BestRES

Best practices and implementation of innovative business models for renewable energy aggregators

Life Cycle Analysis (LCA) of the improved Business Models

Authors: Simon De Clercq and Carlos Guerrero Lucendo (3E)

Co-Authors: Daniel Schwabeneder, Carlo Corinaldesi and Georg Lettner (TUW-EEG)

Contributors:
Daniel Schwabeneder and Carlo Corinaldesi (TUW-EEG)
Danelle Veldsman & Geraldine Carpentier (Good Energy)
Julian Kretz (Next Kraftwerke Germany)
Elias De Keyser (Next Kraftwerke Belgium)
Maximilian Kloess and Friedrich Diesenreiter (oekostrom)
José Rui Ferreira and Gisela Mendes (EDP Portugal)
Venizelos Efthymiou (FOSS)

Reviewers:
Ruben Baetens and Achim Woyte (3E)
Silvia Caneva and Pablo Alonso (WIP)

December 2018
www.bestres.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Acknowledgement

This report has been produced within the BestRES project "Best practices and implementation of innovative business models for Renewable Energy aggregators".

The logos of the partners cooperating in this project are shown below and information about them is available in this report and on the website: www.bestres.eu

This report has been written by Simon De Clercq (3E) and Carlos Guerrero Lucendo (3E). The authors thankfully acknowledge the valuable contributions from all project partners, especially from Daniel Schwabeneder (TUW-EEG) and Carlo Corinaldesi (TUW-EEG) to complete this report.

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 691689. The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither INEA nor the European Commission are responsible for any use that may be made of the information contained therein. While this publication has been prepared with care, the authors and their employers provide no warranty with regards to the content and shall not be liable for any direct, incidental or consequential damages that may result from the use of the information or the data contained therein. Reproduction is authorized providing the material is unabridged and the source is acknowledged.

Contacts

Project coordinator

Silvia Caneva, Ingrid Weiss & Pablo Alonso
WIP – Renewable Energies
Sylvensteinstrasse 2, Munich, Germany

Email: silvia.caneva@wip-munich.de
Email: cathal.cronin@wip-munich.de
Email: pablo.alonso@wip-munich.de

Author(s)

Simon De Clercq (3E) and Carlos Guerrero Lucendo (3E)

Kalkkaai 6 Quai à la Chaux
1000 Brussels, Belgium

Email:
info@3E.eu
Simon.DeClercq@3E.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Table of contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

List of Figures

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

List of Tables

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

List of abbreviations and acronyms

aFRR	automatic Frequency Restoration Reserve
B2B	Business-to-business
BEMS	Building Energy Management System
BM	Business Model
BRP	Balance Responsible Party
DSO	Distribution System Operator
FOSS	Research Centre for Sustainable Energy – University of Cyprus
GHG	Greenhouse gas
GW	Gigawatt
KPI	Key Performance Indicator
kWh	Kilowatt hour
LCA	Life Cycle Assessment
MGP	Mercato del Giorno Prima
MSD	Mercato per il Servizio di Dispacciamento
MW	Megawatt
MWh	Megawatt hour
NKW BE	Next Kraftwerke Belgium
NKW DE	Next Kraftwerke Germany
PV	Photovoltaic
R3	mFRR - manual Frequency Restoration Reserve
RES	Renewable Energy Sources
REScoop	Renewable Energy Source Cooperative
SLP	Synthetic Load Profile
tCO_2	Tonne CO_2
ToU	Time of Use
TSO	Transmission System Operator
TUW-EEG	TU Wien - Energy Economics Group

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

TWh	Terawatt hour
UCY	University of Cyprus
UK	United Kingdom
UVAC	Aggregate Virtual Consumption Units
UVAM	Aggregate Mixed Virtual Production including consumption, storage and production units
UVAP	Aggregate Virtual Production Units
VAT	Value Added Tax

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Executive summary

The aim of a life cycle assessment (LCA) for sustainable business models (BMs) is to quantify the created value of a BM in terms of economic, social, environmental and technical indicators. In general, a LCA consists of the different steps shown in Figure 3. In the first step, the goal and scope of the LCA are defined. The input and output streams, in terms of BM-specific Key Performance Indicators (KPIs), are quantified in the inventory step. This includes the required energy and raw resources as well as the generated waste. The impact assessment then addresses the economic, environmental, social and technical effects of these resource streams on the biosphere.

Figure 1: Life Cycle Assessment Methodology

In this study, the life cycle of a business model is interpreted from a business economic point of view. A BM will consecutively go through the stages 'launch', 'growth', 'shake-out' and 'maturity' before it either renews or declines. This LCA studies the BM's development from the launch moment to the maturity stage, conceptualised as a large-scale rollout of each of the BMs in the respective national power system.

Table 3 gives an overview of each of the BestRES BMs. The reader is referred to BestRES report "Improved Business Models of selected aggregators in target countries" [1] for a complete description of the BestRES BMs.

Table 1: Analysed BestRES BMs

		Brief description
Good Energy (UK)	Automation and control	Use the available flexibility from residential customers on a time variable tariff
	Peer-to-peer (local) energy matching	Match local electricity production and consumption on a regional level
Next Kraftwerke Germany (Germany)	Dispatch flexible generation under changing market design on multiple markets	Optimise the participation of flexible decentralised generation on electricity markets in Germany
	Suppling mid-scale customers with time variable tariffs including grid charges optimization	Optimises the electricity consumption of mid-scale consumers through their flexibility

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

		Brief description
Next Kraftwerke Germany (France)	Providing decentral units access to balancing markets	Optimise the participation of flexible decentralised generation on electricity markets in France
Next Kraftwerke Germany (Italy)	Market renewables on multiple markets	Optimise the participation of flexible decentralised generation on electricity markets in Italy
Next Kraftwerke Belgium (Belgium)	Trading PV and Wind Power	Trade solar PV and onshore wind power on multiple markets in Belgium
	Using flexibility of customers as third party	Valorise the load and generation flexibility on multiple markets in Belgium
Oekostrom AG (Austria)	Demand Side flexibilization of small customers	Offer a time of use tariff to residential customers to incentivize load shifting from peak to off-peak periods
	Valorise distributed generation of customers in apartment buildings	Enable households that live in apartment buildings to collectively invest in a PV installation
EDP (Portugal & Portugal)	Activation and marketing of end user's flexibility.	Offer solutions to its clients to valorise their load flexibility potential
FOSS (Cyprus)	Pooling flexibility for local balancing market and energy service provision	Aggregate loads, production units and storage facilities of a university campus to offer grid services to the local DSO

The inventory step of the LCA is done in the BestRES report "Quantitative analysis of improved BMs of selected aggregators in target countries" [2] in which the BMs are analysed according to several BM-specific KPIs using detailed simulations. The aim of this LCA is to describe and quantify the benefits of a nationwide rollout of this BM in a specific sector of the target country. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level. Secondly, the resulting KPIs are compared to relevant indicators of the national electrical power system in an impact assessment.

The results of the LCA's inventory are analysed according to 6 categories: Cost of electricity, Market Participation, Community, Grid Consciousness, Carbon Footprint and Innovation. A qualitative evaluation is made for each and where possible this is enhanced with quantitative results of the BM extrapolation. The derived indicators are compared to indicators of the respective national power system. This results in an awarded score for each category ranging from '--' to '++'. This is shown in Figure 2.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

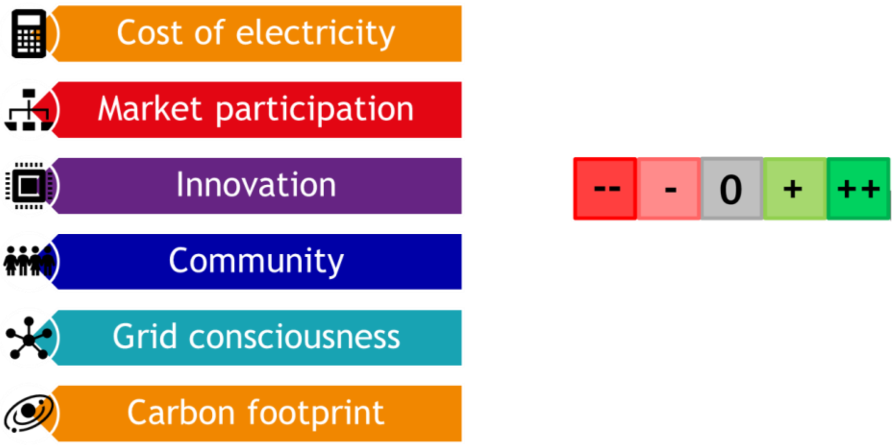


Figure 2: LCA evaluation categories and scores

The results of the evaluation for each of the BMs are shown in Table 2. Note that due to limited simulation results and technical incompatibility it is not possible to evaluate each category for each BM. These fields are therefore left blank.

Table 2: Overview of the awarded scores for the different categories

		Cost of electricity	Market partici-pation	Community	Grid conscious ness	Carbon footprint	Innova-tion
Good Energy (UK)	BM1: Automation and control	+	0	+	+	+	++
	BM2: Peer-to-peer (local) energy matching		++	++	+	0	+++
Next Kraftwerke Germany (Germany)	BM3: Dispatch flexible generation under changing market design on multiple markets	++	++	+	++	0	+
	BM4: Suppling mid-scale customers with time variable tariffs including grid charges optimization	++	+	0	++	0	+
Next Kraftwerke Germany (France)	BM5: Providing decentral units access to balancing markets	++	++	+	++	0	++
Next Kraftwerke Germany (Italy)	BM6: Market renewables on multiple markets					0	+++
Next Kraftwerke (Belgium)	BM7: Trading PV and Wind Power	+	++	+	++	0	+
	BM8: Using flexibility of customers as third party	++	++	0	++	0	+

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

		Cost of electricity	Market partici-pation	Community	Grid conscious ness	Carbon footprint	Innova-tion
Oekostrom AG (Austria)	BM9: Demand Side flexibilization of small customers	+	0	+	+	0	++
	BM10: Valorise distributed generation of customers in apartment buildings	++	+	++	++	++	++
EDP (Portugal & Spain)	BM11: Activation and marketing of end user's flexibility	+	+	0	++	0	+
FOSS (Cyprus)	BM12: Pooling flexibility for local balancing market and energy service provision	++	+	++	++	++	

The conclusion identifies 4 different types of BMs.

- Marketing generation assets on multiple markets

  This group consists of 4 BMs: "Dispatch flexible generation under changing market design on multiple markets", "Providing decentral units access to balancing markets" and "Market renewables on multiple markets" by Next Kraftwerke DE in respectively Germany, Italy and France and "Trading PV and Wind Power" by Next Kraftwerke Belgium in Belgium. The BMs in this group generally score very well in terms of market participation and grid consciousness. They however do not have a direct effect on the carbon footprint. The amount of innovation in each BM ranges from incremental to transformational and the specific score depends strongly on the respective country.

- Optimal dispatch of flexible load

  This group consists of three BMs: "Suppling mid-scale customers with time variable tariffs including grid charges optimization" by Next Kraftwerke Germany in Germany, "Using flexibility of customers as third party" by Next Kraftwerke Belgium in Belgium and "Activation and marketing of end user's flexibility" by EDP in Portugal and Spain. These BMs generally score well in terms of cost of electricity and grid consciousness. They however do not have a strong community component and do not directly lead to reduced GHG emissions. The level of innovation depends on the specific country.

- Household Flexibility

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

The BMs “Automation and control” by Good Energy in the UK and “Demand Side flexibilization of small customers” by oekostrom in Austria make up this group. The LCA results suggest that these can offer significant benefits in terms of cost of electricity, energy communities and grid consciousness. They however do not lead to increased market participation.

- Peer-to-peer energy and flexibility

  Peer-to-peer BMs include “Peer-to-peer (local) energy matching” by Good Energy in the UK and “Valorise distributed generation of customers in apartment buildings” by oekostrom in Austria. Because of their high level of innovation, concrete implementation schemes for these BMs are missing. This means that the LCA is based on a conceptual implementation scheme. Overall the BMs score very well in almost all categories. They perform particularly in the community category and the carbon footprint.

Because of the specific design of the BM “Pooling flexibility for local balancing market and energy service provision” by FOSS in Cyprus, it is not grouped with the other BMs. The LCA results show that it scores well to very well in all categories.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

1. Introduction

In the past, European electricity markets were designed around centralized fossil-fuel generation along national or regional borders. The electricity market landscape is however changing due to a rising share of distributed generation that increases intermittency and price volatility in the system. This requires a more flexible system with more flexible production and consumption. As highlighted in the state aid guidelines published in April 2014 by the European Commission, this implies that renewable sources are better integrated in electricity markets and rely less on subsidies as was the case in the past. Renewable energy aggregation can significantly accelerate the integration of intermittent electricity sources, enhance demand flexibility and decrease the reliance on renewable energy support schemes.

More aggregation and market integration can however not be achieved by individual commercial or domestic consumers since they would only have a limited impact. It is only through a coordinated steering of vast amounts and types of consumers and producers in a market that the use of distributed generation, demand response and battery storage can be effective. A lot of literature has been published with respect to demand response management and more and more market players are active in this field but management of distributed generation and storage including electric vehicles is less developed. An explanation for this might be that this requires the extensive use of new technological solutions and ICT to directly control consumption and generation at lower costs.

For this reason, there is an important role for Renewable Energy Aggregators who act on behalf of consumers and use technological solutions and ICT for optimization. They are defined as legal entities that aggregate the load or generation of various demand and/or generation/production units and aim at optimizing energy supply and consumption either technically or economically. In other words, they are facilitators between the two sides of electricity markets. On the one hand, they develop energy services downstream for industrial, commercial or domestic customers who own generation and storage units or can offer demand response. On the other hand, energy aggregators are offering value to the market players upstream such as BRPs, DSOs, TSOs and energy suppliers to optimize their portfolio and for balancing and congestion management. Furthermore, wholesale electricity markets might benefit from aggregation if appropriate incentives are present. A last option is that energy aggregators offer value to specific customers such as is the case for ESCO’s. In this situation, the player downstream and upstream could potentially be the same entity.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

1.1 The BestRES project

The main objective of the BestRES project is to investigate the current barriers and to improve the role of Energy Aggregators in future electricity market designs. In the first stage, the project focused on existing European aggregation business models taking into account technical, market, environmental and social benefits. In the second stage, we developed improved business models that are replicable in other countries in the EU considering market designs and with a focus on competitiveness and LCA. These improved business models have then been implemented or virtually implemented with real data and monitored in the following target countries: United Kingdom, Belgium, Germany, France, Austria, Italy, Cyprus, Spain and Portugal.

The BestRES project lasted for three years. It entered into force on March 1st, 2016 and will end on February 28th, 2019.

The target group, the Renewable Energy Aggregators, has been directly involved in the BestRES project consortium as partners:

- Good Energy, renewable energy aggregator active in United Kingdom
- Next Kraftwerke Belgium, renewable energy aggregator active in Belgium
- Oekostrom, renewable energy aggregator active in Austria
- Next Kraftwerke Germany, renewable energy aggregator active in Germany, France and Italy
- Energias de Portugal, renewable energy aggregator active in Spain and Portugal

The BestRES activities to be implemented in Cyprus were carried out by FOSS, the research centre for sustainable energy of the University of Cyprus. This is because there are no aggregators in Cyprus at the time being (2016) and no market entrants are expected until 2020.

The innovative business models to be provided during the project are based on ongoing business models available in Europe and adapted to the future market design by research institutions and energy expert partners such as the Energy Economic Group of the Technical University of Vienna (TUW-EEG) and 3E. The consortium also includes a legal expert, SUER (Stiftung Umweltenergierecht /Foundation for Environmental Energy Law), who will provide a relevant contribution to the development of National and European recommendations on the business models implementation.

The BestRES project is coordinated by WIP – Renewable Energies. The project communication and dissemination is carried out by WIP with the support of Youris.

