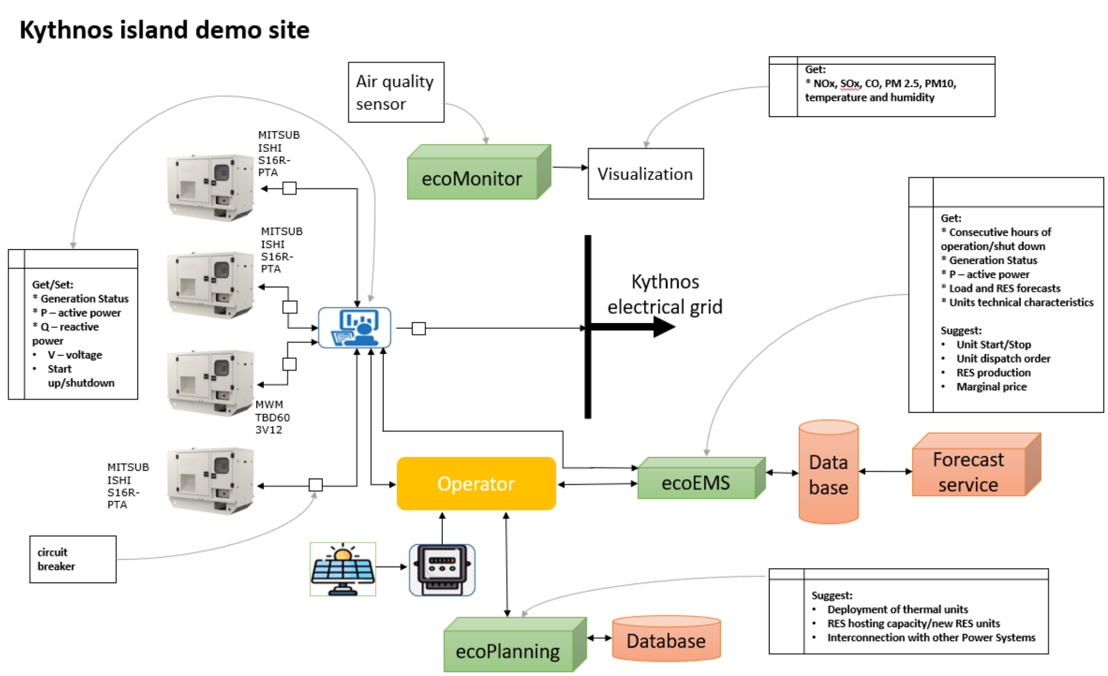

Figure 19. Key components of the Kythnos demo site.

In Kythnos, the following ecoTools will be used:

- ecoEMS: ecoEMS is a tool which will be used as an energy management system (EMS), and will be used to optimize the operation of the demo site, and to minimize the energy cost, maximizing the electricity production using renewable energies.

  ecoEMS will allow to exploit the synergies of the different energy vectors in the Kythnos Island, to allow an optimal dispatching based on forecasting, economic and technical criteria.

- ecoPlanning: ecoPlanning is a tool which can be used in the decision-making process for the deployment of new electricity generation units (conventional and renewable) in a mid-term horizon. Among others, ecoPlanning includes the following analyses: 7-year planning for assessing the deployment plan for new conventional production units, analysis of the renewable energies which can be developed in the power system, and an assessment of the interconnections, carrying out steady state simulations of the electric system.

  ecoPlanning can define different scenarios, considering the electricity demand forecast and the characteristics of the electric system (production units, technical and economic characteristics, operation rules, etc.). The tool informs about the operation of the generation units, and provides information about the energy production, its quality, fuel consumption and cost, produced CO_2 emissions and so on.

  In Kythnos, ecoPlanning is used to optimize the technology mix.

- ecoMonitor: ecoMonitor tool is used to measure the air quality in real time in the Kythnos island, measuring different parameters: NO_x, SO_x, CO_2, PM2.5, PM10, temperature and humidity.

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.

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	Demo sites Kythnos	Association with New BM
ecoEMS	EMS_1UC 1	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_1UC 2	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	▲	
ecoMicro grid	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	Demo sites Kythnos	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	▲	
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)	▲	
			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)	▲	

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Demo sites Kythnos	Association with New BM
ecoResilience	RS_1UC3	WT Local Manufacturing and Testing	RS_2UC3.1	Testing of Small Wind Turbines using Standards	▲	

Table 22. Association of ecoTools and UCs in the Kythnos Island Demo Site: RE-EMPOWERED

3.2.5. Business Canvas and proposed business models.

The business model in Kythnos should consider some particularities of the Kythnos 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%.
- 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.

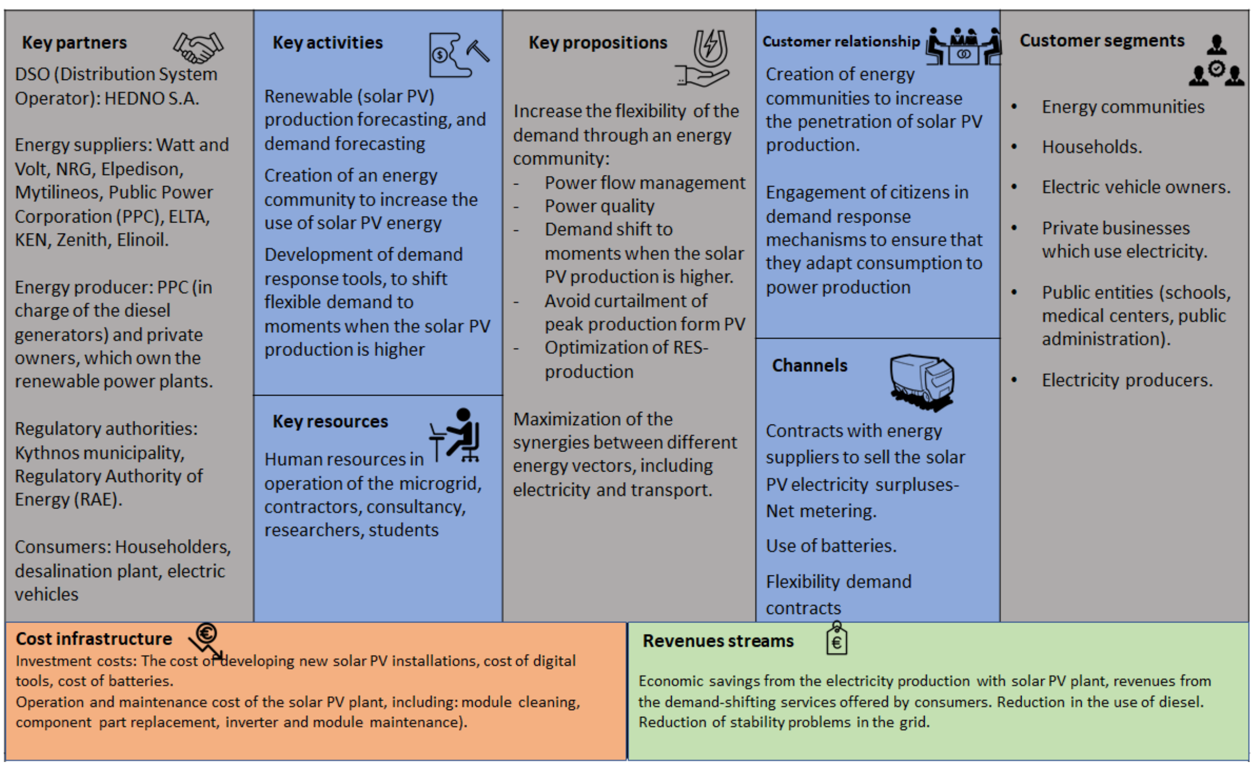

Figure 20. Proposed business canvas to Kythnos demo site

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 join 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.

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 operating 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,	• Not all local authorities support energy communities actively. • Decision processes by local authorities can hinder the development of the energy community.

Business model	Strengths	Weaknesses
	and can offer public lands for the installation of the plant.	
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 23. 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.

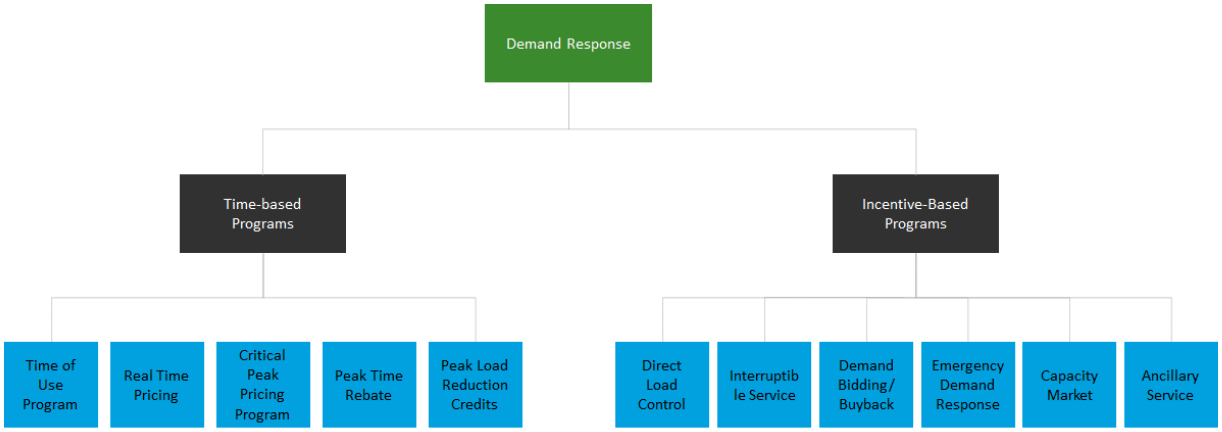

Figure 21. Different categories of demand response [7], [8].

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.

- 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 block hour. 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.

Community engagement

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, 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.

Until now, in Kythnos island there is not any citizen-led energy community. During the RE-EMPOWERED project, the support from the Municipality of Kythnos and different commercial associations has been obtained to promote the development of such communities. Indeed, the creation of energy communities is one of the objectives of the RE-EMPOWERED project, involving local authorities, local citizens, and businesses.

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

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

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).
- 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.

3.2.6. 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 it.

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 22. Location of the Gaidouromantra microgrid in the Kythnos island

Figure 23. View of the Gaidouromantra microgrid[12]

[12] 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.

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 microgrid provides electricity to 14 houses with a 1-phase electrical service. The project was begun in early 2001, with the support of the European projects PV-MODE (JOR3-CT98-0244) and MORE (JOR3-CT98-0215). Besides, in 2006, the microgrid was upgraded thanks to the project MORE MICROGRIDS (FP GA: 019864).

The grid and safety specifications of the house connections follow the technical solutions of the Public Power Corporation, the most important power company in Greece.

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.

During the project MORE MICROGRIDS, several power converters were installed in the microgrid to improve the operation of the system, and to test different control strategies. An agent-based software/hardware for centralized and decentralized control was developed, adapted, and installed at the microgrid. This system consisted of an Intelligent Load Controller (ILC), used to monitor the house power line, as well as the voltage, current and frequency.

In the project MORE MICROGRIDS, five ILCs were installed in these houses. Each ILC was connected to two switches, able to control the non-critical loads. For example, some houses in Gaidouromantra have water pumps, which are used to fill a water tank for the water supply of the house, and for some small-scale agricultural activities and gardening. This is a non-critical load, and can be switched to moments when the power demand is lower.