A short description of the BestRES project partners is provided in the following paragraphs.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

WIP – Renewable Energies (WIP)

WIP - Renewable Energies has been founded in 1968 in Munich, Germany, and has been active in the renewable energy sector for over three decades, working with both industrial and public sector clients at the international level. The company's mission is to bridge the gap between research and implementation of sustainable energy systems. WIP's interdisciplinary team of professionals provides consultancy services to improve the grid and market integration of renewable energies. WIP offers project development, project management, technical supervision and realization of projects, which involve the co-ordination of international consortia. WIP counts more than 300 projects accomplished. WIP organizes international events in the field of renewable energies. Website: www.wip-munich.de

3E

3E is an independent consultancy and software service company, delivering solutions for performance optimisation of renewable energy and energy efficiency projects. We provide expert services to support project developers, asset managers, operators, investors and policy-makers and our key areas of expertise are solar, wind, sustainable buildings & sites and grids & markets. Bridging the gap between R&D and the market, 3E combines in-house innovation and partnerships with leading R&D centres. 3E's international team operates from Brussels (HQ), Toulouse, Milan, Istanbul, Beijing and Cape Town. The company has a project track-record of over 15 years in over 30 countries. Website: www.3e.eu

Technische Universitaet Wien (TUW-EEG)

The Energy Economics Group (EEG) is a department of the Institute of Energy Systems and Electric Drives at TU Wien, Austria. The core fields of research of EEG are: (i) system integration strategies of renewable and new energy technologies, (ii) energy modelling, scenario analysis and energy policy strategies, (iii) energy market analysis in general (competition and regulation), (iv) sustainable energy systems and technologies and (iv) environmental economics and climate change policies. EEG has coordinated and carried out many international as well as national research projects, international and national organizations and governments, public and private clients in several fields of research. Website: www.eeg.tuwien.ac.at

Stiftung Umweltenergierecht (SUER)

The Foundation for Environmental Energy Law (Stiftung Umweltenergierecht – SUER) was created on 1 March 2011 in Würzburg. The research staff of the foundation is concerned with national, European and international matters of environmental energy law. They analyse the legal structures, which aim to make possible the necessary process of social transformation leading towards a sustainable use of energy. Central field of research is the European and German Law of renewable energy and energy efficiency. The different legal instruments aiming towards the substitution of fossil fuels and the rise of energy efficiency are analysed systematically regarding their interdependencies. Interdisciplinary questions, e.g. technical and economical questions, are of particular importance. Website: http://stiftung-umweltenergierecht.de/

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Good Energy

Good Energy is a pioneering clean energy company, powering the choice of a cleaner, greener future together with its people, customers and shareholders. Having led the way in renewable energy development since 1999 in areas including small and larger scale wind turbines, solar panels, biogen and hydro, and now in technologies like battery storage and electric vehicles, Good Energy is making it easier for people and businesses to make renewable energy part of their lives. Good Energy powers homes and businesses with 100% renewable electricity from a community of over 1,400 UK generators and owns and operate two wind farms, including the UK's first commercial wind farm, and eight solar farms. In addition, Good Energy offers a green gas product which contains 6% biomethane — gas produced here in the UK from food waste. To make it completely carbon neutral, emissions from the rest of the gas its customers use is balanced through supporting verified carbon-reduction schemes in Malawi, Vietnam and Nepal. As of 30 December 2017, Good Energy had over 250,000 domestic and business customers. Website: www.goodenergy.co.uk

Next Kraftwerke Belgium (NKW BE)

Next Kraftwerke Belgium pools distributed renewable generation and flexible demand in a virtual power plant (VPP). We trade and deliver the aggregated power on the most relevant markets and, most importantly, we make the virtual power plant's flexibility available to the grid operator to support the management of the Belgian power system. Next Kraftwerke Belgium is a joint venture with Next Kraftwerke GmbH in Germany. Website: www.Next-Kraftwerke.be

Next Kraftwerke Germany (NKW DE)

Next Kraftwerke Germany is the operator of a large-scale Virtual Power Plant (VPP) and a certified power trader on various European energy exchanges (EPEX). The concept of a Virtual Power Plant is based on the idea to link and bundle medium- and small-scale power producing and power consuming units. The objective is to smartly distribute supply and demand and to profitably trade the generated and consumed power. Next Kraftwerk's VPP now bundles around 3,000 medium- and small-scale power-producing and power-consuming units. Among other energy sources, it includes biogas, wind, and solar power generators. Next Kraftwerke also operates in Belgium, France and Austria. Website: https://www.next-kraftwerke.com/

Oekostrom

Oekostrom AG is a holding company owned by about 1.900 stockholders. It was founded in 1999 aiming at building a sustainable energy industry, supplying customers with clean energy and supporting the development of renewable energy sources in Austria. All products and services of oekostrom AG represent an active contribution to climate and environmental protection and increase independence from fossil and nuclear energy sources. Oekostrom AG engages in the fields of power production, trading, sales and energy services and currently supplies 100 % renewable energy from Austria to more than 52.000 customers in all parts of the country. Website: http://oekostrom.at/

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Research Center for Sustainable Energy of the University of Cyprus (FOSS)

The Research Centre for Sustainable Energy of the University of Cyprus (FOSS) was created in order to play a key role in research and technological development activities in the field of sustainable energy within Cyprus and at international level with the aim of contributing to the achievement of the relevant energy and environment objectives set out by Europe. FOSS is heavily involved in all spheres of sustainable energy spreading from sources of energy, smoothly merging RES in the integrated solutions of the grid, development of enabling technologies such as storage and ICT that will facilitate the seamless merging of sustainable technologies in the energy system of tomorrow, the complete transformation of energy use by the effective introduction of sustainable alternatives in meeting the needs for mobility, heating and cooling and exploring ways of achieving even higher levels of efficiency in all areas of the economy. Website: http://www.foss.ucy.ac.cy

Centre for New Energy Technology (EDP-CNET)

EDP Group is an integrated energy player, with strong presence in Europe, US and Brazil and the third player in the world in terms of wind installed capacity. EDP is an innovative European Utility with an important presence across all the energy value chain, in Generation, Distribution, Energy Trading and Retail of electricity and gas. EDP owns HC Energia, the 4th Energy Utility in Spain and Energias do Brasil. EDP Centre for New Energy Technologies (EDP CNET) is a subsidiary of the EDP Group with the mission to create value through collaborative R&D in the energy sector, with a strong focus in demonstration projects. Currently, EDP has no activity as an aggregator, but, as the electricity sector evolves, EDP may consider aggregation either on the generation or supplier side through different companies within EDP Group. In the scope of this project EDP has chosen to focus on the supplying activity, therefore the information provided in this report is focused on the retailer side.

Websites: https://rd-new.com and http://www.edp.pt/en/Pages/homepage.aspx

Youris.com (Youris)

youris.com GEIE is an independent non-profit media agency promoting the leading-edge European innovation via TV media and the web. youris.com designs and implements media communication strategies for large research organizations and EU-funded projects and is able to establish permanent links between the research communities and the media. youris.com media products cover a wide spectrum of research areas including ICT, Environment, Energy, Health, Transport, Nanotechnologies, Food, Society, Gender and many others and are designed for large-scale distribution world-wide. Youris.com is a European Economic Interest Group (EEIG) based in Brussels with branch offices in Italy, Germany and France. Website: http://www.youris.com

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

2. Methodology

2.1 Life cycle assessment (LCA)

2.1.1 LCA fundamentals and the service industry

The aim of a life cycle assessment for sustainable business models is to quantify the created value of a BM in terms of economic, social, environmental and technical indicators. It is a much broader approach than a 1-dimensional profit/loss analysis as it assesses the BM's impact on its entire ecosystem [3].

When an LCA is carried out for a product or service, the goal and scope can vary. Roughly though it will be a variation of the *cradle to grave* approach: what resources are used in each step of the product's lifetime, where have these been sourced and how will they be disposed of. An overview of the different steps of a traditional LCA is given in Figure 3. The first step defines the scope of the LCA and specifies which phases of the product's life cycle will be included. In the inventory step the input and output resources streams are quantified for each analysed stage. This includes the required energy and raw resources as well as the generated waste. The impact assessment then addresses the economic, environmental, social and technical effects of these resource streams on the biosphere.

Figure 3: Life Cycle Assessment Methodology

In this study, the life cycle of a business model is interpreted from a business economic point of view. A BM will consecutively go through the stages 'launch', 'growth', 'shake-out' and 'maturity' before it either renews or declines. This LCA studies the BM's development from the launch to the maturity stage conceptualised as a large-scale rollout of each of the BMs in the respective national power system.

The inventory step of the BM is done in the BestRES report "Quantitative analysis of improved BMs of selected aggregators in target countries" [2] in which the BMs are analysed according to several BM-specific KPIs using detailed simulations. Subsequently, this report's aim is to carry out the impact assessment of a large implementation of the BM starting from the BM-specific case study that is developed in [2]. This narrows down the scope of the LCA to a specific industry. Table 3 gives an overview of each of the case studies that are analysed in the BestRES report "Quantitative analysis of improved BMs of selected aggregators in target countries" and the extrapolated scenarios developed in this report.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Table 3: LCA scope and scenarios

		Quantitative analysis	LCA Scenario
Good Energy (UK)	Automation and control	Household under a time-of-use tariff	Implementation in all British households
	Peer-to-peer (local) energy matching	No case study	Implementation in the UK
Next Kraftwerke Germany (Germany)	Dispatch flexible generation under changing market design on multiple markets	Single biogas plant	Implementation in all German biogas plants
	Suppling mid-scale customers with time variable tariffs including grid charges optimization	Portfolio of water pumps	Implementation in all German water pumping stations
Next Kraftwerke Germany (France)	Providing decentral units access to balancing markets	Generic industrial asset with available flexibility	Implementation in all French biogas plants
Next Kraftwerke Germany (Italy)	Market renewables on multiple markets	Bidding zone analysis of solar and wind power	Implementation in Italy
Next Kraftwerke (Belgium)	Trading PV and Wind power	Medium sized RES portfolio	Implementation in Belgian RES production portfolio
	Using flexibility of customers as third party	Industrial portfolio with backup generator	Implementation in Belgium
Oekostrom AG (Austria)	Demand Side flexibilization of small customers	Households with different consumption profiles	Implementation in all Austrian households
	Valorise distributed generation of customers in apartment buildings	Multi-family apartment building	Implementation in all Austrian apartment buildings
EDP (Portugal & Portugal)	Activation and marketing of end user’s flexibility.	Industrial load profile	Implementation in Portugal and Spain

2.1.2 Categorised evaluation

The results of the LCA’s inventory are analysed according to 6 categories. A qualitative evaluation is made for each and where possible this is enhanced with quantitative results of the BM extrapolation. The derived indicators are compared to indicators of the respective national power system.

The evaluated categories are the following:

BestRES This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

Cost of electricity

The *cost of electricity* concerns the BM's impact on the revenue and cost of electricity, compared to the reference scenario. Depending on whether the BM considers consumption or production, this is either the effect on the cost of sourcing electricity on markets or the increased profit/revenue that the BM generates. The cost of electricity is expressed in euro per MWh of production or consumption to allow a comparison between the different BMs. The percentage difference is calculated to determine the awarded score. In the case production is considered, the increased revenue can be compared to the current support mechanisms.

Market participation

This category evaluates to what extent the improved BM facilitates market participation on different markets. On one hand the role of the considered assets is discussed: to what extent does the BM activate the customer's or asset's potential to become an active market participant. Where possible, the added market volumes are extrapolated from the simulation results. These values are compared to current market volumes. BMs that lead to added volume on additional markets score best in this category.

Community

The *community* category evaluates the community content of the BM, and to what extent it supports the development of a 'local energy community'. The evaluation differentiates between BMs that directly facilitate the creation of energy communities, and those that indirectly support their creation through e.g. added revenue for renewables. A local energy community is an organisation in which there is cooperation between local stakeholders to engage in value-driven activities regarding generation and distribution of electricity.

Grid consciousness

A grid conscious BM creates system value for electricity grids and markets and furthermore builds up an understanding on the integration of RES. BMs score high in the category *grid consciousness* if they provide system value to the national power system. The LCA evaluates this category based on the BM's effect on six grid aspects:

- Peak load reduction
- Imbalance reduction
- Improved power quality
- Increase in local consumption
- Contribution to ancillary services
- Security of supply

Carbon footprint

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

The *carbon footprint* category of the BM considers the BM's impact on greenhouse gas (GHG) emissions. The simulation results from [2] are a starting point of the analysis. The scores differentiate between BMs that actively reduce GHG emissions, and those that indirectly contribute to reduced GHG emissions.

Innovation

The *innovation* category assesses whether the BM can be considered an innovation in its respective market. If so, it is determined whether the innovation is incremental (small and significant improvement to an existing product), breakthrough (release of a new product) or transformational (creation of a new industry).

The first five categories are awarded a score ranging from '**--**' to '**++**'. If a BM is rated '**--**' for a certain category, this indicates a strong negative effect of the BM considering the specific scope of the studied scenario. '**-**' means that there is a clear negative impact, though in the context of the studied scenario the impact is only minor. '**0**' either indicates that the BM is neutral relative to the category, or that the positive and negative effects are negligible. Analogously to the negative scores, '**+**' indicates a minor positive effect and '**++**' a strong positive effect. Specific scoring criteria apply for each of the different categories. Table 4 shows the scoring table that is used for the five categories.

For the category *innovation*, the scores range from '0' to '+++'. The scoring table is shown in Table 5.

Table 4: LCA Scoring Table

	--	-	0	+	++
Cost of electricity	More than 10% increase in cost or decrease in revenue	Less than 10% increase in cost or decrease in revenue	No effect on the cost of electricity	Less than 10% decrease in cost or increase in revenue	More than 10% decrease in cost or increase in revenue
Market participation	Participation on fewer markets with less volume	Participation on the same markets with less volume.	No effect on market participation	Participation on the same markets with added volume.	Participation on additional markets with added volume
Community			No contribution to the formation of energy communities	Indirect contribution to the formation of energy communities	Direct contribution to the formation of energy communities

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Grid consciousness	A negative effect on more than one grid aspect	A negative effect on at least one grid aspect	No significant effect on any of the grid aspects	A positive effect on at least one grid aspect	A positive effect on more than one grid aspect
Carbon Footprint	Direct contribution to carbon footprint increase	Indirect contribution to carbon footprint increase	No effect on carbon footprint	Indirect contribution to carbon footprint reduction	Direct contribution to carbon footprint reduction

Table 5: Scoring Table for the innovation category

	0	+	++	+++
Innovation	**No innovation**	**Incremental innovation**	**Breakthrough innovation**	**Transformational innovation**
	No innovative component in the considered market	Small yet significant improvement to an existing product	Release of a new product	Creation of a new industry.

As the BestRES project analyses a wide scope of BMs, there are BMs for which some categories cannot be evaluated. In those cases, the specific reasons are described, and the BM is not labelled for that category. Furthermore, depending on the simulation results in “Quantitative analysis of improved BMs of selected aggregators in target countries” [2], a quantitative evaluation is not always possible. This is explained in the discussion per category.

BestRES This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

3. Good Energy (United Kingdom)

3.1 Automation and control (BM1)

3.1.1 Introduction and scope definition

In the BM *Automation and control*, Good Energy aims to use the available flexibility from residential customers to create added value for their customers on a time variable tariff. By using a technology solution that informs the customer of electricity prices and consumption on a continuous basis, residential customers are activated to shift consumption from peak demand times to off-peak demand times. This practice can lower the pressure on the grid during peak demand which means more demand can be met by renewables.

In [2], this BM is analysed through a case study of a residential load profile consisting of 7 household appliances. Each device has a certain amount of available flexibility. Two scenarios are studied in this LCA:

- The baseline scenario in which the consumer has a time-of-use (ToU) tariff with two periods but where the electricity price does not change its behaviour.
- The improved scenario in which the consumer has a ToU tariff with two periods and uses the available flexibility to minimise its electricity bill.

The aim of this LCA is to describe and quantify the benefits of a nationwide rollout of this BM in all households in the UK. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level. Secondly, the resulting KPIs are compared to relevant indicators of the electrical power system in the UK in an impact assessment.

All results of the LCA are based on the simulation results from [2]. The actual implementation of this BM by Good Energy might differ significantly.

3.1.2 Inventory

Cost of electricity

The theoretical modelling for the improved scenario shows that using flexibility under a ToU tariff can decrease the cost of electricity for the consumer. The simulation results for the considered scenarios are summarized in Table 6. If a household's flexibility is not used, the average cost of electricity is £254.60/MWh. By shifting load, the average electricity price drops to £252.65/MWh. This corresponds to a cost reduction of 0.77%. Considering a yearly consumption of 3.5 MWh, this leads to an annual cost reduction of £6.82.