The MORE MICROGRIDS project had mainly two objectives:

- To test a complex control system in a real situation.
- To optimize the use of solar PV systems, maximizing its use when there is plenty of solar irradiation, reducing the use of diesel generators.

The Gaidouromandra microgrid has the following topology:

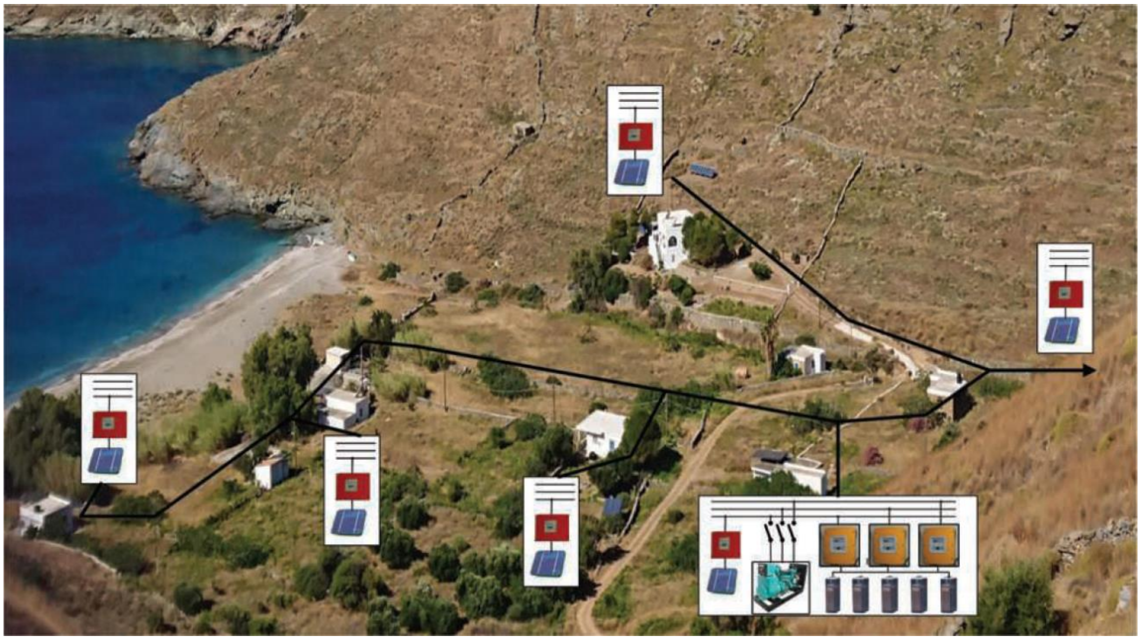

Figure 24. Overview of the Gaidouromantra microgrid

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

- 14 vacation houses as consumers.
- 11.145 kW of solar PV panels: 6 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 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 4.7 MWh/year.

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).

One of the vacation houses, House 7, has additionally installed a Flexmax charger from OutBack, for coupling batteries and solar PV plants in a common DC bus, while it performs the maximum power point tracking algorithm of solar PV plants. Moreover, a Xtender (XTM 3500-24) inverter from Ateca, is used to either connect the battery storage system and the solar PV facilities to the existing AC microgrid or to form the voltage waveform if an outage in the main microgrid supply happens. The total storage capacity is 24V/60Ah.

As described, each house has an agent-based software/hardware for centralized and distributed control, which consists of Intelligent Load Controllers (ILC), for protection against overloading or extreme battery discharge in each house. They are triggered when the frequency goes under 49.14 Hz. The loads are reconnected at least two minutes after the frequency is restored, in a random order to avoid the instant reconnection of all the consumers.

The ILCs use the Wi-Fi to decide the level of consumption of each house according to the batteries' state of charge and the solar production.

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.

All the houses of the microgrid are connected using a 3-phase voltage overhead AC power lines, operating at 230 V, and a communication cable (RD 485) runs parallel to the power lines. The low voltage system is formed by the battery inverters.

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.

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.

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 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. Regulatory background, renewable energy targets and energy efficiency in Gaidouromantra microgrid

The regulatory framework and renewable energy targets which are applicable in Gaidouromantra are the same that were explained in chapter Regulatory background, renewable energy targets and energy efficiency in Kythnos Island.

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.

In this case, Law 4513/2018 is especially important. This law introduces the concept of energy community in Greece, and enables local actors to get actively involved in clean energy transition. This law 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.

3.3.4. Use of the ecoTools in Gaidouromantra Microgrid

In Gaidouromantra microgrid, there will be five different ecoTools: ecoMicrogrid, ecoDR, ecoCommunity 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 be able to adapt the consumption of the houses to the availability of electricity produced with the solar PV panels, or when the battery is charged.

The following figure shows how the existing infrastructure and the new ecoTools will interact in the Kythnos demo site:

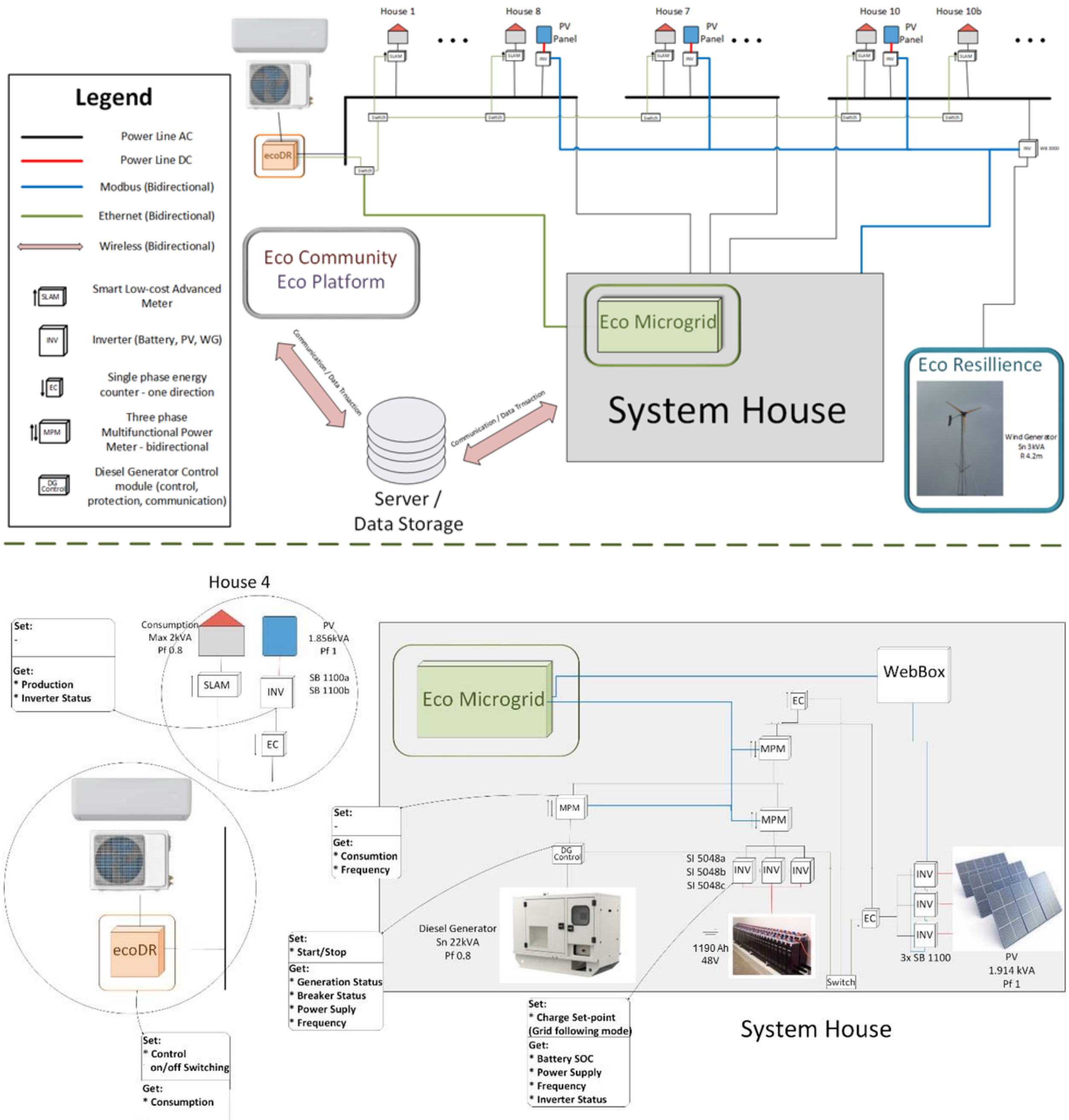

Figure 25. Key components of the Gaidouromantra demo site a) Microgrid overview b) Detail of microgrid components

The following ecoTools will be developed in the Gaidouromantra microgrid:

- ecoMicrogrid: ecoMicrogrid tool is an EMS specially designed for its use in microgrids. In the case of Gaidouromandra microgrid, it will be responsible for the optimized operation of the microgrid, for example, ensuring that the resources are optimally dispatched. ecoMicrogrid can monitor the state of different microgrid components, such as the solar PV plants, the consumption loads and the batteries. It defines the processes of load shedding, diesel generator start-up or shutdown, and the use of renewable energies. It will be placed inside the system house, and consists of hardware components, suitable software, and so on.

  ecoMicrogrid monitors parameters such as voltage, grid frequency, current, active power and reactive power.

- ecoDR: ecoDR controls the development of advanced metering infrastructure (AMI). It measures and bills the household energy consumption, and can also monitor and control remotely the non-critical loads (e.g., the air conditioning systems), allowing to shift consumption to moments when the consumption is lower, the solar PV production is higher, or the battery is charged. This tool can communicate with ecoMicrogrid to access services such as demand-side management, and to implement the scheduling of critical/non-critical loads.

  ecoDR monitors power consumption.

- ecoPlatform: ecoPlatform is a cloud-based platform, which is in charge of providing the RE-EMPOWERED tools with a secure and reliable interface to the deployed distributed energy infrastructure. It is able to manage, process and handle the data and command stream from the RE-EMPOWERED tools, providing a platform to integrate all the other solutions in one software structure.

  ecoPlatform ensures interoperability and takes data from different sources, storing them in a cloud platform.

  It uses as parameters air quality data, consumption and production, forecast of load and renewable generation.

- ecoCommunity: ecoCommunity is a digital platform aimed at increasing the citizen engagement, their participation and technology acceptance. It displays dynamic prices and energy consumption to the consumers. Besides, it can generate consumer bills, and makes easier to electronically pay them. It also schedules and coordinates flexible non-critical loads and shared loads.

  It includes a functionality for community engagement, using forums, feedback and problem reporting portals. It also contains a community support using training materials and guides.

  As inputs, the tool uses the energy prices, energy consumption, and available booking time slots.

- ecoResilience: ecoResilience tool has been designed to increase the capacity of wind turbines to resist extreme weather conditions, including storms and wind fires. In the case of Gaidouromantra microgrid, cyclones are not expected, but storms and fires are likely, and have destroyed the existing infrastructures in the past. It also optimizes the design of solar PV facilities, minimizing the aerodynamic wind loads using numerical simulations, wind tunnel testing and field tests.