These results show that using flexibility under ToU electricity pricing has an impact of less than 10% on the price of electricity. The BM is therefore rated + in this category.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

+

Table 6: Average electricity price (BM1)

	Baseline	Improved
Average electricity price	£254.60/MWh	£252.65/MWh

Market participation

The BM does not have a direct impact on *how* residential consumers participate in electricity markets and the BM does not change their market role. Furthermore, the BM does not result in changed market volumes.

In the UK, suppliers use synthetic load profiles (SLPs) to trade and balance residential consumption, even for households that have a digital meter, to limit the required metering and trading infrastructure. As a result, the load shifting that is caused by this BM will only indirectly impact the way that the residential consumption is sourced on the markets. Only in case of a yearly calibration of the SLPs using measured grid data, or a shift to real-time traded load profiles[1], can this BM influence the households' formal interaction with power system mechanisms such as system balance and overload.

The increase in *market participation* due to the BM is for these reasons labelled as '0'.

0

Community

While the BM is aimed towards residential consumers, it does not explicitly involve cooperation or collaboration of households. The impact of the BM on the potential to form energy communities is therefore indirect: a ToU tariff and residential flexibility aggregated on a neighbourhood level can lead to additional benefits compared to uncoordinated control on an individual household level. In that regard, this BM could support the development of energy communities and their active participation in the power sector. The BM's score for *community* is therefore '+'.

+

It is foreseen that in a future stage of the BM, gamification is added as a feature of the technology solution. This will allow households to work together to meet

[1] In the UK, Ofgem is consulting the possibilities of access to half-hourly electricity data for settlement purposes to suppliers.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

a larger objective on a neighbourhood or regional level. This can increase the community content of the BM.

Grid consciousness

Consumers in this BM are incentivised to shift their consumption patterns, which could result in a load profile that better follows the market's production profile. Countries tend to introduce residential flexibility measures to compensate for inflexible generation, such as coal and run-of-river hydro power, that cannot easily decrease their production when the load is low. The UK has a relatively high share of coal-fired and nuclear power plants that require flexibility to maintain the base load [4]. The BM can be a mechanism to unlock residential load flexibility and adjust the demand to the supply. Based on the calculations in [2], this BM could result in a shift of 3.5% of residential consumption. Assuming a unanimous rollout in all of the UK's 27 200 000 households, this would mean that 3.64 TWh of electricity could potentially be shifted. This is around 1.1 % of the UK's total electricity consumption [5].

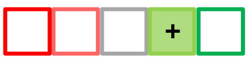
However, the current ToU tariffs in the UK are static and non-reflective of the instantaneous system state, which means that the shifted consumption does not necessarily constitute a service to the electricity grid. The value created by the shifted load is based on a market-specific mechanism (the different periods in the tariff) that 'blindly' incentivises the households to shift consumption. In the case of e.g. a local system peak during an off-peak period, the flexible households under a ToU tariff could unknowingly aggravate the situation.

In conclusion, the technology that is developed in this BM can significantly increase the system value of demand side management once dynamic ToU tariffs are introduced in the UK. At the moment this is however not necessarily the case. Considering the applied scoring scheme, the BM is awarded '+' for this category.

Carbon footprint

The simulation results in [2] show that the temporally shifted load causes a small decrease in the carbon content of the consumed electricity. The decrease in average carbon content between the two scenarios is 0.12%, as shown in Table 6. The reduction in carbon content can be explained because times of lower electricity prices generally correspond to times with low carbon content in the produced electricity.

This effect on the carbon footprint of electricity in the UK is indirect: due to the way that electricity is traded, the electricity would be generated anyway. The BM is for this reason rated '+' in this category.



BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Table 7: Carbon content in the consumed electricity (BM1)

	Baseline	Improved
Average Carbon Content	186.00 kg/MWh	185.78 kg/MWh

Innovation

The BM brings a new product on the British market and is therefore ranked as breakthrough innovation.

		++	

Good Energy knows of two other devices that provide energy intelligence for informed decision making by disaggregation of appliances in households: Eliq and Voltaware. Both offer energy 'dissagregation' analytics (a breakdown of consumption per device) and monitor energy usage and demand patterns in real-time.

3.2 Peer-to-peer energy matching (BM2)

3.2.1 Introduction and scope definition

In their BM *Peer-to-peer energy matching*, Good Energy aims to match local electricity production and consumption on a regional level to lower the energy sourcing cost of their customers. They propose to do this through a virtual platform that allows peer-to-peer interaction to take place between residential prosumers. This would create a so-called *local energy trading community*.

While this BM could offer great potential in the future, at the moment there are several barriers that need to be overcome before a rollout can be envisioned. In the first place, the role of each of the involved actors needs to be defined. Furthermore, the interaction with the DSO and the responsibilities of each of the participants need to be formalised. The LCA therefore focuses on the impact of a conceptual platform that allows peer-to-peer interactions between producers and consumers. It does not assume any specific framework and aims to give a general overview of the life cycle impact of the BM. The analysis focuses on residential consumers and producers, though in many cases the evaluation does not exclude larger scale projects.

This BM was not simulated in [2]. This means that the LCA presented here is based on a qualitative assessment of the BM in the different categories. The aim of this LCA is to describe the benefits of a nationwide rollout of this BM in the electricity sector in the UK.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

For a thorough assessment of local energy trading platforms, the reader is referred to the results of the EMPOWER project (local Electricity retail Markets for Prosumer smart grid pOWER services)[2].

3.2.2 Inventory

Cost of electricity

The price paid for electricity is made up of several components. A breakdown for residential consumers is shown in Figure 4. It indicates that the major cost components are the wholesale electricity cost and the network cost, which make up more than half of the price paid. The supplier's operating cost amount to 17% and the policy component and VAT add up to more than 22%.

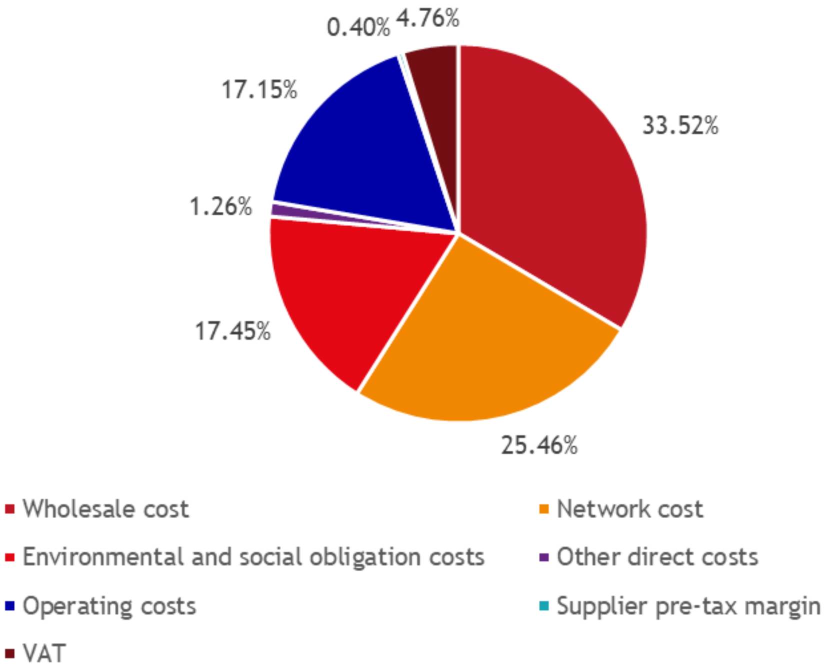


Figure 4: Breakdown of a residential electricity bill in the UK (Ofgem)

Below, the BM's impact on each of the components is discussed separately.

- To estimate the impact of the BM on the **wholesale energy cost**, it is assumed that the peer-to-peer platform acts as a parallel market on which electricity can be traded, as on a regular wholesale market. Two opposing mechanisms in this BM are identified that could either raise or lower the cost of electricity on this parallel market.
  1. The fact that participation on these local markets is limited to neighbouring producers and consumers means that less actors will be competing and that there will therefore be less competition. This might result in wholesale prices that are higher than on regular markets.
  2. On the other hand, instead of locking in (residential) producers through fixed remuneration schemes, the platform can facilitate local dynamic electricity prices that reflect the current state of electricity

[2] http://empowerh2020.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

production. This could result in equal or lower electricity prices by incentivizing consumers to optimally make use of their available flexibility.

In this regard, the commodity price on the local platform will be dominated by the wholesale price unless there is a financial incentive to buy and sell electricity locally [6].

- The BM can have a positive impact on the operation of the transmission grid by optimisation self-consumption on a regional level and reducing the need for long-distance transmission. This could reduce the transmission component in the network cost. The impact on the distribution component depends on the specific design of the platform: to what extent does it lead to localized consumption on a single feeder level, and does it reduce the necessary distribution grid capacity. For both the transmission and distribution level, the design of the grid charges is a decisive factor in how increased self-consumption leads to lower network costs.
- In the case that the peer-to-peer platform is operated and maintained by an external party (such as an electricity supplier), it is unlikely that the operating cost will reduce. While in principle the BM cuts out 'middle men' such as third-party traders and market operators, these functions would merely be incorporated in the activities of the platform operator. As a side note, it is in this regard that blockchain-based platforms can be very promising, as they can allow the transactions to be decentrally legitimated by the power producers and consumers.
- The policy and VAT component are regulated by the government and are therefore not explicitly affected by the BM.

In conclusion, while the BM can have a significant impact on the cost of electricity, its design is at this point too conceptual to draw concrete conclusions. The BM therefore does not receive a label in this category.

Market participation

This BM has the potential to empower a significant part of the British population to invest in, own and benefit from community-owned distributed generation. The BM sets up a new local trading community that works parallel to the wholesale market. A schematic overview of a local market is shown in Figure 5 (from [6]).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

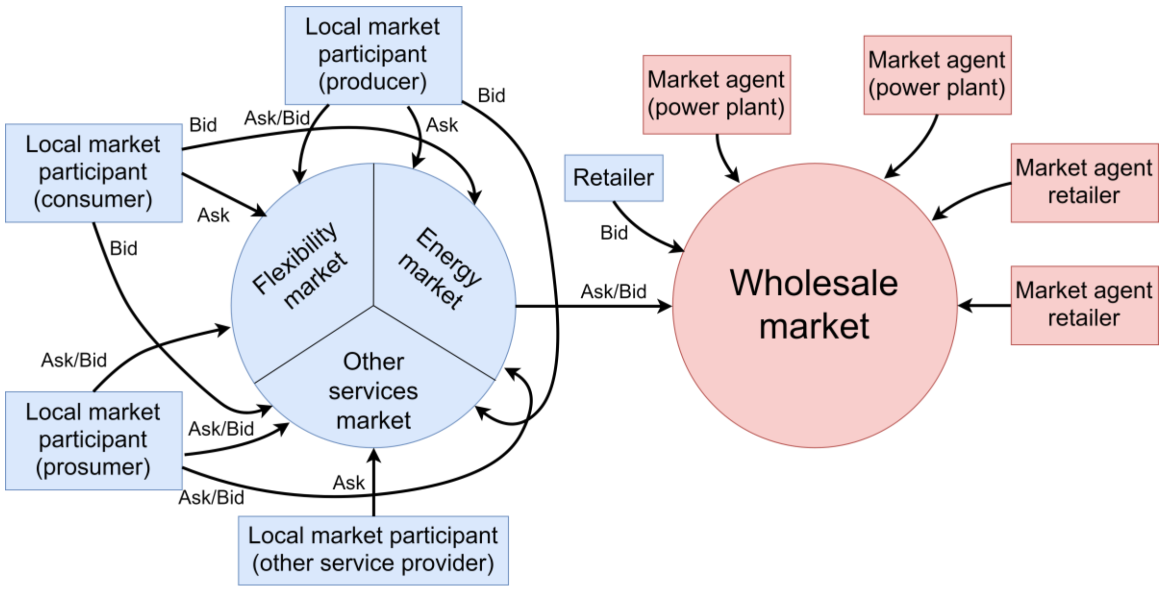
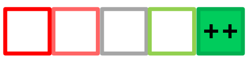


Figure 5: Local market for energy, flexibility and energy-related services

The possibilities of a local trading platform are not limited to an energy-only market. Also, additional energy-related services, including flexibility services, can be traded to create more value. Each of the different participants of the local platform (e.g. prosumers, producers, consumers and other service providers) will place bids and ask services to the platform.

The BM can have a significant positive impact on the market participation of small consumers. A platform is created that allows small consumers to become more active participants in electricity markets. It leads to added volume on additional markets. It therefore receives the label '++' in this category.



Community

A local energy trading community, as discussed under *market participation*, can empower local communities to deploy RES and allow for energy transition models to be developed. The BM can be a concrete tool to create local energy communities as it enables small producers and consumers to be conscious of the source of their electricity. An important driver here is 'localism'. Other parts of the global economy, such as the food and agriculture industry, have already seen an increased importance of localism, driven by ecological values. This BM could further introduce this value to the field of energy supply. As discussed under market participation, this BM can be an important facilitator to increase involvement in additional local energy services, such as flexibility through demand response.

As the BM has a direct contribution to the development of energy communities, this BM is labelled '++' in the *community* category.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

++

Grid consciousness

By encouraging local consumption, the use of medium and high voltage transmission infrastructure is reduced. This means that the BM could result in lower capacity requirements in the future, which can lead to an increased hosting capacity for renewable energy sources. As capacity is a main cost driver in the development, operation and maintenance of grid infrastructure, this BM could reduce grid cost.

Furthermore, local consumption reduces electricity losses. In a trial by Open Utility, the Selectricity platform calculated that the average distance travelled by matched electricity was 177 miles/kWh (284 km/kWh). In an example of a local energy market in Cornwall, this could be brought down to 33 miles (53km) [7]. Lower transport distances will result in lower copper losses, which increases the efficiency of the power system.

As the BM has a positive effect on one of the grid topics, the BM is labelled '+' for this category.

+

Carbon footprint

While this BM can support distributed generation including low-carbon technologies, it does not have a direct effect on the carbon footprint of electricity generation. Furthermore, peer-to-peer platforms can also be used to trade electricity from fossil fuels. The BM is therefore rated '0' in this category.

0

Innovation

Peer-to-peer energy trading platforms projects can be found around the world, often in the form of trial projects that are still waiting to be launched commercially [8]. Two platforms are presented below:

- Selectricity

  Selectricity is a peer-to-peer marketplace for renewable electricity that was used in a trial in 2015 in the UK. It was developed by Open Utility for industrial customers. Good Energy supported the project by providing contracts, meter data and balancing for the operations during the trial. The platform allows consumers to select and prioritise from which generators they buy electricity, while generators have control over who consumes their electricity. Its matching system offers the participants transparency on where their electricity comes.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

- TransActiveGrid

TransActiveGrid is the name of an energy transaction platform that is based on Ethereum blockchain software. The company behind the platform is LO3 Energy, who implemented it in the Brooklyn Microgrid in New York City. It allows residents to sell their excess electricity production from rooftop-PV installations to their neighbours. It was used in a trial in 2106, which saw the first paid peer-to-peer transaction in the US.

As the BM leads to the creation of a new market and has never been implemented in a commercial context, this BM is labelled transformational (+++) in the innovation category.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

4. Next Kraftwerke Germany (Germany)

4.1 Dispatch flexible generation under changing market design on multiple markets (BM3)

4.1.1 Introduction and scope definition

In their BM *Dispatch flexible generation under changing market design on multiple markets*, Next Kraftwerke Germany (NKW DE) optimises the participation of flexible decentralised generation assets on electrical energy and power markets. The BM makes use of changes in the electricity market design to find additional value for the assets, particularly considering the asset's flexibility.

In [2], this BM is analysed through a case study of a biogas plant on the reserve and spot market with varying closure time. Two market designs are studied:

- The reference case where the tender submission period for aFRR products is weekly.
- The improved BM with 4-hour availability periods and daily reserve procurement for aFRR products.

In the analysis, the installation can participate in both the positive and negative aFRR reserve. The cases are evaluated based on the annual profit on the different markets, which is defined as the revenue on the different markets minus the production cost. The LCA considers the case where the production cost is 100€/MWh.

The aim of this LCA is to describe and quantify the benefits of a nationwide rollout of this BM in all biogas plants in Germany. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level. Secondly, the resulting KPIs are compared to relevant indicators of the electrical power system in Germany in an impact assessment.

4.1.2 Inventory

Cost of electricity

Biogas is still an expensive source of renewable energy that heavily depends on government support: the German Renewable Energy Sources Act [9], updated in 2017, foresees a maximum support level for biogas plants of 148.8€/MWh, significantly higher than that for onshore wind (70€/MWh) and solar PV (89.1€/MWh). A major difference between solar PV, wind power and an electricity producing biogas plant, however, is that the former two are hardly able to be controlled. A biogas plant is one of the few renewable electricity sources that can provide flexibility to the grid and it is exactly this flexibility that the considered BM attempts to harvest.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

The results in [2] suggest that valorising the available flexibility through the aFRR reserve market with four hourly availability periods can lead to an increased profit for the asset. This additional profit could to a certain extent reduce the technology's dependency on government support.

An overview of the increased profit is given in Table 8. The improved BM causes an increase in profit of 12 200 €/MW. This represents an increase in profit of 18.7% compared to the scenario with weekly procurement. As a result, the improved BM is labelled '++' for the category *cost of electricity*.

				++

Table 8: Annual profit (BM3)

	Weekly Procurement	4-hourly Procurement	Δ
Annual Profit	65 100 €/MW_{inst}	77 300 €/MW_{inst}	18.7%

Market participation

In both scenarios the installation is participating on multiple markets: the spot market, the secondary downward control reserve and the secondary upward control reserve. In case this BM is implemented in the national biogas portfolio in Germany, a significant amount of capacity volumes could be opened up on the different markets. Currently there is 4166 MW of electricity-generating biogas in Germany [10]. Table 9 shows that around 2000 MW of capacity was tendered on the secondary reserve markets in Germany in 2017 [11]. The implementation of the BM in all of the Germany capacity can thus lead to a large increase in the number of bids on these markets. Note that this will have a considerable effect on the bid ladder, and thus on the price setting of these markets.

An extrapolation of the simulation results indicates that the improved BM increases the opportunities of assets to valorise their flexibility on reserve markets. The unlocked capacity can lead to more competition on these markets and bring down the price that the TSO pays to maintain grid stability [12]. For these reasons the BM is labelled '++' in this category.

				++

Table 9: Tendered secondary reserve capacity in Germany in 2017

	Minimum Tendered Capacity	Maximum Tendered Capacity
Negative reserve	1904 MW	1993 MW
Positive reserve	1973 MW	2054 MW

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Community

As the BM is focused on medium to large-sized (industrial or agricultural) assets, there is no immediate community component to the BM. However, the Renewable Energy Sources Act has promoted a localised approach to biogas in which electricity is generated directly at the place where the gas is produced [10]. As a result, German biogas can be seen as a local energy source that is well integrated communally [13]. In that regard, this BM could support the development of energy communities and their active participation in the power sector. Furthermore, considering that the minimum bid size for secondary reserve is 5 MW, it is possible to aggregate small-scale CHP installations in this BM to activate them as a supplier of grid services. The BM's potential to empower citizens to participate actively in the electricity market is why it is labelled as '+' for *community*.

			+	

Grid consciousness

The principal idea behind BM is to provide services to the transmission grid in the form of secondary reserve. As was shown in the section on *market participation*, the implementation of this BM in all biogas plants in Germany would be able to supply a large share of the necessary secondary reserve flexibility in both upward and downward direction. Furthermore, by offering this product, NKW DE makes clients aware of the value and necessity of ancillary services in the operation of power grids.

Additionally, this BM can to a certain extent improve the security of power supply in Germany. While biogas only has a 6% share in the total power production, it is one of the few sources of electricity that can be sourced locally [10].

This BM is awarded category '++' for *grid consciousness* because it has a positive impact on these two grid aspects.

				++

Carbon footprint

While burning biogas releases CO_2, the released CO_2 is part of the biogenic carbon cycle and the net CO_2 emissions are lower than fossil sources. However, since this BM only impacts the dispatch of the plant and does not directly interact with its CO_2 emissions, the BM is rated '0'. Trading electricity from biogas units does not have a direct impact on the carbon footprint of electricity. Indirectly, the BM could help to substitute fossil fuels fired power plants providing balancing services.

		0		

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Innovation

In Germany there are 33 pre-qualified suppliers of secondary reserve power, under which several with a portfolio that includes biomass [14]. However, it is not known whether these are actively marketing their biogas capacity on the secondary reserve market. In [15] it is identified that there are substantial barriers for the implementation of the BM for biogas plants due to low market prices, high acquisition costs and demanding technological requirements. In addition, the recently introduced mixed pricing creates competitive disadvantages for alternative sources of flexibility such as biogas or demand response. However, there are biogas plant manufacturers that specifically design their equipment to be able to supply grid services [16]. This leads to the opinion that due to the challenges for the implementation, this BM is rated '+' for *innovation*.

	+		

4.2 Supplying mid-scale consumers with time variable tariffs including grid charges optimization (BM4)

4.2.1 Introduction and scope definition

In their BM *Supplying mid-scale consumers with time variable tariffs including grid charges optimization*, Next Kraftwerke Germany (NKW DE) optimises the electricity consumption of mid-scale consumers to reduce their energy bill. The load schedule optimisation considers both the time-of-use pricing and the peak-load pricing component.

In the BestRES report "Quantitative Analysis of Improved BMs of Selected Aggregators in Target Countries" [2], this BM is analysed through a case study of a water pump installation under various scenarios. The LCA compares the follow optimisation strategies:

- The reference case where consumption is optimised only considering the spot market electricity price;
- The optimisation strategy that considers both the spot market price and the yearly grid charges.

In the analysis, the installation's electrical consumption is priced according to an energy component based on the EPEX Spot day-ahead market and a peak load tariff that varies either monthly or yearly.

The aim of this LCA is to quantify the effect of a nationwide rollout of this BM in all water pumping stations in Germany. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level. Secondly, the resulting KPIs are compared to relevant indicators of the electrical power system in Germany in an impact assessment.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

4.2.2 Inventory

Cost of electricity

The theoretical modelling shows that this BM can significantly reduce the sourcing cost of electricity for water pumping stations. If the available flexibility is only used for optimisation of the spot price, the average cost of electricity is 88.90 €/MWh. By shifting load to additionally optimize the peak load charges, the average electricity price drops to 79.58 €/MWh. This corresponds to a cost reduction of 10.48%. These results are summarized in Table 10. As the cost reduction is more than 10%, the awarded score is '++'.

++

Table 10: Sourcing cost reduction (BM4)

	Spot optimisation	Peak load optimisation	Δ
Sourcing cost	88.90 €/MWh	79.01 €/MWh	-10.48%

To put these results in perspective, according to a 2015 report on the profile of the German water sector [17], the total expenditure to deliver one cubic meter of water amounts to €1.2, of which 0.13€ to 0.19€ is due to electricity costs. Electricity thus represents 11% - 16% of the total expenditure of water supply. An electricity cost reduction of 10.48% represents an overall cost reduction of between 1.36% to 1.68% of the operational cost of water supply. Note that this does not only include the cost for pumping but also other electrical consumption.

Market participation

The BM's optimisation algorithm considers both short-term price signals and local peak-load charges. The overall system balance between production and consumption is addressed by taking into account the short-term price signals. This aspect of the optimisation causes a larger price-response and increases the power system's efficiency. This mechanism is more cost-reflective from a grid point of view and enhances market participation of the assets.
The optimisation algorithm concerning the grid charges only considers local peak load reduction without knowledge of the instantaneous state of the overarching power system. The benefits of this part of the optimisation do therefore not necessarily lead to benefits on a system level. The created value through peak-load optimisation is based on a market-specific mechanism (the peak-load charge) that 'blindly' controls the asset's consumption. Current peak-load prices are static and can be nonreflective of the instantaneous system state.
In conclusion, the water pump's demand response capabilities are increasingly valorised, yet the asset's fundamental market role does not significantly change; there is an enhanced participation on spot market, yet the static peak pricing means that it remains largely unaware of the current state of the transmission grid. As a result, the awarded score is '+'.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

			+	

Community

This BM does not explicitly involve the cooperation of citizens and therefore the community content is limited. In Germany there are about 6065 water supply enterprises of which 65% are public sector companies and 35% are private [17]. While this BM could support the numerous small (public) utilities that supply small communities in rural areas, the cost reduction induced by this BM can also result in increased corporate profit for large utilities operating in conurbations. The BM is awarded ‘0’ for the category *community*.

		0		

Grid consciousness

Capacity is the main cost driver in the development, operation and maintenance of grid infrastructure. The peak reduction, induced by this BM’s demand response algorithm, is thus a grid service that is reasonably incentivised through a capacity-based tariff. The impact of a national rollout of the BM on all water pumping stations in Germany is extrapolated from the results in [2] by using a linear scaling factor. The pumping station in [2] serves a population of 4 million [18] and the total population of Germany consists of 82.67 million people [19]. The resulting scaling factor between the case study and the national water pumping facilities is about 20.67.

The order of magnitude of peak reduction is shown in Table 11. It is important to note that these results assume similar operational aspects for all German pumping stations, including energy efficiency, installed capacity per served customer and available flexibility. Furthermore, the electricity tariff for all pumping stations, including the grid component, is assumed to be the same.

Table 11 indicates that a national rollout of this BM could result in a total peak load reduction of all the national water pump installations of up to 415 MW, or 36.5%. Compared to the German national peak load of 80 GW [18], this corresponds to a reduction of 0.52%. While this is relatively small decrease, a general upgrade of the German transmission grid by 415 MW could lead to significant costs [19].

Because of its contribution to peak load reduction, the potential of this BM in terms of *grid consciousness* is labelled as ‘+’.

			+	

BestRES This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

Table 11: Peak load reduction (BM4)

	Spot Optimisation	Grid Optimisation	Δ	German National grid
Peak load of national water supply	1137 MW	722 MW	-415 MW	80 000 MW

Carbon footprint

The simulations indicate that the grid charges optimisation causes a slight increase in the average carbon content of the consumed power. In the case of spot optimisation, demand is shifted to consume more during times of low spot prices, which in Germany correlates with a low carbon content of electricity production [2]. When the grid charges are optimised, however, the peak reduction overrides this correlation and the specific CO_2 emissions subsequently increase.

While it is remarkable that the carbon content in the BM increases due to the BM, the increase is only minor. These results are an indication that the current grid tariff design does not actively encourage consumers to consume electricity during times of low carbon content. It would be important to change the way that the grid tariff is charged to allow flexibility to be used in a positive way. Under grid charges that reflect the carbon content of electricity, the flexibility could decrease greenhouse gas emissions. Considering the current framework, this BM is ranked as ‘0’.

		0		

Innovation

The BM combines two optimisation approaches: optimised variable and intra-day power supply and optimised grid charges. Whereas the former has a high degree of innovation, the latter is something which companies have been doing for many years. Therefore, the BM is considered as an improvement of an existing product and is rated as ‘incremental innovation’. However, in case grid charges will systematically be adapted towards flexibility incentives, this BM has the potential to become a breakthrough innovation.

	+		

BestRES This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

5. Next Kraftwerke Germany (France)

5.1 Providing decentralized units access to balancing markets (BM5)

5.1.1 Introduction and scope definition

In their BM *Providing decentralized units access to balancing markets*, Next Kraftwerke Germany (NKW DE) optimises the participation of flexible decentralised generation assets on power and reserve markets in France. The BM specifically considers valorising the asset's available flexibility on the day-ahead market and the rapid reserve market.

In [2], this BM is analysed through a case study of a portfolio which has a flexibility availability of 2 MWh per day, deliverable at a power of 1 MW. In this LCA two scenarios are specifically considered:

- The status quo in which the flexibility is used to produce electricity that is sold on the day-ahead market.
- The improved BM in which the flexibility is used to participate on the rapid reserve market with 4-hour availability periods and daily reserve procurement.

In the analysis, the installation can participate in both positive and negative reserve markets. The cases are evaluated based on the annual profit on the different markets, which is defined as the revenue on the different markets minus the fuel cost. Facility cost, O&M and other operation expenditures are not considered.

The aim of this LCA is to describe and quantify the benefits of a nationwide rollout of this BM in all biogas plants in France. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level. Secondly, the resulting KPIs are compared to relevant indicators of the electrical power system in France in an impact assessment.

5.1.2 Inventory

Cost of electricity

The results in [2] show that valorising the available flexibility through the rapid reserve market can lead to an increased revenue for the asset. An overview of the increased profit per MWh is given in Table 12. The improved BM causes an increase in profit of 4.39€/MWh. This represents an increase in profit of 17.3% compared to the reference scenario.

As the improved BM is able to increase the revenue of the asset with more than 10%, the improved BM is labelled '++' for this category.

++

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Table 12: Profit per MWh (BM5)

	Status Quo	Improved	Δ
Profit per MWh	34.24 €/MWh	47.26 €/MWh	+38%

Biogas is a source of renewable energy that still requires government support: the French Act on Energy Transition for Green Growth from 2017 foresees a support level for biogas plants of 150€/MWh to 175€/MWh, depending on the size of the specific plant [20]. This is comparable to the support level for solar PV (150-180€/MWh). A major difference between solar PV and a biogas plant, however, is that solar PV can only provide downward flexibility, and is therefore only limitedly dispatchable. A biogas plant is one of the few renewable electricity sources that can provide full flexibility to the grid and it is exactly this flexibility that the considered BM can activate.

Market participation

In the improved BM, the biogas installation is participating on multiple markets: the day-ahead market and the rapid reserve market. In case this BM is implemented in the national biogas portfolio in France, a significant amount of capacity volumes could be opened up on the different markets. Currently there is 412 MW of electricity-generating biogas in France [21]. Around 1000 MW of capacity is tendered on the rapid reserve market [22]. The implementation of the BM in all of the French biogas capacity can thus lead to a large increase in the number of bids on this market. Note that this will have a considerable effect on the bid ladder, and thus on the price setting of these markets.

The extrapolation results indicate that the improved BM can bring additional volume to the rapid reserve markets and that the improved BM increases the opportunities of assets to valorise their flexibility on reserve markets. The unlocked capacity can lead to more liquidity and competition on these markets and bring down the price that the TSO pays to maintain grid stability. This can reduce the operational cost of the electrical system. For these reasons the BM is labelled '++' for *market participation*.

				++

Community

As the BM is focused on medium to large-sized (industrial or agricultural) assets, there is no immediate community component to the BM. However, several cases in France, such as Éteignières and the Moulin Guérin farm, show that biogas allows for a localised approach in which electricity is generated directly at the place where the gas is produced [23], [24]. As a result, French biogas can be seen as a local energy source that can be well-integrated in communities. In that regard, this BM could support the development of energy communities and their active participation in the power sector. This BM's potential to empower citizens

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

to participate actively in the electricity market is why it is ranked '+' for this category.

			+	

Grid consciousness

The principal idea behind BM is to provide services to the transmission grid in the form of rapid reserve. As was shown in the section on *market participation*, the implementation of this BM in all biogas plants in France would be able to supply a share of the necessary rapid reserve flexibility in France. Furthermore, by offering this product, NKW DE makes clients aware of the value and necessity of ancillary services in the operation of power grids.
Additionally, this BM can to a certain extent improve the security of power supply in France. While biogas only has a 0.44% share in the total power production in France, it is one of the few sources of electricity that can be sourced locally [21].
This BM is awarded category '+' for *grid consciousness* because of these two reasons.

				++

Carbon footprint

While burning biogas releases CO_2, the released CO_2 is part of the biogenic carbon cycle and the net CO_2 emissions are lower than fossil sources. The added revenue from biogas units could lead to a more favourable investment climate for biogas plants. However, since this BM does not directly interact with the CO_2 emissions from the biogas plant, the BM is rated '0'.