As parameters, ecoResilience will use wind speed and wind or W/T system rated power.

3.3.5. 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. Probably, 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.

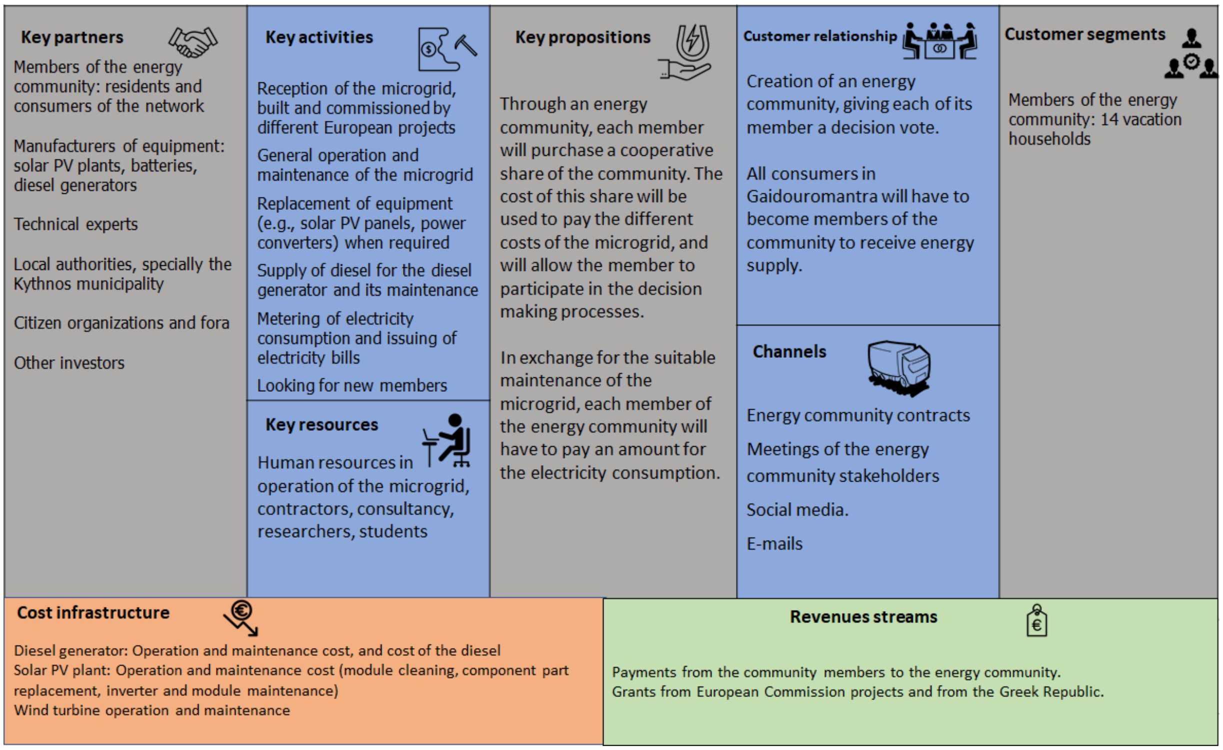

Figure 26. Proposed business canvas to Gaidouromantra microgrid

Proposed business model

As mentioned in Figure 25, the creation of an energy community is considered to be the best business model for the Gaidouromantra microgrid.

The 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 members of the energy community can be manufacturers of equipment, such as solar PV modules, batteries or diesel generators, other technical experts, 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 are made up by 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.

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.
- Technical experts.
- Local public authorities, especially the Kythnos municipality.
- Citizen organizations and fora.
- Other investors.
- 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

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.

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.

3.3.6. Financing tools applicable to the demo site. Availability of subsidies.

Economic and financial model 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 letters, 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 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 24. Economic model for the Gaidouromantra microgrid, including the cash flow mode 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.

In the economic model shown before, it has been supposed that the clients will only pay for the real used of diesel, and that the investment cost is paid by the energy community.

However, the economic model will be some different if it is considered that:

- The investment cost of the microgrid will be covered by different European Commission projects, so, for the energy community members, it will be €0.
- The energy community members will be charged the total cost of the microgrid, once put into operation. This means that, in exchange for having renewable energy produced by the solar PV panels and the wind turbine, the energy community members will have to pay for the operation and maintenance of the diesel generator, the solar PV plant and the wind turbine.

The objective is that the energy community obtains revenues to cover their costs, but neither an economic profit nor economic losses. Apart from economic considerations, the project has clear environmental benefits, since there is a high reduction in the use of diesel and the greenhouse gas emissions in the microgrid.

To do so, the energy community members will have to pay, at least, €668/year, to be able to pay the cost of the new infrastructure.

Financing tools for Gaidouromantra microgrid

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 Use of the ecoTools in Ghoramara Island and Keonjhar Microgrid

This section presents the business model propositions for the two Indian demo sites – Ghoramara island (West Bengal) and Keonjhar (Odisha) in the form of a qualitative Business Model Canvas (BMC) followed by quantitative assessments of revenue streams analyses regarding the tariffs, number of consumers, tariff, energy savings, etc. Also, demo specific UCs mapping, with the applicable ecoTools with prospective business propositions, has been derived to identify the most suited business models, viable in the local conditions, for each demonstration site. This chapter examines key innovative technologies, digital infrastructure and smart devices that are to be deployed impacting market strategy and community participation. It also identifies businesses that are currently delivering some of these use cases in mature markets, where digital infrastructure and analytics are disrupting other industries and creating cross-sector linkages. Therefore, it guides for the development of digital flexibility solutions supporting a net-zero environment.

Unlike the traditional power generation, energy communities undertake heterogeneous activities including generation, distribution, storage, supply, and consumption. Conventionally, energy cooperatives operate with the government support schemes for renewables and are the most common type of energy community in local renewable projects. This business model analysis includes energy communities operating under power purchase agreements and/ or peer-to-peer (P2P) trade, under several conditions. It differs from virtual power plants in that batteries are used for flexibility within the community. This considers participation of households in energy-sharing communities, electric vehicles and energy trading between small enterprises or public entities. Residential power consumption makes up a significant share of overall energy and electricity consumption. P2P trading as well as energy sharing among energy communities could contribute to the energy surplus trading locally and storing for later usage or trading. Thus, the use of batteries by energy communities for energy sharing or P2P trading may be distributed among prosumers – energy-community members, individual energy consumers, community-related, and few anchoring loads. It also addresses flexibility trading within energy communities. Community demand response covers the provision of flexibility by energy communities in external flexibility markets, such as the wholesale intraday spot market and ancillary services markets, while local microgrid/ off-grid communities, covers the additional requirements for the use of flexibility, such as for congestion management, frequency and voltage control or power system restoration.

Mapping UCs, ecoTools and Business Models in the Indian Demo sites

For the RE-EMPOWERED project, the present chapter highlights the development of potential new business model for the two Indian demo sites. This is based on the following exercise of mapping the identified UCs in WP02 with the innovative solutions (ecoTools) for demonstration and deployment. This in-depth exercise helps in the emergence of some new insights in association with the new business model along with services to the involved stakeholders' and various actors. This analysis is utilized for devising the business canvas model accordingly, in-order to understand the cost and benefit implications generating from niche value propositions offered.

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Demo sites		Association with New BM
					Ghoramara Island	Keonjhar	
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_2UC1.4	Outage detection and location identification	▲	▲	
	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	▲	▲	**Energy Sharing and P2P Communities**
			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		▲	**Digital Business Models**
			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		▲	**Networked Smart Microgrids**
	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.		▲	**Privacy Pricing**
	PN_1UC3	Multi-energy vector microgrid management of operation	PN_2UC3.1	Electrical models, demand peak models & interconnections design, RES & Load estimation		▲	**Time of use Tariffs**
			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)		▲	**Digitally Enabled Flexibility services**
			PN_2UC4.2	Electrical models & demand peak design, RES & Load estimation, energy carriers scenarios integration		▲	**Dynamic Containment**
			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	▲	▲	**EVs Smart Charging**
			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	▲	▲	**Price Responsive Charging**
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	▲	▲	**Vehicle to Microgrid**
ecoMonitor	MN_1UC1	Drinking water quality surveillance	MN_2UC1.1	Acquisition and monitoring of water quality	▲		**Demand Response, Energy Storage and Generation**
ecoCommunity	CM_1UC1	Dynamic pricing of electricity*	CM_2UC1.1	Displaying the dynamic pricing based on shape of energy profile		▲*	
			CM_2UC1.2	Billing and payments		▲*	
			CM_2UC2.2	Coordination of communal/shared loads	▲	▲	
	CM_1UC3	Outreach forum	CM_2UC3.1	Feedback and suggestions from users about the tools	▲	▲	**IoT Based Real Time Monitoring**
			CM_2UC3.2	Reporting of problems	▲	▲	
			CM_2UC3.3	Forum to share experiences	▲	▲	
	CM_1UC4	Guidance and Training	CM_2UC4.1	Training material (troubleshooting)	▲	▲	

ecoTool	Primary UC ID	Primary UC	Secondary UC ID	Secondary UC	Demo sites: Ghoramara Island	Demo sites: Keonjhar	Association with New BM
			CM_2UC4.2	Easy-to-use multimedia material and step-by-step guides (walkthroughs)	▲	▲	**Self-consumption Optimization** **Residential Solar Pumps**
ecoResilience	RS_1UC1	Optimal passive resilient support structure for solar photovoltaic system	RS_2UC1.1	Optimal selection of parameters	▲		
			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	Testing of Small Wind Turbines using Standards	▲		
ecoVehicle	VH_1UC1	Tailor-made Electric Vehicle (EV) charging facility	VH_2UC1.1	Effective control strategies for dc-bus voltage regulation	▲	▲	
			VH_2UC1.2	State of charge and temperature estimation	▲	▲	
			VH_2UC1.3	Temperature regulated charging strategies	▲	▲	
	VH_1UC2	Selection and customization of rickshaw	VH_2UC2.1	Sizing and Selection of the power train components	▲	▲	
			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	▲	▲	
			VH_2UC3.2	Optimal Energy management algorithms	▲	▲	

*Depending on the installations

Table 25. Association of New Business Model with two Indian Demo sites and UCs: RE-EMPOWERED

Following are the novel potential business propositions that can be monetized for the operators, service providers and energy communities:

- **Smart Sustainable Energy Community**: It is a legal body, which is autonomous, formed based on open and voluntary participation of shareholders or members located in proximity of the renewable energy projects. It comprises an elected executive body registered as per national laws under the by-laws of Co-operative Societies Act 2006. Renewable energy projects are effectively monitored and controlled projects that are owned and co-developed by smart energy communities. The shareholders or members include villagers, beneficiaries, local enterprises, and local authorities. Primarily, the energy community participates during build, own, operate and transfer model of the community energy projects ensuring environmental, economic, or social community benefits. The operation and maintenance, tariff collection, financial management, community asset management are few more responsibilities and obligations led by these entities. Community ownership fosters acceptability of the energy transition to a carbon free economy and society. However, strong handholding in India is required for such entities and must be offered timely training, technical support, collaborative opportunities and robust funding for energy infrastructure retrofitting, energy bills reduction, energy saving, local job creation and entrepreneurship.

- **Energy Sharing and P2P Community**: P2P allows direct selling of local electricity, offering profitable trading opportunities to prosumers in defined local or virtual communities who cannot participate in wholesale markets. The dynamic market of P2P energy networks effects lower energy costs by stimulating the supply of intermittent renewable energy demand with shifting consumption to either surplus electricity and/or low electricity prices. Moreover, it can result in new solar PV investments and energy storage systems as demand-responsive energy trading is likely to be further profitable. Emerging R&D on digital innovations such as smart meters, advanced algorithms and control technologies with essential digital infrastructure makes P2P trading feasible. In microgrid-driven P2P markets peers buy and sell electricity while guaranteeing the microgrid stability, requiring the control of generators, loads, and storage. Community-based P2P markets emerge from community initiatives by combining prosumers' resources, enabling to participate in energy markets and frequency control. Beyond electricity supply, more value creation can happen by back-up power, ancillary services, distribution upgrade deferral applications. Also, battery storage is key to increase the flexibly of consumers to maximize the trading revenue and to keep the market balanced.

- **Digital Business Models**: Digital technologies and protocols for creating smart microgrids are still under development. New innovations may increase transparency and safety, reduce transition costs, and integrate heterogeneous consumer groups. Investment, maintenance, and cybersecurity can be critical barriers to its implementation. Alternatively, blockchain-based smart contracts can meet some of the requirements. Therefore, this new digital infrastructure has the potential to disrupt the energy markets by amalgamation of advanced digital technologies with the engineering and business applications.

- **Networked Smart Microgrids**: This can enhance the power system resilience. An important feature is 'self-adequacy' of the microgrids which loads are managed by the local distributed generators ensuring the uninterrupted electricity. Hence, networked microgrids can support by continuous supply during emergencies like outages while in normal operation can exchange electricity for efficiency and economic benefits. The challenge lies in real-time balancing of supply and demand, while maintaining voltage and line flow constraints. Further complications are inherent uncertainties of distributed renewable resources and customer loads. A reinforcement learning based approach can assist in coordination and control actions.

- **Privacy Pricing**: Based on the consumer energy data and other details for generating revenue streams for the operators or energy cooperative/ committee who are monitoring and controlling the community microgrid.

- **Time of Use Tariffs**: It provides an incentive, via tariff price signals, to the customer to manage when or how much electricity they consume in order to access reduced electricity costs in response to the tariff price signals. This is relevant to small businesses and residential consumers. A few suppliers also offer more generic Time of Use tariffs that could benefit those customers who can use flexibility to manage demand to reduce electricity costs in response to the tariff price signals or who due to their lifestyles consume most electricity outside of peak time. It is suited to all types of demand and storage and is levied for per kWh basis.

- **Digitally Enabled Flexibility Services**: It is a new service that has been developed to respond to extremely low levels of demand on the network. It was deployed in response to low demand created by the Covid-19 pandemic, but could be used again, especially in severe weather conditions where both supply and demand is low. In principle this service could be delivered by both community-scale wind and solar farms. Control of asset requires some investment in hardware installed onsite. It may be provided to energy systems operator and suited to demand response and generation seasonally.
- **Dynamic Containment**: It is a new service that is designed for delivery by batteries and requires a very fast response time of one second. It is used when there is an unexpected imbalance in the system (not anticipated through balancing) which affects the quality (frequency) of power. It's used to quickly bring the system back into balance. This is a new service created in response to an increasingly decentralized electricity generation model. Others like this may be needed in the future. This may be provided to energy system operator and may be suited to battery / energy storage for a less aggregate level.
- **Distribution Charge Management (DCM)**: Customers with electricity generation could receive a benefit if exporting power during these peak demand periods. This service is suitable for demand response, energy storage and generation with a minimum capacity varying by agreement.
- **EVs Smart Charging**: For ecoVehicles i.e., three-wheelers and e-boats for sustainable mobility and transportation. The electricity will be provided as per the tariffs per unit of charging from the charging station which will be prepaid. EV charging, especially under the assumption of a wider EV deployment, will also pose challenges to the grid. On a household level, charging is limited by the capacity of the connection point, meaning that charging usually occurs with low power and will therefore take longer. Another option is to install charging stations in the community. In this case, members want their EV to charge fast as they cannot simply charge it from home and also need to be charged quickly to allow several members to charge their cars. This fast charging however creates significant peaks in the load profiles which troubles the grid. One solution is to connect a battery, allowing to flatten the load profiles. However, batteries are not viable from an economic viewpoint yet.
- **Vehicle-to-Microgrid (VTMG):** The wide deployment of Electric Vehicles (EVs) in the future will challenge the grid, but it will also offer the possibility to use EVs for internal balancing and/or grid support. This is not only true for EVs but also for the deployment of other flexible sources such as batteries and heat pumps. The chapter investigates internal EV optimisation improving self-consumption or carrying out price arbitrage as well as external optimization aiming for market revenues. Internal EV optimization can be done without or as part of an energy community depending on the technical preconditions (e.g.,

availability of charging opportunities). External EV optimization needs a cooperation with an aggregator in case of RECs or can be directly done via CECs who are market actors. In the case of smart charging – also referred to as demand response, unidirectional charging – the charging pattern of an EV is adjusted (i.e., the EV's demand is shifted) based on a price signal from the overarching energy system or from the local grid. VTMG charging comprises bidirectional charging activities, in which power from an EV can also be fed back to the microgrid. With VTMG, EVs become "self-contained resources that can manage power flow and displace the need for electric utility infrastructure".

- **Price Responsive Charging**: It sees EVs adapt their load-shifting charging pattern based on real-time or time-of-use price signals. It lets EVs interact bi-directionally with the grid by adjusting their charging and discharging pattern and responding to real-time or time-of-use price signals, creating a significant monetisation opportunity. Finally, the congestion management and ancillary services with VTMG case applies the VTMG concept to EVs so they can participate in the congestion and ancillary markets.

- **Self-consumption Optimization**: targets the maximisation of households' power self-supply with renewable sources such as solar panels and EVs, which may be equipped with further flexibility sources.

- **Demand Response, Energy Storage and Generation**: Integrating variable renewable energy sources such as wind and solar requires a flexible microgrid. Integration studies have identified that demand response and energy storage are among a limited set of options. Storage and demand response provide means to better align wind and solar power supply with electricity demand patterns: storage shifts the timing of supply, and demand response shifts the timing of demand. These enabling technologies can reduce curtailment and facilitate higher penetrations. Furthermore, in addition, both storage and demand response can also provide operational flexibility. The associated significant implementation costs can be economized by the use of innovative technical solutions ecoTools being developed in the project with quantifying the value of the array of services— particularly the operational benefits such as ancillary services.

- **IoT Based Real Time Monitoring**: The benefits offered by IoT based real time monitoring system are many. Energy providers can deploy more efficient, reliable, and sustainable infrastructure, and adapt to varying environmental conditions like wind speed and sunlight. They can reduce downtime by introducing intuitive sensors and automation to boost forecasting and predictive maintenance. On the customer side, such systems can monitor consumption and regulate the flow of electricity, creating time and demand-based power supply. It would also facilitate charging schedules; help store energy and minimize wastage. A robust and capable monitoring system allows for the smooth relay of large amounts of data, better communications, and deployment of IoT-based predictive maintenance and operate efficiently at remote locations. From cutting-edge connectivity solutions, IoT, cloud computing, robotics, augmented and virtual reality and big data analytics, the latest digital innovations are helping to speed up the drive towards decarbonization significantly.

- **Residential Solar Pumps**: Unreliable electricity supply causes huge delays and economic stress among the farmers. A solar water pump is an application of photovoltaic technology to run the pumping system, replacing erratic grid supply and pollution-causing diesel-powered versions. The solar water pump is powered by solar modules that helps draw surface or ground water out for irrigation. Both DC and AC range of Solar Water Pumps are available for surface and submersible categories. These pumps help reduce farmers' dependency on expensive fuels and their maintenance costs as opposed to conventional irrigation systems. This can be a solely new revenue stream in between residential and commercial services like quasi-services for agricultural purposes. The local government would also be interested to incentivize such propositions by providing subsidies.

Following benefits may be derived by implementing the above proposed new business models for generating relatively new revenue streams for the local energy generators, energy service providers and local energy communities.

For local energy generators	For local energy communities
▪ Creating new revenue streams for existing community scale renewable generation projects like local solar/ wind/ biomass/ biogas. ▪ Creating opportunities for projects to expand, for example increasing their generation capacity or adding storage ▪ Improving the financial viability of new community scale renewable projects. ▪ Enabling more renewable generation to connect to a local network (where before there might not have been 'room'). ▪ Reducing the cost and how long it takes to get a new connection.	▪ Increasing access to participation, so more people benefit and get involved. ▪ Making more space in the energy network to support the electrification of heat and transport, and drive further carbon reductions. ▪ Widening the range of local energy strategies that communities and individuals can use to meet their needs, based on their local situation. For example, to use in conjunction with Peer-to-Peer electricity trading and energy efficiency initiatives. ▪ Creating new business opportunities for community-run energy services that increase income and support carbon reduction.

Table 26. Energy Generators and Energy Community Benefits

New Opportunities and Services

In this section, we will focus on business models that can be created when the Smart Sustainable Energy Communities uses RE-EMPOWERED ecoTools which comprises of nine innovative technical solutions for creation of local energy systems. These ecoTools assist in microgrid operation and are designed to different users. In this section, we will first look into the following nine ecoTools with their core functionalities and their potential revenue sources. Lastly, the new opportunities and services emerging out of innovative solutions and niche business modelling are presented.

The project could attract revenue from licenses of ecoTool's users and from consultancy services. For the definition of business models, we based our analysis only on the technical tools and technical UCs as they provide the new services which enable the creation of revenue streams. The Table 1 sums up the UCs used for the development of RE-EMPOWERED main services and business models. It is critical to identify the group of stakeholders in this project as well at four different demonstration sites for the deployment of the RE based technologies and innovation. Local people participation with local authorities will be of foremost importance for successful implementation and functioning of the isolated microgrid in India. Four categories of services were defined for the project, which target different stakeholders. Those four categories are:

1. Services for the Smart Sustainable Energy Community (SSEC).
2. Services for the Village Council i.e., Gram Panchayats, this is, basic village-governing entities in Indian villages. Gram Panchayat consists of ward members or Panchs elected or selected by the villagers as voters known as Gram Sabha. All the members of Gram Sabha also elect the Sarpanch or President of the Panchayat for five years. A secretary is also appointed by the government. Roles and responsibilities of Gram Panchayat include maintenance and construction of water resources, road, drainage, school, and common property resources. It levies and collect local taxes, execute government schemes related to employment, social issues, below poverty line benefits, etc.).
3. Services for the Energy Service Companies (ESCOs) and IoT company.
4. Services for the empowerment of end-consumers

For each of the above service, main actors have been identified: the SSEC, the prosumer (community member), the Village council and the ESCOs. In present scenario, the SSEC is considered as a market actor, being the supplier and aggregator of all members, managing and aggregating their demand energy response to bid on electricity market if allowed. Above services can be explored further suitable for the development and demonstration of the project.