		0		

Innovation

Currently, aggregation in France is mainly done for demand response or behind the meter generation. Furthermore, ancillary services are at this stage mainly provided by central power plants. Allowing controllable and decentralized renewables to participate in ancillary service therefore has a high degree of innovation. The BM can be transformational for the ancillary service market in France, which is why it is ranked '++' in this category.

		++	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

6. Next Kraftwerke Germany (Italy)

6.1 Market renewables on multiple markets (BM6)

6.1.1 Introduction and scope definition

In their BM *Market renewable on multiple markets*, Next Kraftwerke Germany (NKW DE) expands their operations to participate in power and reserve markets in Italy. The BM specifically considers valorising the electricity produced by wind and solar assets on the day-ahead market (MGP).

Specifically for the situation in Italy is that there are 6 different bidding zones present in the country. In [2], the price difference for selling electricity from solar and wind assets on the different bidding zones is analysed.

The aim of this LCA is to describe and quantify the benefits of a nationwide rollout of this BM in all wind and solar assets in the different bidding zones of the country. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level. Secondly, the resulting KPIs are compared to relevant indicators of the electrical power system in France in an impact assessment.

As the simulation results for this BM are limited to an evaluation of the different Italian bidding zones, it is for some categories not possible to give a specific label. Furthermore, based on the simulation results it is not possible to evaluate the categories *community* and *grid consciousness*.

6.1.2 Inventory

Cost of electricity

The simulation results for solar and wind power in the different Italian bidding zones are given in Table 13. For solar power, there is a difference of up to 6.1€/MWh between the different bidding zones. This is 16% of the average revenue. For onshore wind power, there is a difference of up to 7€/MWh, or 16.6% of the average revenue. The percentage difference between the average price for solar power and wind power is 10.47%.

The regional differences can be due to localized market effects, such as the local electricity mix and load conditions. The difference in revenue between solar and wind power is the result of the different production profiles of the technologies. The simulation results indicate that solar PV produces more during times of lower electricity prices than wind power. A possible correlation could for example exist between systems with higher RES penetration and a wider gap between revenue of solar and wind power.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

As the simulation results do not indicate whether the BM causes an increase of decrease in cost of electricity, it does not receive a label in this category.

Table 13: Revenue RES in the different bidding zones (BM6)

Revenue in € / MWh	North market	Central North market	Central South market	South market	Sicily market	Sardinia market
Solar	39.8	38.2	37.0	35.1	41.2	36.9
Wind Onshore	42.3	41.7	41.1	40.1	47.1	41.1

Market participation

The installed capacity of solar and wind power in each of the Italian bidding zones is given in Table 14. In total the country has 29 GW of RES capacity, of which 68% is solar capacity and 32% is wind capacity. The distribution of each of the technologies is shown in Figure 6 and Figure 7. Most of the solar capacity is present in the north of the country, and the wind capacity is mostly located in the south. Puglia, in the south, is the region with both the highest capacity of wind power and solar power.

Similarly to the previous category, the BM does not receive a label for market participation.

Table 14: Installed capacity of RES per Italian bidding zone

	North Market	Central North Market	Central South Market	South Market	Sicilia Market	Sardinia Market	Total
Solar capacity	8703 MW	2333 MW	2832 MW	3688 MW	1377 MW	749 MW	19682 MW
Wind capacity	114 MW	144 MW	1634 MW	4710 MW	1795 MW	1011 MW	9410 MW

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

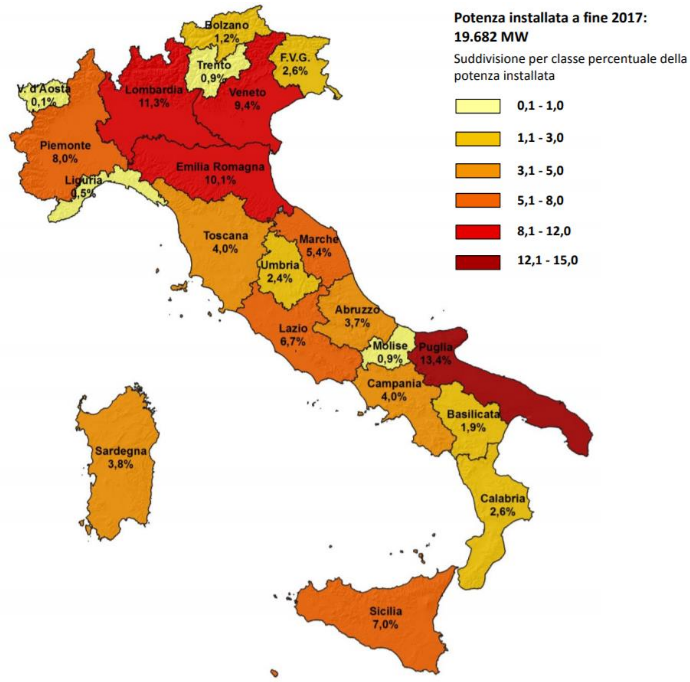


Figure 6: Distribution of solar capacity in Italy [25]

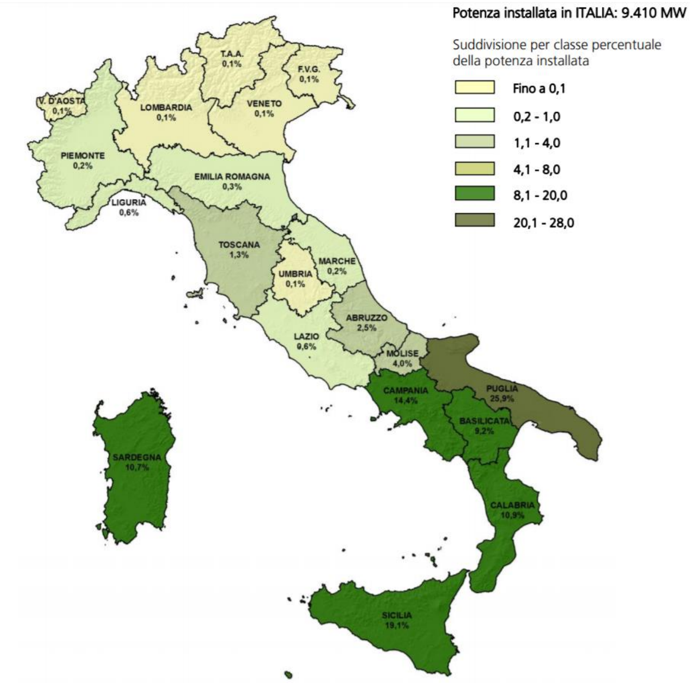


Figure 7: Distribution of wind capacity in Italy [26]

Carbon footprint

Trading electricity from renewable energy sources does not have a direct impact on the carbon footprint of electricity. Aggregated wind and solar assets would anyway produce the electricity, no matter in which way the power is traded. On the short term there is thus no difference in CO_2 emissions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

As a result, the BM is labelled ‘0’ for this category.

0

On the longer term, better trading results in higher revenues for the renewable power and thus means shorter payback times for the investors. This can indirectly lead to more renewables being installed in Italy.

Innovation

In May 2017, with the deliberation AEEGSI 300/2017/R/EEL, the Italian balancing market (MSD - Mercato per il servizio di dispacciamento), was opened to a large range of distributed technologies (variable renewable energy sources, distributed generators, storage systems and loads), including aggregated portfolios of production and consumption units, denominated as UVA. In this regard, this BM can be seen as part of a larger process of integrating aggregators in the Italian power system.

The Italian Transmission System Operator TERNA differentiates between three aggregated UVA units:

- UVAC – Aggregate Virtual Consumption Units
- UVAP – Aggregate Virtual Production Units
- UVAM – Aggregate Mixed Virtual Production including consumption, storage and production units.

So far there have been pilot projects for the UVAC and UVAP category, and there is as of yet no commercial operation in any of the categories.

The UVAC pilot projects test the ability of consumption units to participate in the balancing market as upward tertiary reserve. UVAP units have been tested in a pilot project for a total of 94 MW of flexible upwards and downwards power to test their effectiveness to provide tertiary reserve and to solve congestion problems. UVAM pilot projects have not taken place yet.

These recent developments show that the BM is transforming the industry and is therefore labelled as ‘+++’.

+++

BestRES This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

7. Next Kraftwerke Belgium (Belgium)

7.1 Trading PV and Wind Power (BM7)

7.1.1 Introduction and scope definition

In their BM *Trading PV and Wind Power*, Next Kraftwerke Belgium (NKW BE) trades the electricity from solar PV and onshore wind assets on the day-ahead market based on a day-ahead forecast. The improved BM additionally uses short term forecasting to mitigate the error on the day-ahead forecast. The aim is to optimally trade the deviation on the intraday market while considering the imbalance price to increase the asset's turnover.

In [2], this BM is analysed through a case study of several renewable energy portfolios:

- Trading of the national installed capacity of PV based on the Belgian TSO's day-ahead forecast
- Trading of a sample portfolio based on day-ahead and generation data provided by NKW BE
- Trading of the national installed capacity of onshore wind power based on the Belgian TSO's day-ahead forecast

Three trading strategies are studied, of which we will consider the following:

- The *reference* case where the day-ahead forecast is traded on the day-ahead market and all the deviations are settled on the imbalance market.
- The *optimal* case where the deviations are only traded on the intraday market if the value on the intraday market is higher than the value through imbalance settlement.

More details of the theoretical analysis can be found in [2].

The aim of this LCA is to quantify the benefits of a nationwide rollout of the *optimal* case BM in all solar power plants and onshore wind power plants in Belgium. The LCA considers the current installed capacity of renewable technologies in Belgium. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level. Secondly, resulting performance indicators for the different categories will be compared to relevant indicators of the electrical power system in Belgium.

7.1.2 Inventory

Cost of electricity

The simulation results in [2] show that the *optimal* case, in which the aggregator has perfect knowledge of market and imbalance prices, can result in an increase of revenues for both solar and wind assets. The increased revenue ranges from 5.3% to 12.0% depending on the specific technology and portfolio size. The results

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

per technology are shown in Table 15. As the average increase in revenue is smaller than 10€/MWh, the BM is classified as '+'.

			+	

The Solar NKW portfolio witnesses the largest increase in revenue which is due to the correlation between forecast error and portfolio size: a smaller portfolio is harder to forecast and will benefit more from optimised trading on the intra-day market. Overall, the results suggest that aggregation can create value by optimising trading strategies.

Table 15: Revenue from RES (BM7)

	Reference revenue €/MWh	*Optimal* revenue €/MWh	Added revenue €/MWh
Solar (2.9 GW portfolio)	36.40	38.49	+2.09 (+5.7%)
Solar NKW (2.0 MW portfolio)	33.44	37.57	+4.13 (+12.4%)
Wind onshore (1.2 GW portfolio)	31.05	33.55	+2.50 (+8.1%)

The increased revenue through optimised trading would be able to slightly reduce the government support for renewables. In Belgium, renewable energy sources receive a market premium in the form of green power certificates for each unit of produced electricity. The exact values of support depend on the specific technology. The current range is around 58€/MWh for wind power to almost 150€/MWh for solar power. This means that the added revenue represents between 1.4% and 4.3% of the support.

Market participation

Compared to the reference scenario, the BM causes an increased participation on electricity markets. Instead of only trading on the day-ahead market and paying the incurred imbalance fees, the BM tries to maximise the created value on the intra-day market.

The intraday market has several uses. In the first place it offers traders an alternative to avoid portfolio imbalance due to forecast deviation. This aims to reduce the activation of balancing mechanisms to keep the grid stable. Low imbalance prices, however, mean that several large market players prefer to keep settling forecast deviations through imbalance instead of trading them on

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

the intra-day market. This has as a result that the Belgian intra-day market is relatively illiquid and therefore economically inefficient.[3]

Table 16 gives the increased market participation on the intra-day market due to forecast deviation in case of a national rollout of the BM. At the moment the intra-day has a liquidity of 1089 GWh [27]. The results show that this BM can cause a market volume increase of 50% and potentially help to resolve the existing issues with intra-day trading. It is important to note that this extrapolation only considers the added volume on the market and does not consider which effect this has on the market's price.

The BM is for these reasons classified as '++' for the category *market participation*.

++

Table 16: Extrapolated Intra-day market volumes (BM7)

	Intraday	
	Reference GWh/year	*Optimal* GWh/year
Solar	0	145
Wind onshore	0	407
Total	0	552

Community

This BM can bring additional value to renewable energy sources and therefore indirectly support the development of renewable energy communities. Depending on the ownership of the assets, the community can receive a part of the added revenue. The BM's benefits can in this way support the development of renewable energy cooperatives and municipal participation in renewable energy projects. In Belgium, several Renewable Energy Cooperatives (REScoops) are active, and many of the larger developers are co-owned by municipalities. Participation is particularly important in wind projects, as these have a large impact on their environment and are more prone to be blocked by the local inhabitants. Private developers will therefore set up participative vehicles to facilitate community engagements particularly for wind projects.

Some examples are:

- Ecopower, a citizen cooperative for renewable energy with more than 50 000 participants;

[3] One could note that with the recent increase of the imbalance price cap by the CREG from 4500 to 13500, and the tightness on the market which make periods of high imbalance prices more likely, the bigger players might soon start to pay more attention.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

- Aspiravi, a developer of which the shareholders are 96 Belgian municipalities;
- Aspiravi Samen, the cooperative counterpart of Aspiravi
- Limburg Wind(t), a developer co-owned by Aspiravi and LRM;
- Energent, an energy cooperative active in Ghent;
- Beauvent, an energy cooperative in West Flanders

Only considering the largest developers, at least a significant share of RES in Belgium is community-owned and the profit of this BM will, directly or indirectly, go to the Belgian citizens. The BM is therefore labelled '+' for the community category.

			+	

Grid consciousness

This BM considers the optimisation of imbalance cost, which will lead to the reduction of imbalance in the grid compared to the reference scenario where the forecast deviation is settled through imbalance mechanisms. The extrapolation assumes a rollout in all the installed capacity of solar and wind power in Belgian. The results are shown in Table 17. The calculated value indicates that the BM can reduce the imbalance due to forecast deviation by 46%. The imbalance reduction is not linearly correlated with the reduction in balancing energy activation: When the national grid simultaneously contains injection points with positive and negative imbalance, these cancel each other out and don't result in activated balancing energy.

Other than the imbalance benefits, trading on the intra-day market causes a maximum use of transmission capacity and provides prices that reflect market fundamentals. As it improves several grid aspects, the BM is labelled as '++' for *grid consciousness*.

				++

Table 17: Imbalance due to forecast deviation (BM7)

	Reference GWh/year	*Optimal* GWh/year
Solar	319	173
Wind onshore	864	457
Total	1 182	630

Carbon footprint

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Trading electricity from renewable energy sources does not have a direct impact on the carbon footprint of electricity. Aggregated wind and solar assets would anyway produce the electricity, no matter in which way the power is traded. On the short term there is thus no difference in CO_2 emissions.

As a result, the BM is labelled ‘0’ for this category.

		0		

On the longer term, better trading results in higher revenues for the renewable power and thus means shorter payback times for the investors. This can indirectly lead to more renewables being installed in Belgium.

Innovation

A major innovation in this BM is that the trading is based on real-time data. At the moment, many solar and wind installations are still traded only based on weather forecasts and the installation’s rated capacity. In this BM, NKW BE uses monitoring data from the plant to update the forecasts in real-time, and to improve the forecasting over time. Furthermore, not all traders of renewables are also BRP, which means that they cannot do imbalance optimisations unless they have several agreements with all affected BRPs. The imbalance forecast and optimisation is thus an innovation in the Belgian market.

The innovation is rated as incremental as it is a significant improvement of an existing product.

	+		

7.2 Using flexibility of customers as third party (BM8)

7.2.1 Introduction and scope definition

In their BM *Using flexibility of customers as third party*, NKW BE valorises the load and generation flexibility of their customers on multiple markets with the aim to optimise the created value. The BM specifically looks at the operation of the aggregator on the day-ahead market, the intra-day market and the positive tertiary reserve market.