	Activities	Cost	Revenue
Prosumers'	Membership of the SSEC Installation of microgrid, generation system, smart meters, etc. Provides NOC for any land utilization Installs internal wiring system Responds to DR requests	Availability of clean reliable energy for residential/ commercial purposes Saves money due to lower electricity bills by PV production and optimising self-consumption Saves money on fossil fuel significant expenditure	Pays for the electricity based on usage Pays for charging facility for the EVs Pays for the services provided by SSEC
Gram Panchayats (i.e. village governing entities)	Formation of SSEC and Executive Body election	Pays money for biomass fuel to villagers	Receives membership fees

	Activities	Cost	Revenue
	NOC for land acquisition and other clearances from local authorities Collection of biomass fuel from villagers		
SSEC	Monitoring and maintenance of the microgrid Tariff collection Offering various services to members and other actors Community asset ownership and management, energy trading, financial accounting Manages local production and storage units Offers flexibility, demand response services Monitors real-time grid conditions, load flow simulation and state estimation	Pays for microgrid system installation, generation, operation and maintenance Pays money for biomass fuel to villagers Pays money to Gram Panchayat (i.e. village governing entitiy) for availing and utilizing community resources to run microgrid	Receives money for energy supply
ESCOs/ IoT company	Reduces electricity costs through increased renewable production and flexibility services Adapts electricity demand Remunerates ancillary Services Improves local network conditions (increase network resilience) Provides network performance data using a series of KPIs Monitors real-time grid conditions, load flow simulation and state estimation Forecasts production and consumption of SSEC members	Penalty payment for any deviation from the committed provisions	Receives payments and remuneration for services provided to SSEC and its members

Table 27. Activities, Cost and Revenue of Main Actors

4.1.1. Regulatory background, renewable energy targets and energy efficiency

The State of West Bengal has as objective to reach 2,706 MW of capacity from renewable energy sources by 2022 (including cogeneration), according to the First Renewable Energy Policy, launched in 2012. The new revised Energy Policy 2016 included a new target of 5,336 MW by 2022, for solar PV power plants, including large scale grid connected projects and rooftop projects. Later, the target was reviewed to 4,500 MW. 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. By 2018, West Bengal had installed 80 MW of solar PV, and it is expected that, in a year, the state would have ramped to 200 MW, mainly driven by private stakeholders.

The power demand of West Bengal reaches 16,069.8 MW, produced by various institutions. 64% of the total capacity installed in the State is owned by the State. Additionally, 10.5 MW are generated from small IPP (Independent Power Producers)/CCP , and 29 MW from the WBSEDCL. Both generators use solar PV energy. The state utility WBSEDCL, transmission availability is 99.9%. The Government of West Bengal created the West Bengal Renewable Energy Development Agency (WBREDA), as well as the separate energy institute West Bengal Green Energy Development Corporation Limited (WBGEDCL), in Public-Private Partnership to increase the penetration of renewable energies in the State, by encouraging the investment of private sector.

Odisha has undertaken necessary policy formulation and implementation over past few years to propel growth of various RE vectors. 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 National Tariff Policy 2016, the Renewable Purchase Obligation (RPO) to reach 8% solar by 2022. In order to achieve targeted capacity in 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 under 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: 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: It is dedicated zones for development of solar power generation projects, solar manufacturing projects and R&D.

OREDA undertakes commercial feasibility of Biomass Power Projects with resource assessment and supply chain mechanism to identify biomass catchments in different parts of State. Government of Odisha will make land available to project developer according to IPR-2015. Waste and fallow lands may be allocated for plantations to meet up to 20% of annual biomass fuel requirement. State Government to develop Odisha Renewable Energy Development Fund (OREDF) for accelerated development of RE in State. According to Orissa Draft Renewable Energy Policy 2015-22, targets under policy are 2,300 MW solar and 180 MW biomass. Various incentives under Odisha Industrial Policy, 2007 provided, for power being sold to off-grid areas, an additional subsidy of INR 0.50/kWh will be provided for first three years of operation. Also, an incentive of INR 0.50 per unit to be provided on gross generation from systems installed by residential consumers. Further, exemption from electricity duty and cess for a period of 10 years from the date of commissioning will be given with waiver of some test charges.

Odisha Electricity Regulatory Commission amended Net Metering / Bi-directional Metering and their connectivity with respect to Rooftop Solar PV Projects. As, several issues such as group net metering, virtual net metering etc. have been raised by various stakeholders so Ministry of New and Renewable Energy (MNRE) requested States to issue guidelines. In addition, Ministry of Power, has made amendment to the Electricity (Rights of Consumers) Rules, 2020 and has capped the maximum Net Metering capacity of a Prosumer up to 500 kW or up to the sanctioned load, whichever is lower. After considering the notification of Ministry of Power and advisory of MNRE, as well as suggestions from various stakeholders, the Commission hereby made amendments to Net Metering/ Bi-Directional Metering/ Gross Metering/ Group Net Metering/ Virtual Net Metering and their connectivity with respect to Solar PV Projects 2016 (as amended up to 05.05.2022). 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.

4.1.2. Energy system and Business models in West Bengal and Odisha

Value propositions analysis for target market and access to finance are critical for microgrid growth and reach commercial viability to overcome incentive-based approach fostering replicability of micro-grids. Scope is to prove investment viability and reassure financing entities on potential customers’ ability to pay. Also, to adopt pricing models reducing customers’ expenditure in electricity substitutes accounting their perception of ex-ante costs and consumptions in familiar time dimension. Rural market penetration rate implies that bottom of pyramid remains under flat tariff threshold and electricity consumption. Investigations for business models applying integrated services are required.

- Reaching acceptable return on investment, achieve payback is fundamental for project feasibility in the piloting phase justifying its replicability.
- Appropriate financing structure leverage revenue streams/ cash flows ensuing **annual savings**.
- Operating cost-reflective tariffs to compensate for OPEX, adopts operational sustainability.
- Complementary activities (**business incubation, microcredit support, innovation accounting, technical trainings, awareness drives, knowledge, and data management**) are means to engage local communities, promote community inclusion, and pursue project sustainability.
- Benchmarking of proposed model will explore and translate subjective criteria into objective ones to be quantified and measured. Concept of lean start-up Build-Measure-Learn Feedback Loop for managing business model may be used for continuous improvement.

Business Model Archetype		Description
Existing BMs in practice	Power Purchase Agreements (PPAs)	Third party ownership model to procure, install, and operate solar PV system. PPAs allow reducing electricity costs and realizing increased savings over time. Consumers enter into an agreement to purchase the solar electricity produced by the system owned by the PPA provider at a predetermined rate per kilowatt-hour.
	Owner financing and maintenance	Facility owner to finance the project and then maintain the assets. Many grid-tied microgrids today use this business model, especially in market segment of campus/ institutional microgrids.
	Utility rate base	Utility to place the costs of designing, building, and maintaining a microgrid into its rate base. Deployment of microgrids by utilities within a grid-tied context is not a mature market. But the main goal of microgrid would be integration of distributed energy resources to help support reliability and resilience of the utility distribution system.
	O&M	O&M contracts are a common way to ensure microgrid performance. Microgrids not developed by utility or under owner financing and maintenance model, O&M contracts represent opportunities for both utilities and other vendors to capture relatively small revenue streams from microgrid deployments. Contracts are designed to maintain optimum performance and to become popular as microgrids move into mainstream.

Innovative BMs and Financing tools in few developed and developing countries with high future potential	Build-own-operate (BOO) or Build-own-operate-transfer (BOOT)	Private ownership projects operate through a build-own-operate, community ownership projects operate through a build-short operate-transfer. Latter addresses peculiarity of non-profit developers and assign the ownership to a local association/cooperative/ community-based organization as a partner in development via actual transfer of responsibility planned in project design.
	Direct Current (DC)	Most novel technological microgrid is developing a non-synchronous DC microgrid. It represents a completely different take on the microgrid business model, based on the disruptive technology of grid-tied, DC-based, non-synchronous microgrid architectures.
	Pay-as-you-go (PAYG)	Most unique business model in terms of financial innovation, aimed at accelerating progress on energy access front. Microgrid may be financed by several mechanisms, but customers pay for energy as they use it.
	Software as a Service (SaaS)	Software distribution model where a third-party provider hosts applications and makes them available to customers over Internet. SaaS is one of three main categories of cloud computing and deployed in few microgrids. Depending upon service level agreement, customer's data stored locally/ cloud or both and may become leading future platform.
	Microgrid-as-a-Service (MaaS) under Energy as a Service (EaaS)	New, industry-leading financing tool that enables organizations to deploy microgrids without any upfront investment. Besides, hardware and software, providers arrange financing and O&M agreements as affordable solution. Firms specializing in different microgrid technology (generation, automation, or controls) forms partnerships to offer new green power options, infrastructure modernization to commercial customers.
	Design, Build, Operate, Own, and Maintain (DBOOM)	Reliance upon one entity offering a comprehensive solution associated with upfront microgrid design and planning, construction, and ongoing operations e.g., Siemens, first private sector company became one stop shop.

Table 28. Business Model Archetype

4.2 Ghoramara Island Microgrid: West Bengal, India

4.2.1 Access and cost of energy supply in the Ghoramara island

Ghoramara island has no grid connectivity, and the only mode of transportation is ferry, which highly constraints the mobility creating logistic issues. It is also characterized by severe weather conditions posing a threat to the proposed 250 kW solar-wind (230 kW with conventional technology + 20 kW with RE-EMPOWERED technology) micro grid local system and the assets. In 2016, there were roughly 3,000 inhabitants in Ghoramara island and is about 5 km^2. The area is isolated form the main utility grid and inhabitants rely on kerosene lamps and some households have been able to install PV panels on the roofs. The region is severely affected every 5-10 years due to cyclonic storms that damage the roof-top PV panels that are situated in some households. There is no connection to the grid. The residents have no access to electricity, except for the production coming from some solar PV panels. Poor access to electricity in the community. Only a few households have access to electricity via the installation of roof-top PV panels. There is not a normal access to the Internet. PV panels are only used by a few households in the community. PV panels are difficult to obtain in the region. In general, setting large scale solar PV plants is difficult, due to the limited arid land.

4.2.2 Business Canvas and proposed Business models

Access to clean electricity will definitely enhance the welfare and quality of life of the people however, the impoverished population requires handholding for income generating avenues through the acquired electricity. It will provide clean energy for limited residential use and commercial purposes. Technical feasibility is critical for economic and financial viability of the project. Hence, with the help of local technical solutions (ecoTools) demonstrating novel state-of-the-art features will resolve specific issues and enhance efficiency with better management of the micro grid:

- 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.

Low-cost hardware is often installed to keep tariffs affordable, but the combination of less efficient hardware, deficient technical training, lack of spare and replacement parts, and late payments often contributes to reducing the life span of systems. The proposed business plan will be geared to accommodate real time challenges toward long term sustainability. For instance, 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. Moreover, such novel multiple technology expertise with demonstrated competencies motivates the consumers to pay guaranteed or shared savings fees to ESCOs. Many a times actual saving is much lower than forecasted which can be checked by the consumers via developed software with consumer interface to choose from the energy scenarios based on dynamic pricing. Further, the plug-and-play modular devices not only develops operational simplicity but also allows quick fault detection and maintainability.

With the given hardware and software proprietary technology, it becomes pertinent to evaluate the economic viability form business perspective. It can be elaborated in two ways, first the ownership business model for the micro grid and secondly the business and commercial potential that it can create among the communities of Ghoramara with a clear sustainable socioeconomic impact in long run. This section will describe both the aspects of business modelling for the energy community.