This BM is analysed in [2] through a case study on load profiles for B2B clients that fall within the following categories: lighting, cooling and industry. The flexibility availability is different for each load profile, as described in [2]. Additionally, a diesel generator is considered. For the LCA, the ‘baseline’ scenario, without participation on reserve markets, is compared to the ‘reserve’ scenario, in which all flexibility is offered on the R3+ reserve market. In the reserve scenario, all reserve activations are balanced on the intra-day market.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

The aim of this LCA is to describe and quantify the benefits of a rollout of this BM in Belgium. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level for Belgium. Secondly, the resulting KPIs are compared to relevant indicators of the Belgian electrical power system in an impact assessment.

7.2.2 Inventory

Cost of electricity

The theoretical modelling shows that this BM can reduce the customers' cost for electricity supply. Considering the average price for the aggregated load profile in the baseline and reserve scenario including diesel generation activation, the sourcing cost reduces from 38.80€/MWh to 34.57€/MWh in the reserve scenario. This represents a reduction of 11%. Considering the significant cost reduction (>10%), the awarded category is '++'.

				++

Table 18: Electricity cost reduction (BM8)

	Status Quo	Improved	Δ
Cost of electricity	38.80 €/MWh	34.57 €/MWh	-11%

An estimate of the applicability of the BM is given in Table 19. Industrial electricity consumption in Belgium amounts to 45% of the national total [28]. Under the assumption that the modelled flexibility corresponds to the available flexibility in the industrial consumption, the BM can lead to a cost reduction for 37 939 GWh of consumption in Belgium.

Table 19: Applicability of BM8 [29]

	Belgium
Industrial electricity consumption	37 939 GWh
Share of total	45%

Market participation

The BM's control algorithm is twofold: it considers both short-term price signals and national reserve activation.

The overall system balance between production and consumption is addressed by taking into account the sport market price signals. This aspect of the optimisation causes a larger price-response and increases the power system's

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

efficiency: times of high production (low prices) are met with times of high demand. This leads to an enhanced market participation of the assets.

The reserve market participation also acts based on knowledge of the instantaneous state of the overarching power system: the reserves are only activated in case of a national deficit or excess. The benefits of this part of the optimisation can therefore lead to benefits on a system level. The created value through reserve market participation is a grid service that is reflective of the instantaneous system state. On average in 2018, 351 MW of tertiary reserves were contracted [30]. This BM could unlock the flexibility of an additional share of assets that can contribute to this reserve requirement. The unlocked capacity can lead to more competition on the R3+ reserve market and bring down the price that the TSO pays to maintain grid stability.

Since the BM leads to added value on additional markets, the awarded score is '++'.

				++

Community

This business model is oriented towards industrial assets and therefore does not contribute to the development of local energy communities. The benefits that this BM generates are sensibly distributed between NKW BE, on one side, and industrial asset owners on the other side. As a result, the awarded score is '0'.

		0		

Grid consciousness

The principal idea behind this BM is to diversify the role of a portfolio and use its flexibility to provide services to the transmission grid. Here tertiary reserve is considered. As was shown in the section on *market participation*, the implementation of this BM could help to provide a significant part of the tertiary reserve balancing requirements in Belgium. Furthermore, by offering this product, NKW BE makes clients aware of the value and necessity of ancillary services in the operation of power grids.

Other than the participation on the tertiary reserve, optimised trading on the day-ahead market causes a maximum use of transmission capacity and provides prices that reflect market fundamentals. The BM is therefore labelled as '++' for *grid consciousness*.

				++

Carbon footprint

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

The simulation results in [2] indicate that the reserve scenario causes a slight increase in the average carbon content of the consumed power compared to the national average carbon content. As Belgium has a large share of nuclear power, the average carbon content in electricity is rather low.

Since nuclear assets do not participate on the tertiary reserve, a more correct reference would be to look at the technology that the portfolio would replace on the R3 market. In general, only gas plants and diesel gensets participate on R3. However, since R3 activations are generally less than 2 hours per year, there is no significant impact on CO_2 emissions. The BM is therefore rated ‘0’ for this category.

		0		

Innovation

The BM is in several ways innovative in the Belgian market. Firstly, the flexibility solution is technologically ‘agnostic’ in the sense that it can unlock flexibility for a wide range of assets. Secondly, it uses a control box to dispatch different technologies within a portfolio using real-time monitoring in a way that is very secure. This service can be delivered with a compliancy rate that is higher than the average provision compliancy from other market actors.

Since this BM provides a significant improvement of an existing product in the Belgian market, it is rated as incremental innovation.

	+		

BestRES This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

8. oekostrom (Austria)

8.1 Demand side flexibilization of small customers (BM9)

8.1.1 Introduction and scope definition

In the BM *Demand side flexibilization of small customers*, oekostrom offers a dynamic electricity tariff to their residential customers that incentivizes them to shift consumption from peak demand times to off-peak demand times. The tariff has an hourly pricing based on spot prices. The electricity price on the Austrian spot market is higher during peak hours compared to off-peak hours, which means that the shifted load can allow oekostrom to reduce its electricity sourcing cost. Part of the benefits can be passed on to the customer through a reduction of their electricity bill.

In [2], this BM is analysed through a case study of four residential load profiles under a two-period ToU tariff. The considered tariff consists of two 12-hour blocks, one during the day (peak: 8am to 8pm) and one during the night (off-peak: 8pm to 8am). Note that this is different from the theoretical BM. The analysed load profiles are constructed by aggregating 5000 residential load profiles of the same household type. The following types are considered:

- An employed person living on their own,
- An employed couple under 30 without children,
- A middle-aged couple without children of which one partner is employed and the other stays at home,
- A family with two employed parents and 3 children.

The upper and lower price, for respectively peak and off-peak consumption, is varied to analyse their effect on the create value. In the baseline scenario the upper and lower price are the same.

The aim of this LCA is to describe and quantify the benefits of a nationwide rollout of this BM in all households in Austria. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level. Secondly, the resulting KPIs are compared to relevant indicators of the electrical power system in Austria in an impact assessment.

8.1.2 Inventory

Cost of electricity

The theoretical modelling in [2] shows that a ToU tariff, if correctly designed, can decrease the cost of electricity for the consumer while increasing the revenue of the aggregator. If only the off-peak/peak price combinations are considered that bring benefits to both the supplier and aggregator, the average reduction per type of client is shown in Table 20. The average reduction for all

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

clients is 0.76%. Note that these values only consider the energy component of the electricity bill.

The total electricity price of residential consumers, including the energy component, the distribution and transmission tariff and any taxes and levies, in Austria is 197.8€/MWh [31]. Assuming a relative share of the electricity component in the total electricity bill of 30.3%, the BM leads to a reduction of the total cost of electricity of 0.23%. For an average residential consumer with an annual consumption of 3.5 MWh, this correspond to a reduction of €1.59 per year. This means that the dynamic pricing of the energy component of the electricity price has a very low impact on the total electricity price.

Since the BM leads to a decrease of less than 10%, the BM is rated ‘+’ in this category.

			+	

Table 20: Average electricity price (BM9)

Load type	Baseline tariff	Reduced tariff (Average)
Single with work	59.9 €/MWh	58.82 €/MWh (-1.79%)
Couple under 30 with work	59.9 €/MWh	59.49 €/MWh (-0.68%)
Couple between 30-64, one with work	59.9 €/MWh	59.89 €/MWh (-0.02%)
Family with 3 children, both with work	59.9 €/MWh	59.56 €/MWh (-0.57%)
Average	59.9 €/MWh	59.44 €/MWh (-0.76%)

Market participation

The BM does not have a direct impact on *how* residential consumers participate in electricity markets and the BM does not change their market role. Suppliers use synthetic load profiles (SLPs) to trade and balance residential consumption, even for households that have a digital meter, in order to limit the required metering and trading infrastructure. As a result, the load shifting that is caused by this BM will only indirectly impact the way that the residential consumption is sourced on the markets. Since February 2018 there is theoretically the option in Austria to request the DSO to switch to a real load profile for trading. However, practically this does not work up to now. Only in case that this service becomes operational, or when the SLPs are calibrated yearly using measured grid data, can this BM influence the households’ formal interaction with power system mechanisms such as system balance and overload.

BestRES This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

The increase in market participation due to the BM is for these reasons labelled as ‘0’.

0

Community

While the BM is aimed towards residential consumers, it does not explicitly involve cooperation or collaboration of households. The impact of the BM on the potential to form energy communities is therefore indirect: a ToU tariff and residential flexibility aggregated on a neighbourhood level can lead to additional benefits compared to uncoordinated control on an individual household level. In that regard, this BM could support the development of energy communities and their active participation in the power sector. The BM’s score for *community* is therefore ‘+’.

+

Grid consciousness

Consumers in this BM are incentivised to shift their consumption patterns, which could result in a load profile that better follows the market’s production profile. Countries tend to introduce ToU tariffs to compensate for inflexible generation, such as coal and run-of-river hydro power, that cannot easily decrease their production when the load is low. Austria has a high share of run-of-river type hydro power plants that requires flexibility to maintain the base load [4]. The BM can be a mechanism to unlock residential load flexibility and adjust the demand to the supply. Based on the calculations in [2], this BM could result in a shift of up to 22% of residential consumption. Assuming a unanimous rollout in all of Austria’s 3,900,000 households, this would mean that 3.05 TWh could potentially be shifted. This is almost 5% of Austria’s electricity consumption [32].

A dynamic ToU tariff is reflective of the instantaneous system state, which means that the shifted consumption can contribute to a more resilient power system. A dynamic ToU optimisation can incentivise the households to postpone consumption during times of peak demand. Furthermore, the BM raises awareness about the time-dependency of electricity consumption.

Because the BM leads to an increased load shifting, the BM is awarded ‘+’ for this category.

+

Carbon footprint

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

The simulation results in [2] show that the temporally shifted load can either cause a small increase or decrease in the carbon content of the consumed electricity. The decrease in average carbon content between the two scenarios varies between -0.64% and +1.18%. This effect is not found to be significant and the BM is for this reason rated '0'.

		0		

Innovation

Almost three-quarters of Austrian electricity providers and all former public utilities have included night-time electricity tariffs in their offer.

Several countries, especially those with a high smart meter rollout, are implementing tariffs that are more dynamic than a bi-periodical tariff. For example, in Spain these innovative tariffs are grouped under the program Precio Voluntario al Pequeño Consumidor (Voluntary price for small consumers). One of these tariffs designates an electricity price to each hour throughout the day based on the foreseen supply and demand on the national markets. The prices are fixed one day beforehand and can be consulted online. In the UK, ToU tariffs with two rates such as Economy 10 and Economy 7 have existed for several years. In 2017, the electricity supplier Green Energy introduced their *Tide* tariff, which uses a smart meter to differentiate between three different electricity prices across four periods during the week and two during the weekend.

In Austria, however, dynamic tariffs are not operational yet. This means that this BM will lead to a new product on the market. oekostrom is in this regard a front-runner in the country. The BM is therefore labelled '++' for *innovation*.

		++	

8.2 Valorise distributed generation of customers in apartment buildings (BM10)

8.2.1 Introduction and scope definition

In their BM *Valorise distributed generation of customers in apartment buildings*, oekostrom aims to enable households that live in apartment buildings to collectively invest in a PV installation. Until recently, it was impossible in Austria to install collective solar panels on urban roofs because each installation needed to be allocated to a single metering point. Now regulation has changed, which means that there is a large untapped potential for PV development on roofs of apartment buildings.

The most lucrative way of investing and operating PV plants on buildings is to evade paying the electricity's residential retail price by maximising self-

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

consumption. Aggregating the consumption of an entire apartment building inherently increases the self-consumption of the locally produced PV power and thus improves the asset's economic performance.

In [2], this BM is analysed through a case study of a residential apartment building in Vienna that consists of 10 individual households. The inhabitants are chosen to be representative for a typical apartment building in Vienna and each household is characterised by its average electric load profile for a single day. Three different scenarios are considered:

- The *baseline* scenario considers the situation in which there is no PV plant installed.
- The *dynamic* scenario considers the situation in which each individual flat owns a part of the collective PV installation and the generated power can be traded between the individual flats.

In the dynamic scenario, power will only be traded with the utility grid in case the total produced solar power is higher than the building's total electrical consumption.

The aim of this LCA is to describe and quantify the benefits of a nationwide rollout of this BM in all apartment buildings in Austria. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level. Secondly, the resulting KPIs are compared to relevant indicators of the electrical power system in Austria in an impact assessment.

8.2.2 Inventory

Cost of electricity

The theoretical modelling shows that this BM can significantly reduce the sourcing cost of electricity for apartment buildings. The simulation results indicate that savings up to 25.7% are possible in the case of an optimally sized collective PV installation on a typical apartment building in Vienna. These results are shown in Table 21. The reduction on the electricity bill is higher than 10%, and the BM is thus awarded '++' for this category.

				++

Table 21: Electricity bill reduction (BM10)

	Baseline	Dynamic	Δ
Cost of electricity	229.89 €/MWh	170.74 €/MWh	-25.7%

The LCA analyses of the applicability of the calculated cost savings for Austrian households. In Austria, 44.7% of the population lives in multi-family buildings [33]. This amounts to a total of 1.771 million households in multi-dwelling buildings that have not been able to benefit from residential PV production. For

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

a building's roof to be suitable for this BM it must be correctly oriented (preferably facing the south) and be unobstructed. Based on the conservative estimate that 40% of the available rooftop space fulfils these criteria [34], almost 18% of the population could benefit from the advantages of this BM. This corresponds to approximately 708 000 dwellings.

Market participation

This BM has the potential to empower a significant part of the Austrian population to invest in, own and benefit from community-owned distributed generation. The results of the previous section allow to make an estimate of the total potential of PV production on multi-dwelling rooftops. Based on an assumption of on average 3 stories per building and a multi-dwelling building stock that covers 126 km² of living area, the available rooftop space is of the order of 42 km². A rooftop suitability of 40% is assumed, which results in a total suitable area of 16.9 km². Based on the assumed spatial density of PV technologies of 0.13 GW per km² [34], the total potential of PV on multi-dwelling rooftops in Austria is 2.2 GW. The calculations are summarised in Table 22.

Table 22: Estimation of PV potential on rooftops of multi-dwelling buildings (BM10)

	# dwellings	Living area	Rooftop area	Suitability	Suitable Area	Total potential
2018	1 771 000	126.74 km²	42.25 km²	40%	16.90 km²	2.2 GW

To put these results in perspective, 2.2 GW of solar PV under average Austrian meteorological conditions can annually generate 2.2 TWh of electricity. Compared to a residential electricity consumption in Austria of 17.81 TWh [29], the unlocked capacity in this BM could thus provide 12% of the national residential power demand.

While the BM does not cause participation on additional markets, it does significantly increase the electricity volume. The BM is therefore labelled '+' for this category.

			+	

Community

The principal purpose of this BM is to empower communities to invest in PV installations and to reap the collective benefits. The BM can present innovative solutions to overcome the major obstacles of collective PV installations: ownership and investment. Below several implementation models are discussed that try to mitigate these issues [35].

In a first possible implementation scheme, the PV system is owned and financed by the building owner and the produced electricity is distributed between the consumption of the building's general facilities and the residents of the

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

individual apartments. The PV system is considered a part of the building's collective infrastructure, similarly to the elevator, a common laundry room or bicycle storage. Even though the residents of the building do not own the installation, they don't pay to auto-consume the produced solar electricity. The right to auto-consume is an inherent benefit of owning an apartment in the building, similarly to access to its other collective facilities. In this way, all residents automatically participate in the project. Each apartment is equipped with a smart meter to determine the simultaneity of production with consumption. When production and consumption coincide, the amount of electricity produced is distributed among the consumers. A contract is signed between the building owner and a supplier to sell the excess local production. The generated revenues are collected by the building owner. This way the free choice of supplier for this individual apartment is guaranteed.

In the second model, the owners of the individual apartment set up a resident association and collectively finance and own a rooftop PV installation. The members of the association pay a share of the investment cost and receive the right to self-consume the produced PV power. A difference between this scheme and the previous one is that participation in the association is voluntary. Residents can choose not to participate in the project.

A third scheme to facilitate a collective PV installation is through an external company, responsible for the investment and operation of the PV installation, that leases the installation to the residents. The participating households pay lease to the external company, for example as a fixed sum per year. Solar power is distributed to the participants when there is simultaneous production and consumption. The external company receives the revenue from the sale of electricity to a supplier in case of excess production. Another option is that instead of a lease, an external company charges a fixed price (in €/kWh) for electrical auto-consumption of the produced power. If production and consumption coincide, the used PV power is charged. The charged price should be lower than the supplier's price. As the PV contractor and the supplier are different entities, the participating households will receive two bills: one for the PV self-consumption and one for electricity sourced from the grid. In this case the external company receives the benefits of the sale of excess production.

In the fourth scheme an energy supplier finances and operates the PV system. The residents can only benefit from the collective PV installation when they receive their electricity from this supplier. Similarly to the case of an external operator, the energy supplier charges a fixed price for the used PV electricity (in €/kWh) and this price should be below the price of regular electricity supply. The participating households only receive a single bill that incorporates both the PV auto-consumption and the regular electricity supply.

Even though these schemes present viable options for the rollout of this BM, several barriers still exist that are inherent to the situation in apartment buildings. In many cases, apartment buildings are inhabited by tenants rather than property owners, which means that provisions of the PV installation have to be included in a long-term contract between the owner and occupier. In case an

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

occupier decides to move, there is always uncertainty on whether the new tenant will be willing to take over this contract. Even when the respective property-owner inhabits the dwelling can there be complication of innovative implementation forms of this BM: it is possible that mortgage lenders do not accept a third party or collectively owned installation on the mortgaged property. This introduces several types of risk in the PV project that, depending on the scheme, is either taken by the residents, the external investor or the electricity supplier.

This BM can present an important step forward in the emancipation of community-owned facilities and is therefore awarded the score '++' in the community category.

++

Grid consciousness

The BM is found to contribute to three grid-related aspects: increased local consumption, security of supply, and potentially improving power quality.

By allowing residents of apartment buildings to invest in solar PV systems, consumption and production are integrated on a building level. A price difference between locally-produced electricity and grid-sourced electricity correctly indicates the importance of auto-consumption on grid infrastructure

On a national level, the BM has furthermore the potential to increase the security of supply for residential consumers. As is shown under the category *market participation*, a large-scale rollout of this BM could lead to local installations that produce a significant part of the residential electricity demand.

From a power quality point of view there is an advantage between a scenario with a collective PV installation, and one where flats have individual PV installations. In the case with individual PV installations each PV-installation would be equipped with an individual inverter. This setup can have a significant effect on power quality at the connection point. Invertors introduce harmonics in the system, and when multiple inverters are connected these harmonics could interact to aggravate the situation. While multiple inverters can increase the reliability of the system (the outage of one inverter will only have a minor effect on the plant's total performance), it decreases resource efficiency compared to a single large inverter.

Because the BM addresses 3 different aspects of grid operation it is awarded '++' in the category *grid consciousness*.

++

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Carbon footprint

The proposed rollout considering the potential of all Austrian apartment building indicates that 2.2 GW can be installed by 2020 and 2.64 GW by 2030, shown in Table 22. Considering an average capacity factor of 11.4% and a carbon content of Austrian electricity of 85kg/MWh, the resulting reduction ranges from 187 000 tCO_2 per year in 2020 up to 224 400 tCO_2 per year in 2030. This is approximately a reduction of 3% of all CO_2 emissions due to electricity generation in 2017.

				++

Innovation

Until recently, the legislative framework in Austria made the Dynamic scenario impossible. Metering points had to be kept individual which made it impossible to assign an asset to multiple metering points. Furthermore, electricity generated by a collectively-owned is transmitted through the building's grid infrastructure, which was considered as a part of the public grid. Additionally, the grid operator's monopoly required a grid licence to use the public grid. However, recent changes in the legislative framework, particularly the Amendment of the Electricity Management and Organization Act 2010 from 26th July 2017, include several provisions to promote community production facilities.

Article 2 of this amendment specifically defines community production facilities as
"... a production facility generating electrical energy to cover the consumption of the participating beneficiaries".

It explicitly includes that network access beneficiaries shall have the right to operate collectively owned generation assets if the free choice of suppliers to the end consumers is not restricted. The production asset is only allowed to be connected to communal power lines that are located close to the connection points of the local beneficiaries. The DSO is granted an important role concerning allocation, metering and data communication and management.

These changes have only been in place for little more than one year, which means that this BM can be considered innovative. Nevertheless, several Austrian projects already exist in which this BM has been implemented by other parties:

- In Graz, a 6-dwelling building has been equipped with an 11.4 kWp solar PV installation and a lithium ion battery of 10 kWh with the aim to optimise self-consumption and drive down electricity cost for residential consumers [36].
- Also in Graz, a 12.2 kWp PV installation combined with a 12 kWh salt water storage plant has been installed in an 8-dwelling building. Just like the previous project, the residents were supported by the utility Energie Graz [36].

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

- A larger scale project was realised in Innsbruck where 38 households in a multi-party house collective installed around 30 MW of PV supported by the utility iKB [37].

Since the BM causes the launch of a new product, the BM is rated as breakthrough innovation.

		++	

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

9. EDP (Spain and Portugal)

9.1 Activation and marketing of end user's flexibility (BM11)

9.1.1 Introduction and scope definition

In their BM *Activation and marketing of end user's flexibility*, EDP offers solutions to its clients to valorise their load flexibility potential. EDP targets to use the flexibility of B2B consumers that want to manage and optimize energy consumption in their office buildings to decrease the cost of electricity. This happens through two mechanisms: the flexibility is used to reduce the price paid for imbalances of EDP's entire portfolio and to reduce the electricity sourcing cost by buying electricity at times of low electricity prices.

This BM is analysed in [2] through a case study on load profiles from EDP's B2B clients that are active in different sectors of activities. In the Portuguese case, the considered load profiles are Water Supply, Heat and Other. For Spain, an office building is considered with an HVAC load, Power load and Lighting. The flexibility availability is different for each load profile, as described in [2]. For the LCA, the optimal scenario is considered in which the flexibility is optimally used between sourcing optimisation and imbalance reduction in order to achieve the largest cost reduction. Note that this optimal scenario is a theoretical optimal since imbalance prices are not known in real-time. The results therefore represent a maximum scenario.

The aim of this LCA is to describe and quantify the benefits of a rollout of this BM in EDP's entire portfolio. Initially, the results of the quantitative analysis from [2] are inventoried and scaled up to a national level for both Portugal and Spain. Secondly, the resulting KPIs are compared to relevant indicators of the electrical power system in Portugal and Spain in an impact assessment.

9.1.2 Inventory

Cost of electricity

The theoretical modelling shows that this BM can reduce EDP's operational cost for electricity supply. Considering the average cost reduction of the aggregated load profile over the total electricity consumption, the resulting sourcing cost reduction is 2.11€/MWh in Portugal and 0.74€/MWh in Spain. These results indicate that there is more value in imbalance and spot price optimisation in Portugal than in Spain. It is assumed that half of this cost reduction is passed on to the consumer.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

A comparison with the average electricity price for medium size[4] industrial consumers in Spain and Portugal is shown in Table 23 and Table 24 [38]. The results indicate that the BM can lead to a cost saving of between 0.38% and 1.26%.

Table 23: Electricity cost reduction in Portugal (BM11)

Portugal	Sourcing cost reduction	Consumer benefit	Electricity price Portugal	Δ
Industrial Portfolio	2.72 €/MWh	1.86 €/MWh	83.7 **€/MWh**	-2.22%

Table 24: Electricity cost reduction in Spain (BM11)

Spain	Sourcing cost reduction	Consumer benefit	Electricity price Spain	Δ
Office Building	0.74 €/MWh	0.37 €/MWh	98.2 **€/MWh**	-0.38%

According to the criteria of this category, the BM is awarded a score of + because it reduces the electricity cost with less than 10%.

			+	

An estimate of the applicability of the BM is given in Table 25. Industrial electricity consumption in Spain and Portugal amount respectively to 30% and 35% of the national total. Under the assumption that the modelled flexibility corresponds to the available flexibility in the industrial consumption, the BM can lead to a cost reduction for 80 442 GWh and 17 607 GWh of consumption in respectively Spain and Portugal.

Table 25: Applicability of BM11 [39], [40]

	Spain	Portugal
Industrial electricity consumption	80 442 GWh	17 607 GWh
Share of total	30%	35%

Market participation

The BM's optimisation algorithm is twofold: it considers both short-term price signals and instantaneous imbalance prices.

[4] Defined as consumers with an annual consumption between 500 MWh and 2 000 MWh. (Eurostat)

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

The overall system balance between production and consumption is addressed by taking into account the sport market price signals. This aspect of the optimisation causes a larger price-response and increases the power system's efficiency: times of high production (low prices) are met with times of high demand. This leads to an enhanced market participation of the assets.
The optimisation algorithm concerning the imbalances costs also acts based on knowledge of the instantaneous state of the overarching power system. The benefits of this part of the optimisation can therefore lead to benefits on a system level. The created value through imbalance optimisation is a grid service that is reflective of the instantaneous system state.

While this BM does not lead to participation on additional markets, it does enhance the asset's participation through the current markets and mechanisms. The BM could be further improved if it allows flexible clients to participate in reserve markets. As a result, the awarded score is '+'.

			+	

Community

This business model is oriented towards industrial assets and HVAC systems in buildings and therefore does not contribute to the development of local energy communities. The benefits that this BM generates are sensibly distributed between EDP, on one side, and industrial asset owners on the other side. As a result, the awarded category is '0'.

		0		

Grid consciousness

This BM considers the optimisation of imbalance cost, which will lead to a reduction of system imbalance in the grid compared to the reference scenario where the portfolio's deviation is settled through imbalance mechanisms. The extrapolation calculates the amount of available flexibility for imbalance mitigation assuming a rollout in the entire industrial sector in Portugal and Spain. The resulting values are calculated as a linear extrapolation of the simulated flexibility activations and an electricity consumption of 17 607 GWh and 80 442 GWh in respectively Portugal and Spain. The BM's flexibility potential for Portugal is shown in Table 26. Around 725 GWh and 904 GWh of respectively upward and downward flexibility for imbalance reduction could be made available in Portugal. Table 27 gives the results for Spain, where 10.7 GWh and 7.11 GWh of flexibility could be made available. Both tables gives the ancillary service activations[5] in each of the countries as a references [40]. The results suggest that the BM's imbalance mitigation could lead to a significant reduction in reserve activation.

[5] In Spain, the reserve activations are calculated as the sum of secondary reserve, tertiary reserve and deviation management. In Portugal it is defined as the grid imbalance.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Other than the imbalance benefits, optimised trading on the day-ahead market causes a maximum use of transmission capacity and provides prices that reflect market fundamentals. The BM is therefore labelled as '++' for *grid consciousness*.

++

Table 26: Imbalance reduction potential in Portugal (BM11) [41]

Reserves	BM Flexibility potential	National reserve activation (2017)
Upwards	725 GWh	2330 GWh
Downwards	903 GWh	2080 GWh

Table 27: Imbalance reduction potential in Spain (BM11) [40]

Reserves	BM Flexibility potential	National reserve activation (2017)
Upwards	10.7 GWh	4560 GWh
Downwards	7.1 GWh	3780 GWh

Carbon footprint

The simulations indicate that the optimal scenario causes a slight increase in the average carbon content of the consumed power in Portugal. In Spain there is a slight decrease. In both Portugal and Spain there is a general correlation between low spot prices and low carbon content of consumed electricity [2]. It is however important to consider between which points the consumption is shifted. The analysis shows that under the optimal scenario there is generally more shifting from low carbon content to high carbon content. The CO_2 emissions subsequently increase.

While it is remarkable that the carbon content in the BM increases due to the BM, the increase is only minor. These results are an indication that the current imbalance design does not actively encourage consumers to consume electricity during times of low carbon content. It would be important to change the way that imbalances are charged to allow flexibility to be used in a positive way. Under a system that reflects the instantaneous carbon content of electricity, the flexibility could decrease greenhouse gas emissions. Considering the current framework, this BM is ranked as '0'.

0

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Innovation

Optimised control of assets is an existing service in Portugal and Spain. However, this BM assesses the available flexibility based on the thermal inertia of buildings, which is something that is innovative in Portugal. EDP is planning to launch this technology as a new product. The BM is therefore labelled as breakthrough for the *innovation* category.

		++	

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

10. FOSS (Cyprus)

10.1 Pooling flexibility for local balancing market and energy service provision (BM12)

10.1.1 Introduction and scope definition

In their BM *Pooling flexibility for local balancing market and energy service provision*, FOSS aims to aggregate loads, production units and storage facilities of a university campus and residential prosumers to offer grid services to the local DSO. By using net billing and net metering tariffs with Time-of-Use cost components the BM offers options to minimize energy cost through an effective use of local RES generation and storage.

The original BM consists of two distinct use-cases:

- Single mid-scale commercial or industrial consumers through the control of all assets from a single point of connection to the grid,
- Multiple small prosumers who are aggregated through the use of appropriate in-house energy management systems and smart connectivity with the local DSO.

In this LCA, only the first use-case will be analysed.

In [2], the BM is analysed through a case study of the campus of the University of Cyprus that is operated as a grid-connected controllable microgrid. In particular, two scenarios are analysed:

- The optimal sizing of the solar and battery system based on the electricity cost reduction under a net billing tariff.
- The additional benefits to the DSO based on the peak load reduction.

The aim of this LCA is to describe and quantify the effect of the implementation of this microgrid on the Cypriot power system. The results from the quantitative analysis from [2] are inventoried and compared to relevant indicators of the electrical power system in Cyprus in an impact assessment.

10.1.2 Inventory

Cost of electricity

The modelling results show that this BM can significantly reduce the sourcing cost of electricity for the university campus of Cyprus. The simulation results, restated in Table 28, indicate that savings up to 58% are possible in the case of an optimally sized PV installation. This represents a cost saving larger than 10% and the BM is thus awarded '++' for this category

++

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Table 28: Reduction in electricity cost (BM12)

	Without PV and battery	With PV	With PV and battery
Electricity cost	101.86 €/MWh	42.58 €/MWh	44.12 €/MWh

Market participation

Complete liberalisation of the Cypriot electricity market was legally achieved on the 1st of January 2014. However, at the moment there is no operational wholesale market in Cyprus and the development of open and competitive energy markets is still ongoing. Market participation in a Cypriot context, as such, does not exist.

The BM, however, will lead to additional energy in the Cypriot power system regardless of the applicable market design. To evaluate the *market participation* category, the proposed installed capacity of PV in the microgrid is compared to the national installed solar PV capacity in Cyprus. The results indicate that the microgrid could add 10% to the national solar capacity.

In conclusion, due to the current market design in Cyprus the BM does not lead to participation on additional markets. However, it leads to added energy volume from the PV production. The BM therefore receives the score '+' for the category *market participation*.

			+	

Table 29: Relative share of installed PV capacity in Cyprus

	Solar PV
National installed capacity	105.3 MW
UCY microgrid	10 MW (+9.5%)

Community

The university microgrid can form the basis of a local energy community on the university campus. The BM can be a concrete tool to create local energy communities as it enables the campus community to engage in value-driven activities regarding generation and distribution of electricity. All activities within the university done by third parties such as bank services, book sellers, other commercial shops, refectories, restaurants, cafes, student halls of residence, sport centres etc are serviced through the centrally managed microgrid acting as an energy community.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

As discussed under *market participation*, this BM can furthermore be an important facilitator to increase involvement in additional local energy services, such as flexibility through demand response.

As the BM has a direct contribution to the development of an energy community, this BM is labelled '++' in this category.

				++

Grid consciousness

The presence of distributed generation and energy storage within the microgrid can reduce the maximum load demand, thereby extending the life cycle of grid components. This can allow a reduced need for grid investments in the future, with associated benefits to the DSO. Since maximum demand occurs only a few hours per year, the microgrid operation can provide a reliable way to avoid transmission and distribution grid reinforcements by relieving peaks in demand. Table 30 shows the campus' peak demand (monthly average) in the case with and without solar PV and battery storage. The results indicate a reduction of about 10%

Table 30: Microgrid peak demand with and without PV and battery system

	Without solar PV and battery system	With solar PV and battery system	Δ
Peak demand	593.4 kW	527 kW	-11.2%

Besides the possible reduction in peak demand, the BM has the potential to transform the large campus of University of Cyprus into a self-consumption controllable microgrid that offers additional services to the overarching national grid. The campus microgrid will be able to operate either grid-connected, possibly offering ancillary services to the DSO, or isolated in case of a grid fault or other operational necessities. Depending on the exact design and algorithm of the mini-grid controller, additional services can be offered.