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 while 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).

The project aims to build entrepreneurship within the community and network with other enterprises and industry outside the island for effective monetary growth and rotation. Well planned and executed strategies will lead to pro-business environment for emerging new businesses like rice hullers; additional fishing due to electric boats; extended operation hours to shops. It may multiply the revenue streams by diversifying into monetary generation from charging stations, logistics and transportation to and from nearby islands and mainland, ecotourism, poultry farming.

A user-friendly ecosystem for electricity generation and transmission, which could be operated directly by the village community will be created. This will help the locals to gain necessary skills to operate their own electricity generation, transmission and maintenance of plant. It is realised that there is a need for local interface to ensure last mile connectivity as it facilitates to generate awareness, to build trust and transparency. Therefore, training and skilling becomes an integral activity to be engaged as technical support, customer service agents, local entrepreneurs, across the value-chain. Novel financing options model will be tested for offering end to end energy solutions by enabling door-step financing and door-step servicing with integration of microfinancing elements for providing customised solution. Such model will become a de-facto guideline for project developers and energy service providers in rural areas characterizing high scalability and replicability potential. Therefore, business model will be tested and benchmarked over time leading to standardisation of processes and protocols. Since, ESCOs have used varying methods of repayment and financing including vendor financing, direct ownership, energy service contracts, power purchase agreements, debt financing, and other alternative energy financiers, the business model will explore in-depth to incorporate all-inclusive elements factoring to implementation of best business practices.

A commonly applied business model is the user cooperative, which involves the establishment of a non-profit community organization owned and managed by its members. It acts as an ESCO, providing services under a fee-for-service system. The user cooperative owns and maintains the system, and users pay a fee for electricity consumed, including the power used to charge batteries. 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 will be 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 will therefore depend on the state of the infrastructure, the local energy resource, and the geographic setup of the remote rural area.

The following business model canvas is explored and presented based on the initial information, primary field survey, current development progress of technical solutions with deployment plans and their integration architecture.

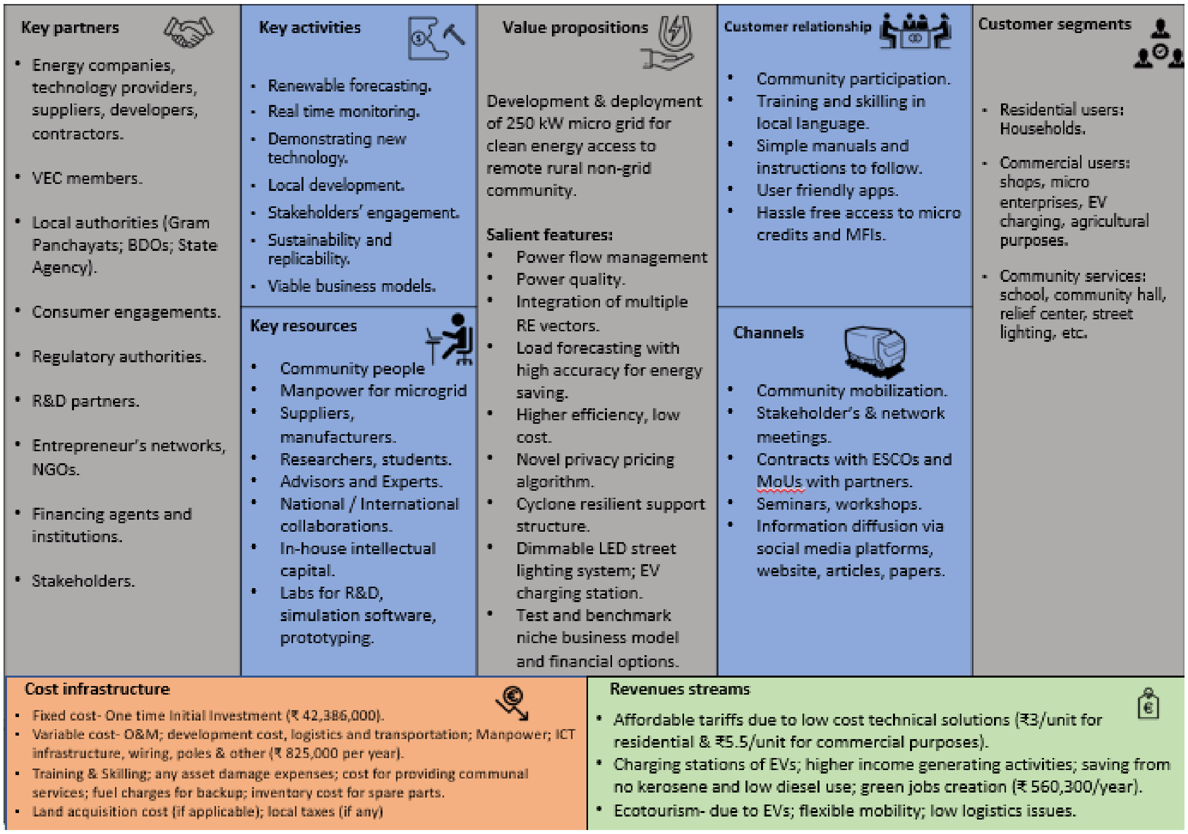

Figure 27. Business Canvas Model for Ghoramara island, India

4.2.3 Financing tools applicable to the demo site

Economic and financial model for Ghoramara Island microgrid

Following are the information details based on the data collected from the demo site leader through a questionnaire and further by interactive meetings and discussions. Some assumptions have been considered as the microgrid is yet to be deployed and demonstrated in the Ghoramara island, therefore data points are estimates:

AC microgrid # 1 (Phase-1): 155 kW capacity (150 kW PV + 5 kW Wind, 700 kWh BESS).

AC microgrid # 1 (Phase-2): 75 kW capacity (70 kW PV + 5 kW Wind, 500 kWh BESS).

AC microgrid # 2: 20 kW capacity (17.5 kW PV + 2.5 kW Wind, 100 kWh BESS).

- Number of Households (HHs): 1100 having 0.57 kWh/ day/ family for 365 days.
- Number of Microenterprises to be developed: 50 units.
- Number of e-boats: 1 unit having 15 pax and increase by one unit in every 5 years.
- Wind turbine: 2 units, 5 kW.
- One Charging Facility (3 ports, 11 kW).
- Conventional Smart Meters: 50 no. and Smart meters with advanced features: 5 no.
- Mini Rice-Flour Huller Mill: 1 unit, 3 HP, 70% power rating.
- Dimmable street lights with common features: 80 units (60 non-dimmable & 20 dimmable) and Dimmable street lights with advanced features: 5 no.
- One IoT based remote monitoring system.
- Residential Tariff is ₹ 3 per unit (€0.036).
- Commercial Tariff s ₹ 5.5 per unit (€0.066).
- Solar pumps: 2 no. with 1.8 kW, 60% power rating and increase by 2 no. in every 5 years.
- Lifetime of Microgrid is 20 years.
- Discount rate considered is 10%.
- Minimum Alternate Tax (MAT) is 15% and Surcharge is 7%.

Type	No.	Description	Yearly Electricity Bill
No. of HHs	1100		₹ 6,86,565, €8,272
No. of Microenterprises	50	2 No. 10 W LED for 4 hours/ day & 1 No. 30 W Fan	₹ 22,000, €265
No. of e-boats (20 pax.)	01	20 kWh/ day for 365 days	₹ 40,000, €482
No. of e-4 wheelers	02	6.3 kWh/ day for 365 days	₹ 76,000, €916
No. of Solar Pumps	02	6 hours/ day for 300 days	₹ 25,000, €301
Mini Rice - Flour Huller Mill	01	8 hours/ day for 250 days	₹ 24,000, €289
Poultry Farm	01	48 kWh/ day for 365 days	₹ 96,000, €1,157

Type	No.	Description	Yearly Electricity Bill
Recovery from other Earnings (e-boat/ vehicle renting)		at ₹ 600/ day (€7.23/day) & ₹ 150/day/ (€1.81/day) per 3-wheelers for 365 days	₹ 3,28,000, €3,952
Savings from Kerosene oil for lightning 2 lamps	0.5 litre/ day	₹ 30/ day, €0.36/day (Open Market Rate)	₹ 60,22,500, €72,560
Savings from cost of diesel and oil for one ferry (8 trips in total per day approx. 140 Km per day)	30 litres/ day & INR 2000/ month for oil	₹ 96/ litre, €1.16/litre	₹ 10,73,200, €12,930
Total Yearly Commercial Electricity Revenue	**Per Annum**		**₹ 6,11,000, €7,361**
Total Electricity Revenue	**20 years**		**₹ 2,59,51,300, €312,666**
Initial Investment of 250 kWp solar-wind microgrid with 1400kWh Battery	One time	₹ 3,09,41,000, €372,783	
Deployment of other infrastructure & ecoTools	One time	₹ 1,14,45,000, €137,892	
Total Capital Expenditure	One time	₹ 4,23,86,000, €510,675	
O&M @ ₹ 15000 for Supervisor & ₹ 10000 for Field Assistant per year	20 years	₹ 60,00,000, €72,289	
Other Administrative cost	20 years	₹ 20,00,000, €24,096	
Battery replacement	One time in 20 years	₹ 80,00,000, €96,386	
O&M Costs of Existing Equipment and ecoTools	Per Annum	₹ 5,00,000, €6,024	
Total O&M Expenditure	**20 years**	**₹ 1,65,00,000, €198,795**	
Total Yearly O&M Expenditure	**Per Annum**	**₹ 8,25,000, €9,940**	

Table 29. Estimates and Assumptions considered, Ghoramara Island

The economic modelling has been done in-order to understand the feasibility and the viability of the microgrid with the proposed technical solutions. Various financial ratios have been estimated like Net Present Value (NPV), Internal Rate of Return (IRR), Payback period etc. to generate deeper insights for the implementation of proposed new business models and service for new revenue generation and stacking streams with lowering of the cost in long term perspective.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Initial investment	-₹ 4,23,86,000.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0
Total O&M Expenditure	₹ 0.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0
Depreciation and Amortization	₹ 0.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0
Residential Revenue	₹ 0.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0
Commercial Revenue (E-vehicle charging, microenterprises, mill, poultry, others)	₹ 0.0	₹ 5,60,300.0	₹ 5,60,300.0	₹ 5,60,300.0	₹ 5,60,300.0	₹ 6,25,300.0	₹ 6,25,300.0	₹ 6,25,300.0	₹ 6,25,300.0	₹ 6,25,300.0	₹ 6,90,300.0
VEC Membership (@10 INR/ HH)	₹ 0.0	₹ 11,000.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0
Community asset maintenance (@300 INR/ HH/ year)	₹ 0.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0
Savings from Kerosene oil for lightning	₹ 0.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0
Savings from Cost of Diesel	₹ 0.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0
Profit Before Tax	₹ 0.0	₹ 57,39,265.0	₹ 57,28,265.0	₹ 57,28,265.0	₹ 57,28,265.0	₹ 57,93,265.0	₹ 57,93,265.0	₹ 57,93,265.0	₹ 57,93,265.0	₹ 57,93,265.0	₹ 58,58,265.0
Surcharge	₹ 0.0	-₹ 4,01,748.6	-₹ 4,00,978.6	-₹ 4,00,978.6	-₹ 4,00,978.6	-₹ 4,05,528.6	-₹ 4,05,528.6	-₹ 4,05,528.6	-₹ 4,05,528.6	-₹ 4,05,528.6	-₹ 4,10,078.6
Minimum Alternate Tax (MAT)	₹ 0.0	-₹ 8,60,889.8	-₹ 8,59,239.8	-₹ 8,59,239.8	-₹ 8,59,239.8	-₹ 8,68,989.8	-₹ 8,68,989.8	-₹ 8,68,989.8	-₹ 8,68,989.8	-₹ 8,68,989.8	-₹ 8,78,739.8
Net Cash Flow	-₹ 4,23,86,000.0	₹ 65,95,926.7	₹ 65,87,346.7	₹ 65,87,346.7	₹ 65,87,346.7	₹ 66,38,046.7	₹ 66,38,046.7	₹ 66,38,046.7	₹ 66,38,046.7	₹ 66,38,046.7	₹ 66,88,746.7
Cummulative Cash Flow	-₹ 4,23,86,000.0	-₹ 3,57,90,073.3	-₹ 2,92,02,726.6	-₹ 2,26,15,379.9	-₹ 1,60,28,033.2	-₹ 93,89,986.5	-₹ 27,51,939.8	₹ 38,86,106.9	₹ 1,05,24,153.6	₹ 1,71,62,200.3	₹ 2,38,50,947.0

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Initial investment	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0
Total O&M Expenditure	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0	-₹ 8,25,000.0
Depreciation and Amortization	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0	-₹ 21,19,300.0
Residential Revenue	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0	₹ 6,86,565.0
Commercial Revenue (E-vehicle charging, microenterprises, mill, poultry, others)	₹ 6,90,300.0	₹ 6,90,300.0	₹ 6,90,300.0	₹ 6,90,300.0	₹ 7,55,300.0	₹ 7,55,300.0	₹ 7,55,300.0	₹ 7,55,300.0	₹ 7,55,300.0	₹ 7,55,300.0
VEC Membership (@10 INR/ HH)	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0	₹ 0.0
Community asset maintenance (@300 INR/ HH/ year)	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0	₹ 3,30,000.0
Savings from Kerosene oil for lightning	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0	₹ 60,22,500.0
Savings from Cost of Diesel	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0	₹ 10,73,200.0
Profit Before Tax	₹ 58,58,265.0	₹ 58,58,265.0	₹ 58,58,265.0	₹ 58,58,265.0	₹ 59,23,265.0	₹ 59,23,265.0	₹ 59,23,265.0	₹ 59,23,265.0	₹ 59,23,265.0	₹ 59,23,265.0
Surcharge	-₹ 4,10,078.6	-₹ 4,10,078.6	-₹ 4,10,078.6	-₹ 4,10,078.6	-₹ 4,14,628.6	-₹ 4,14,628.6	-₹ 4,14,628.6	-₹ 4,14,628.6	-₹ 4,14,628.6	-₹ 4,14,628.6
Minimum Alternate Tax (MAT)	-₹ 8,78,739.8	-₹ 8,78,739.8	-₹ 8,78,739.8	-₹ 8,78,739.8	-₹ 8,88,489.8	-₹ 8,88,489.8	-₹ 8,88,489.8	-₹ 8,88,489.8	-₹ 8,88,489.8	-₹ 8,88,489.8
Net Cash Flow	₹ 66,88,746.7	₹ 66,88,746.7	₹ 66,88,746.7	₹ 66,88,746.7	₹ 67,39,446.7	₹ 67,39,446.7	₹ 67,39,446.7	₹ 67,39,446.7	₹ 67,39,446.7	₹ 67,39,446.7
Cummulative Cash Flow	₹ 3,05,39,693.7	₹ 3,72,28,440.4	₹ 4,39,17,187.1	₹ 5,06,05,933.8	₹ 5,73,45,380.5	₹ 6,40,84,827.2	₹ 7,08,24,273.9	₹ 7,75,63,720.6	₹ 8,43,03,167.3	₹ 9,10,42,614.0

NPV	₹ 14,172,323.18	170,750.88 €
IRR (%)	14.630%	14.630%
First positive accumulated cash flow	₹ 3,886,106.9	46,820.57 €
Payback (years)	Year 7	Year 7

Table 30. Economic model for the Ghoramara Island Microgrid, including the cash flow mode and a profitability analysis.

The financial modelling clearly shows that the microgrid at Ghoramara island is a viable business proposition with a positive NPV value and a higher IRR of 14.63% which is greater than the 10% discounting rate which shows higher ROI in the form of profitability along with the initial cost recovery with O&M expenditures. Payback period is seven years. Major component is in the form of savings on the current consumption of diesel and oil for commercial as well as residential purposes. Thereby, providing concrete revenue streams for the electric charging facility for the ecoVehicle to be deployed in the demo site.

4.3 Keonjhar Microgrid: Odisha, India

4.3.1. Access and cost of energy supply in Keonjhar microgrid

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. At present these villages are not connected to the main utility grid. The proposed site is ideal as a test bed and demonstration site as it already has some basic renewable energy facilities. These will be 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. Promote off-grid systems in selected remote villages to create support ecosystems to promote income-generating energy uses in agriculture and small businesses. Increase of population awareness and customer engagement, such that rural to urban migration is minimized.

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 tube lights and a fan. These solar PV installations are completely isolated. 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 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.

In this demo site various energy vectors such as electricity from solar PV, biomass and storage will be integrated with the existing PV system. The proposed 40 kWp microgrid system will be primarily used for livelihood activities apart from household supply. The main challenge is to design power converters with high efficiency at low power range. The field test is anticipated to demonstrate optimized use of renewable PV solar and biomass power by means of stiff DC-link control capability in standalone mode. 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.

4.3.2. Business Canvas and proposed Business model

In the Keonjhar District of Odisha – three villages viz., Kanheigola, Nola and Ranipada – are supplied with clean energy of 77 kWp isolated solar micro grid to approximately 1,000 people. The project proposes to upgrade this existing infrastructure through indigenously developed technology by deploying secondary 50kW micro grid comprising various renewable energy vectors with a mix of PV, Biomass and Biogas, a unique local energy solution. 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.

State-of-the-art hardware and software solutions will be tested not only for technical upscaling but also for economic viability having higher efficiency coupled with low cost. This will enhance access to clean energy mostly for commercial activities by replacing fossil fuel and build new income streams in the involved community. Novel product features enables the users and operators for responsible energy consumption as well as production conditions. Seamless integration and interoperability allow low outages while providing cumulative saving, optimal usage with high satisfaction rate. This will make RE micro grid community systems attractive and feasible to serve low-income tier customers and will encourage rational fiscal and promotional incentives facilitating private investment on account of increasing market characterized with sufficient internal rate of returns.

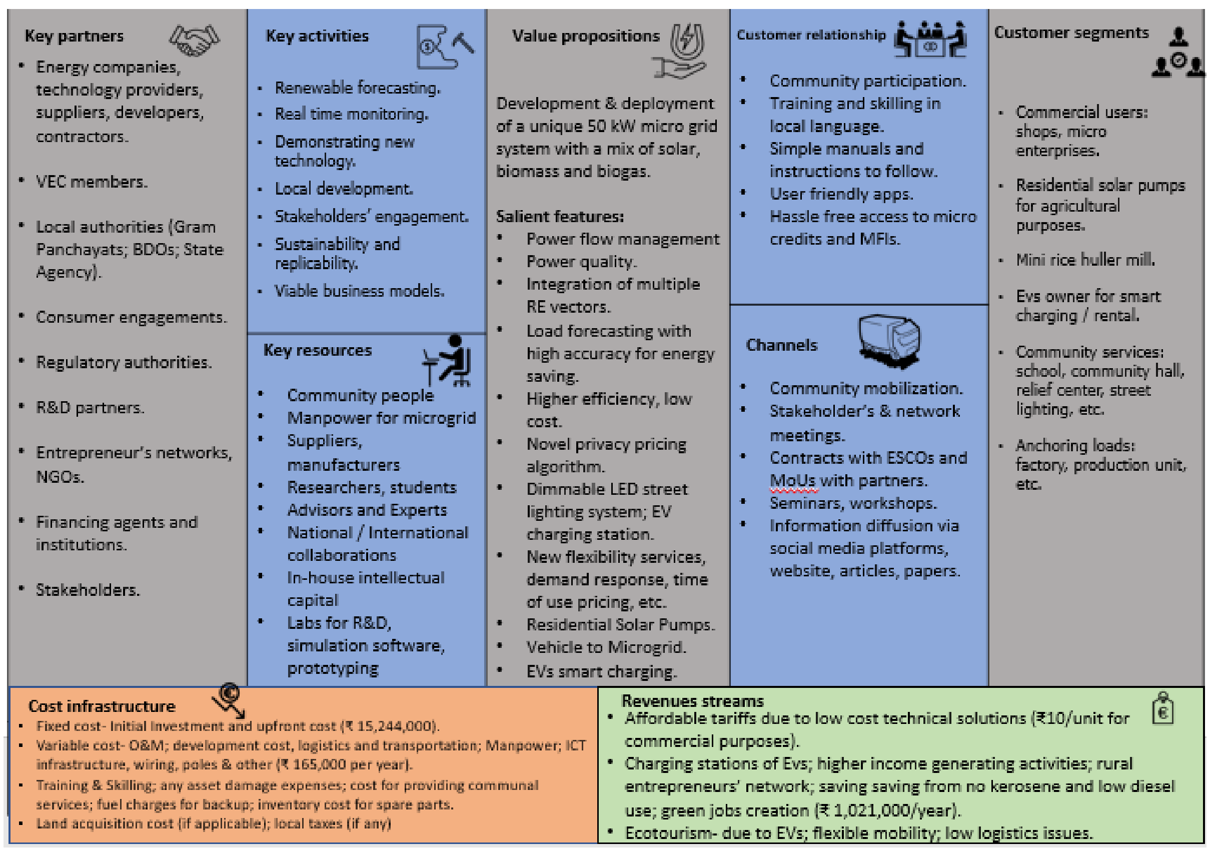

Figure 28. Business Canvas Model for Keonjhar, India

The proposed business model will establish sustainability by addressing current challenges with a scope to configure and deliver measurable impact towards livelihood creation, entrepreneurship development, social upliftment, reduce migration, better health, and education, etc. To enable such deep impact, it is imperative that the proposed technical solutions are demonstrated successfully with continuous operation and maintenance support. This will be achieved by capacity building of the local community members by imparting technical knowledge, training, and skilling. Possible scenarios for dynamic pricing may be estimated from advanced forecasting algorithms to offer affordable tariffs from consumption patterns. IoT remote monitoring will further equip the service providers to exercise some control and data management.

4.3.3. Financing tools applicable to the demo site

Economic and financial model for Keonjhar microgrid

Following are the information details based on the data collected from the demo site leader through a questionnaire and further by interactive meetings and discussions. Some assumptions have been considered as the microgrid is yet to be deployed and demonstrated in the Keonjhar, therefore data points are estimates:

- No. of Households (HHs): 75 having 100 W per HH.
- No. of Microenterprises to be developed: 25 units.
- No. of e-3 wheeler: 2 no. and increase by 3 no. in every 5 years.
- One Charging Facility (2 ports, 1.5 kW, 48V).
- Mini Rice Huller Mill: 3 no., 1 HP (0.7457 kW).
- Solar powered dimmable lights: 20 units.
- Smart meters with Fuse and MCCB/ MCB: 20 units.
- One IoT based remote monitoring system.
- Residential Electricity Tariff is not applicable and is free.
- Commercial Tariff s ₹ 10 (€0.12) per unit.
- Solar pumps: 2 no. and increase by 2 no. in every 5 years.
- Lifetime of Microgrid is 20 years.
- Discount rate considered is 10%.
- Minimum Alternate Tax (MAT) is 15% and Surcharge is 7%.

Type	No.	Description	Yearly Electricity Bill
No. of HHs	**75**	100W/ HH	**₹ 0 (€0)**
No. of Microenterprises	25	₹ 1000/ month (€12/month) for 8 hours/ day	₹ 3,00,000 (€3,614)
No. of e-3 wheelers	03	3 wheeler charging at ₹ 7,500/ month (€90/month)	₹ 2,70,000 (€3,253)
No. of Solar Pumps (1 HP)	02	11.768 units / 8 hours for 300 days	₹ 35,000 (€422)
Mini Rice Huller Mill	03	₹ 7,000 (€84)/ month/ mill for 8 hours/ day	₹ 2,52,000 (€3,036)
Recovery from other Earnings (e-vehicle renting)	At ₹ 150 (€1.81)/ day/ per three-wheelers for 365 days	₹ 1,64,000 (€1,976) for 3 no.	₹ 1,64,000 (€1,976)
Total Yearly Commercial Electricity Revenue	**Per Annum**		**₹ 10,21,000 (€12,301)**
Total Electricity Revenue	**20 years**		**₹ 2,04,20,000 (€246,024)**
Savings from Kerosene oil for lightning 2 lamps	0.5 litre/ day	₹ 30 (€0.36)/ day (Open Market Rate)	₹ 4,11,000 (€4,952)
Savings from cost of diesel	8 litres/ day	₹ 96/ litre (€1.16/litre)	₹ 2,80,000 (€3,373)
Initial Investment of 50 kWp solar-biomass-biogas microgrid with 150kWh Battery	One time	₹ 1,15,00,000 (€138,554)	
Deployment of other infrastructure & ecoTools	One time	₹ 34,94,000 (€42,096)	
Electric 3 wheelers and Charging Station Cost	One time	₹ 2,50,000 (€3,012)	
Total Capital Expenditure	**One time**	**₹ 1,52,44,000 (€183,663)**	
Cost of Fuel (Biomass/ Biogas)	₹ 10,000 (€120)/ month	₹ 1,20,000 (€1,446)	
O&M @ ₹ 15000 for Supervisor & @ ₹ 10,000 for Field Assistant per year	Per Annum	₹ 3,00,000 (€3,614)	
Other Administrative cost	20 years	₹ 20,00,000 (€24,096)	
Battery replacement	One time in 20 years	₹ 10,00,000 (€12,048)	
O&M Costs of Existing Equipments and ecoTools	Per Annum	₹ 3,00,000 (€3,614)	
Total Operational Expenditure	**20 years**	**₹ 33,00,000 (€39,759)**	
Total Yearly Operational Expenditure	**Per Annum**	**₹ 1,65,000 (€1,988)**	

Table 31. Estimates and Assumptions considered, Keonjhar Microgrid

The economic modelling has been done in-order to understand the feasibility and the viability of the microgrid with the proposed technical solutions. Various financial parameters have been estimated like NPV, IRR, Payback period etc. to generate deeper insights for the implementation of proposed new business models and service for new revenue generation and stacking streams with lowering of the cost in long term perspective.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Initial investment	-₹1,52,44,000.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0
Total O&M Expenditure	₹0.0	₹0.0	₹0.0	₹0.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0
Cost of Fuel (Biomass/ Biogas)	₹0.0	₹0.0	₹0.0	₹0.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0
Manpower Cost	₹0.0	₹0.0	₹0.0	₹0.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0
Depreciation and Amortization	₹0.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0
Commercial Revenue (E-vehicle charging, microenterprises, mill, others)	₹0.0	₹10,21,000.0	₹10,21,000.0	₹10,21,000.0	₹10,21,000.0	₹13,26,000.0	₹13,26,000.0	₹13,26,000.0	₹13,26,000.0	₹13,26,000.0	₹16,31,000.0
VEC Membership (@10 INR/ HH)	₹0.0	₹750.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0
Community asset maintenance (@300 INR/ HH/ year)	₹0.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0
Savings from Kerosene oil for lightning	₹0.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0
Savings from Cost of Diesel	₹0.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0
Profit Before Tax	₹0.0	₹12,80,870.0	₹12,80,120.0	₹12,80,120.0	₹6,95,120.0	₹10,00,120.0	₹10,00,120.0	₹10,00,120.0	₹10,00,120.0	₹10,00,120.0	₹13,05,120.0
Surcharge	₹0.0	-₹89,660.9	-₹89,608.4	-₹89,608.4	-₹48,658.4	-₹70,008.4	-₹70,008.4	-₹70,008.4	-₹70,008.4	-₹70,008.4	-₹91,358.4
Minimum Alternate Tax (MAT)	₹0.0	-₹1,92,130.5	-₹1,92,018.0	-₹1,92,018.0	-₹1,04,268.0	-₹1,50,018.0	-₹1,50,018.0	-₹1,50,018.0	-₹1,50,018.0	-₹1,50,018.0	-₹1,95,768.0
Net Cash Flow	-₹1,52,44,000.0	₹17,61,278.6	₹17,60,693.6	₹17,60,693.6	₹13,04,393.6	₹15,42,293.6	₹15,42,293.6	₹15,42,293.6	₹15,42,293.6	₹15,42,293.6	₹17,80,193.6
Cummulative Cash Flow	-₹1,52,44,000.0	-₹1,34,82,721.4	-₹1,17,22,027.8	-₹99,61,334.2	-₹86,56,940.6	-₹71,14,647.0	-₹55,72,353.4	-₹40,30,059.8	-₹24,87,766.2	-₹9,45,472.6	₹8,34,721.0

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Initial investment	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0
Total O&M Expenditure	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0	-₹1,65,000.0
Cost of Fuel (Biomass/ Biogas)	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0	-₹1,20,000.0
Manpower Cost	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0	-₹3,00,000.0
Depreciation and Amortization	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0	-₹7,62,200.0
Commercial Revenue (E-vehicle charging, microenterprises, mill, others)	₹16,31,000.0	₹16,31,000.0	₹16,31,000.0	₹16,31,000.0	₹19,36,000.0	₹19,36,000.0	₹19,36,000.0	₹19,36,000.0	₹19,36,000.0	₹22,41,000.0
VEC Membership (@10 INR/ HH)	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0	₹0.0
Community asset maintenance (@300 INR/ HH/ year)	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0	₹3,30,000.0
Savings from Kerosene oil for lightning	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0	₹4,11,000.0
Savings from Cost of Diesel	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0	₹2,80,320.0
Profit Before Tax	₹13,05,120.0	₹13,05,120.0	₹13,05,120.0	₹13,05,120.0	₹16,10,120.0	₹16,10,120.0	₹16,10,120.0	₹16,10,120.0	₹16,10,120.0	₹19,15,120.0
Surcharge	-₹91,358.4	-₹91,358.4	-₹91,358.4	-₹91,358.4	-₹1,12,708.4	-₹1,12,708.4	-₹1,12,708.4	-₹1,12,708.4	-₹1,12,708.4	-₹1,34,058.4
Minimum Alternate Tax (MAT)	-₹1,95,768.0	-₹1,95,768.0	-₹1,95,768.0	-₹1,95,768.0	-₹2,41,518.0	-₹2,41,518.0	-₹2,41,518.0	-₹2,41,518.0	-₹2,41,518.0	-₹2,87,268.0
Net Cash Flow	₹17,80,193.6	₹17,80,193.6	₹17,80,193.6	₹17,80,193.6	₹20,18,093.6	₹20,18,093.6	₹20,18,093.6	₹20,18,093.6	₹20,18,093.6	₹22,55,993.6
Cummulative Cash Flow	₹26,14,914.6	₹43,95,108.2	₹61,75,301.8	₹79,55,495.4	₹99,73,589.0	₹1,19,91,682.6	₹1,40,09,776.2	₹1,60,27,869.8	₹1,80,45,963.4	₹2,03,01,957.0

NPV	-₹ 768,904.54	-9,263.91 €
IRR (%)	9.286%	9.286%
First positive accumulated cash flow	₹ 834,721.0	10,056.88 €
Payback (years)	Year 10	Year 10

Table 32. Economic model for the Keonjhar Microgrid, including the cash flow mode and a profitability analysis.

The financial modelling clearly shows that the microgrid at Keonjhar shows a negative NPV value with an IRR of 9.29% which is very close to the 10% discounting rate. This analysis clearly demonstrates that the microgrid in-order to be a sustainable business proposition must generate additional and new revenue streams like from flexibility services, demand response, e-mobility and transportation, etc. beyond the traditional revenue generation. Hence, for the ROI and profitability along with recovery of the initial cost and O&M expenditures requires more subsidized access to finance and implementation of niche services within and outside the community by creating positive externalities. Since residential electricity is provided free for the operation of the microgrid hence commercial services needs to be emphasized more with efficient energy system by providing reliable and quality energy services.

5. Conclusions

The main objective of WP8 is the design, development and testing of new business models which will enable the development of new renewable energy projects, energy communities, and demand response mechanisms in isolated energy systems and energy islands.

In this direction, special focus is put on the final users of the energy system: the prosumers. The involvement of citizens can be achieved through active engagement, fostering the participation in energy communities, and developing new business models.

In this Deliverable, business models have been studied for each demo site, including 3 demo sites in the European Union (Kythnos Island in Greece, Gaidouromantra microgrid as a particular case of Kythnos, Bornholm Island in Denmark), and 2 demo sites in India (Ghoramara island in West Bengal and Keonjhar microgrid in Odisha). The candidate business models are adapted to the special characteristics of each demo site, considering how energy users are provided with the energy supply, the costs which they are usually charged, and tools to increase their engagement.

Moreover, economic models have been developed for each ecoTool and demo site, to evaluate the economic viability of such tools, and to propose very preliminary commercialization plans (to be updated in Task 9.3).

As a result of the carried-out analyses, it can be seen that, although the costs of energy for citizens can increase due to the use of the new business models, this will lead to a reduction of the energy costs for the whole electric system, and citizens will benefit from a more stable and secure energy supply. Besides, additional services can be offered, and their participation in the energy system can be increased.

This deliverable has included the first results of Work Package 8, from the work carried out during the first 18 months of the RE-EMPOWERED project. However, these results have to be refined as the development of the ecoTools continue in the RE-EMPOWERED project. As soon as the ecoTools are finished and tested, the used hypotheses can change and be improved. For this reason, in Month 39, the Deliverable 8.2 “Report on the business models and financing tools (V2)” will be prepared, including a review and update of the business models and economic models according to the advances made concerning each ecoTool and Demo Site.

It should also be noted that the results from Deliverable 8.1 will provide input to WP9 “Dissemination and exploitation”, specifically in the Task 9.3 “Exploitation and commercialization analysis”, and Deliverable 9.3 “Report on exploitation and commercialization analysis (V1)”, due in month 24.

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