This BM is awarded the score '++' in the category *grid consciousness* because it has a positive effect on multiple grid aspects.

				++

Carbon footprint

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

The proposed rollout will lead to an added installed capacity of 10 MW solar PV. Considering an average capacity factor of 18.5% and a carbon content of Cypriot electricity of 792 kg/MWh, the resulting displacement of more polluting electricity sources can lead to a reduction of 12 835 tCO_2 per year. This is approximately a reduction of 0.3% of all CO_2 emissions due to electricity generation in Cyprus in 2017. The BM is therefore rated as '++' for the *carbon footprint* category.

				++

Innovation

Cyprus has adopted a tariff of self-consumption for commercial and industrial consumers offering the possibility of using local RES for up to 80% of their energy needs without storage and up to 100% with storage. This tariff has recently been modified to net billing, which offers the benefit of using local storage to further minimize energy costs by avoiding peak prices as much as possible. However, the solutions implemented go beyond the state of art in Cyprus by introducing the following innovative additions which offer additional capabilities for further lowering the energy cost of the campus and generate tradable flexibilities for the local DSO:

- Smart meters, temperature sensors and other smart sensors at selected points in the campus that facilitate observability and control.
- A central management system that has direct control of the entire campus through the dedicated BEMS (Building Energy Management Systems), battery controllers, inverter controllers etc to offer community control for generating flexibilities, optimizing resources and managing peaks.
- A sophisticated forecasting tool capable of offering an accurate day ahead forecast for the locally generated energy above 95% that is shared with the local DSO for his own services, capable of adding to the effective use of energy resources in a planned regime in line with the needs of the electricity market. The forecasting tool is directly connected to the central management system providing reliable data for planning the energy profile of the next day capable of offering the minimum cost and provide the required flexibility benefits in line with the needs of the market.
- Broad band connectivity throughout the campus with direct broadband link with the DSO servers that offer full versatility of operating as an energy community as far as the needs of the grid operator and the market operator.

Because of the extensive level of innovation in the micro-grid concept, the BM is labelled as breakthrough innovation.

		++	

11. Overview of all Business Models

Table 31: Overview of the scores for all BMs

		Cost of electricity	Market participation	Community	Grid consciousness	Carbon footprint	Innovation
Good Energy (UK)	BM1: Automation and control	+	0	+	+	+	++
	BM2: “Peer-to-peer” (local) energy matching		++	++	+	0	+++
Next Kraftwerke Germany (Germany)	BM3: Dispatch flexible generation under changing market design on multiple markets	++	++	+	++	0	+
	BM4: Suppling mid-scale customers with time variable tariffs including grid charges optimization	++	+	0	++	0	+
Next Kraftwerke Germany (France)	BM5: Providing decentral units access to balancing markets	++	++	+	++	0	++
Next Kraftwerke Germany (Italy)	BM6: Market renewables on multiple markets					0	+++
Next Kraftwerke (Belgium)	BM7: Trading PV and Wind Power	+	++	+	++	0	+
	BM8: Using flexibility of customers as third party	++	++	0	++	0	+
Oekostrom AG (Austria)	BM9: Demand Side flexibilization of small customers	+	0	+	+	0	++
	BM10: Valorise distributed generation of customers in apartment buildings	++	+	++	++	++	++
EDP (Portugal & Spain)	BM11: Activation and marketing of end user’s flexibility.	+	+	0	++	0	+
FOSS (Cyprus)	BM12: Pooling flexibility for local balancing market and energy service provision	++	+	++	++	++	++

BestRES This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

12. Conclusions

The aim of the life cycle analysis is to assess the effects of a nation-wide rollout of each of the BMs in their respective countries. The simulations results from the BestRES report "Quantitative Analysis of Improved BMs of Selected Aggregators in Target Countries" [2] are scaled-up in an impact assessment that describes and quantifies the benefits of the BM on a national level. The resulting KPIs are compared to relevant indicators of the national electrical power system to derive a final score per category. This categorised assessment is used to evaluated to the BMs according to 6 categories:

- Cost of electricity

  This category evaluates the BM's impact on revenue and cost of electricity compared to the reference scenario. In the case production is considered, the increased revenue is compared to the current support mechanisms. For BMs that consider electricity consumption, the results are compared to national average for electricity consumption.
- Market participation

  This category evaluates to what extent the improved BM facilitates market participation on different markets. The category also evaluates to what extent the BM activates the customer's or asset's potential to active market participants. Where possible, the added market volumes are extrapolated and compared to current market volumes.
- Innovation

  The Innovation category assesses whether the BM can be considered an innovation in its respective market.
- Community

  The community category evaluates the community content of the BM, and to what extent it supports the development of a 'local energy community. An important aspect here is that there is cooperation between local stakeholders to engage in value-driven activities.
- Grid consciousness

  A grid conscious BM builds up an understanding and knowledge on RES and their integration in the electrical grid and electricity markets. This category assesses to what extent the BM provides system value to the national power system.
- Carbon footprint

  The carbon footprint of the BM is evaluated considering the BM's impact on greenhouse gas emissions. The simulation results from [2] are a starting point of the analysis.

Overall the results of the LCA show that the aggregation BMs score well on all of the assessed categories. As the BestRES project analyses a wide scope of BMs, the conclusions are grouped per BM type. Four types of BMs are identified:

- Marketing generation assets on multiple markets
- Optimal dispatch of load
- Peer-to-peer energy and flexibility
- Household flexibility

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

The categories are separately discussed below.

12.1 Marketing generation assets on multiple markets

Figure 8 shows the 4 improved BMs that market generation assets on multiple markets. All of these improved BMs are either proposed by Next Kraftwerke Belgium or Next Kraftwerke Germany.

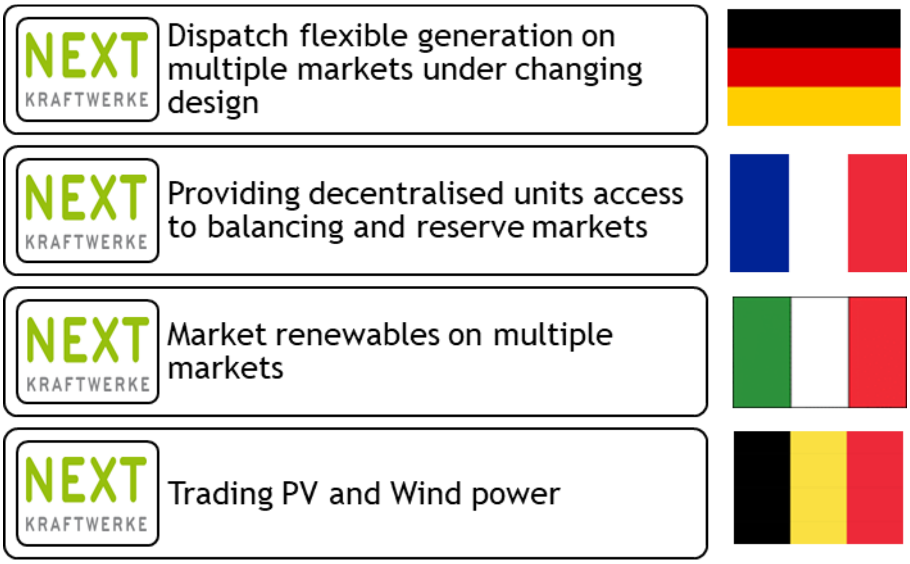


Figure 8: BMs that market generation assets on multiple markets

The LCA results indicate that these BMs have a positive impact on the **revenue** from renewable energy sources: the enhanced market participation leads in all simulated cases to added revenue. In one BM this increase is more than 10%.

The BMs add volume to the different markets on which they participate. In case of a nation-wide rollout, this increase is significant. The BMs therefore score very well in terms of **market participation**.

As these BMs are focused on medium to large-sized (industrial or agricultural) assets, there is no immediate **community** component. However, they could offer benefits to cooperative energy initiatives and in that way contribute to their formation.

Each BM covers multiple aspects of **grid consciousness**, be it through offering ancillary services to the grid operator or reducing portfolio imbalance.

Since the BMs only consider trading, they do not directly reduce **CO_2 emissions**.

12.2 Optimal dispatch of flexible load

The BMs that fall under the type *Optimal dispatch of flexible load* are shown in Figure 9. These BMs use the flexibility that is available in industrial and

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

commercial load to create extra value. The three improved BMs were proposed by aggregators in Germany, Belgium and Portugal.

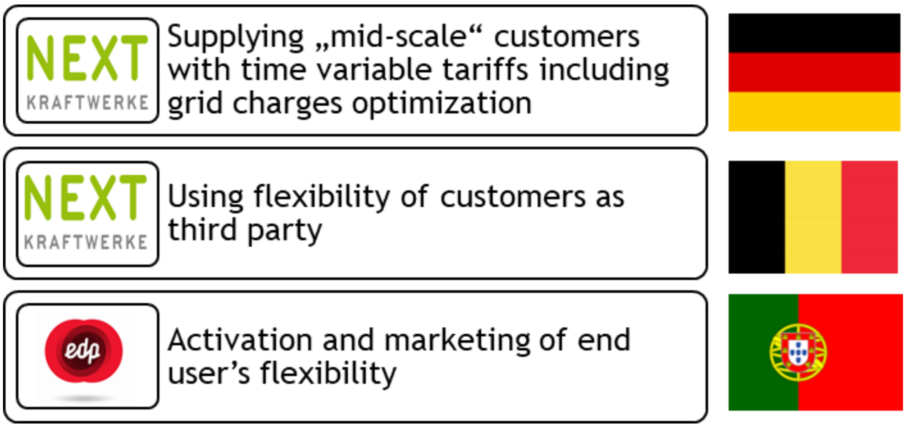


Figure 9: BMs that perform optimal dispatch of flexible load

Optimizing load dispatch decreases the **cost of electricity** for the three BMs. The BM-specific effect of each BM depends mainly on the assumed flexibility constraints of the considered portfolio. Furthermore, the specific cost reduction mechanism (imbalance prices, peak load charge, etc.) has a significant effect on the score of the individual BMs.

While the studied scenarios do not allow for an exact extrapolation of the added **market participation**, the BMs either diversify electricity sourcing or increase the valorisation of flexibility within the traditional tariff structure.

As the BMs are oriented towards industrial assets, they do not directly contribute to the development of **local energy communities**.

The offered **benefits to the grid** include peak load reduction, optimised trading and imbalance reduction.

The three BMs are labelled as incremental **innovation**.

12.3 Household Flexibility

BMs in the household flexibility category create value through the available flexibility at a residential level. In the considered BMs, proposed for the Austrian and British market, the flexibility potential of customers under a Time-of-Use tariff are evaluated. Figure 10 gives an overview of the two BMs.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

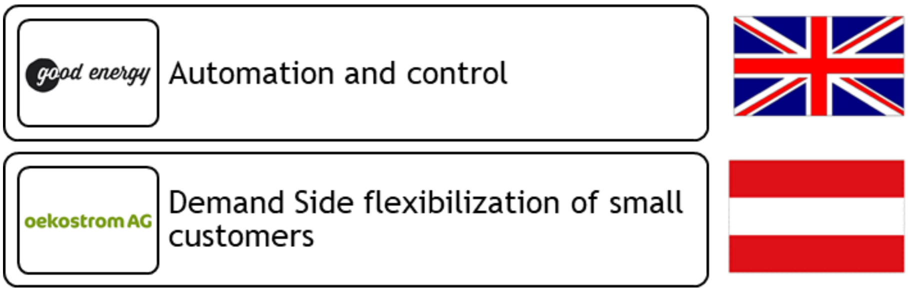


Figure 10: Household Flexibility BMs

The BMs have the potential to decrease the **electricity bill** of residential consumers. The impact assessment results, however, indicate that this impact is only minor. Financial incentives for residential load shifting are thus small.

The proposed BMs do not directly change the fundamental **market participation** of residential consumers. Since suppliers use synthetic load profiles to trade and balance residential consumption, the shifted load will not directly impact the way that residential consumption is sourced on the markets.

As there is no direct cooperative component to the BMs, they score neutral for the category **community**.

From a **grid** point of view, their main benefit is the shifted load.
Both BMs are found to be breakthrough **innovations** in their respective countries.

12.4 Peer-to-peer energy and flexibility

In the peer-to-peer BMs, local trading platforms or sharing mechanisms allow prosumers to benefit from direct energy and flexibility interactions between each other. The two considered BMs are shown in Figure 11.

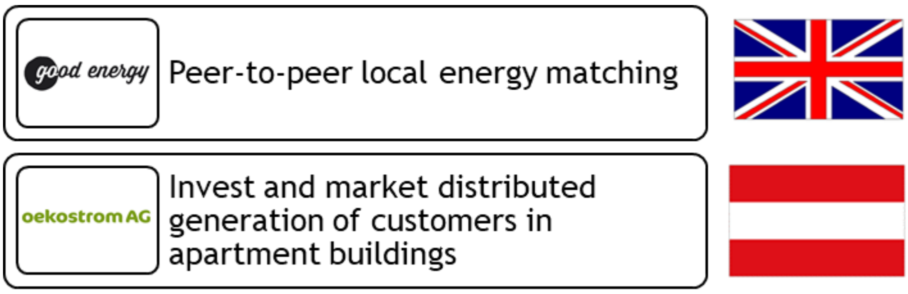


Figure 11: Peer-to-peer energy and flexibility BMs

Overall, peer-to-peer BMs score very well on the LCA assessment, with a score of + or ++ in nearly all categories. It is however important to note that these results are based on an assumed implementation framework, since actual implementation frameworks face several regulatory boundaries.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

Nevertheless, the assessment concludes that peer-to-peer interactions can have a positive effect on the **cost of electricity** for the participating consumers. This is mainly the result of increased auto-consumption.

Market participation for these BMs is evaluated positively, as they either lead to an increased rooftop potential for PV systems or a more active market role for residential prosumers.

The BMs can furthermore contribute to an improved **grid operation** by stimulating local consumption.

Both BMs are considered highly **innovative** in their markets.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

13. References

[1] A. Fleischhacker, G. Lettner, D. Schwabeneder, and F. Moisl, "Improved Business Models of Selected Aggregators in Target Countries," Energy Economics Group, Vienna University of Technology, BestRES D3.2, Aug. 2017.

[2] D. Schwabeneder, A. Fleischhacker, and G. Lettner, "Quantitative Analysis of Improved BMs of Selected Aggregators in Target Countries," Energy Economics Group, Vienna University of Technology, BestRES D3.3, 2018.

[3] E. Mieras, "An LCA-based framework to validate sustainable business models." 2015.

[4] IEA, "Austria - Energy System Overview." 2016.

[5] IEA, "World Energy Balances," 2018.

[6] B. A. Bremdal, P. Olivella-Rosell, J. Rajasekharan, and I. Ilieva, "Creating a local energy market," *CIRED - Open Access Proc. J.*, vol. 2017, no. 1, pp. 2649–2652, Oct. 2017.

[7] Open Utility, "A glimpse into the future of Britain's energy economy." 2016.

[8] C. Zhang, J. Wu, C. Long, and M. Cheng, "Review of Existing Peer-to-Peer Energy Trading Projects," *Energy Procedia*, vol. 105, pp. 2563–2568, May 2017.

[9] "Renewable Energy Sources Act (EEG 2017)." 2017.

[10] "Bundesverband Bioenergie :: Strom." [Online]. Available: https://www.bioenergie.de/themen/strom. [Accessed: 11-Jul-2018].

[11] Bundesnetzagentur, "Monitoring Report 2017," Nov. 2017.

[12] J. Haucap, U. Heimeshoff, and D. Jovanovic, "Competition in Germany's Minute Reserve Power Market: An Econometric Analysis," *Energy J.*, vol. 35, no. 2, Apr. 2014.

[13] "Bioenergy in Germany," *Clean Energy Wire*, 30-Sep-2016. [Online]. Available: https://www.cleanenergywire.org/dossiers/bioenergy-germany. [Accessed: 17-Jul-2018].

[14] H. Staubitz, "The German Energy Transition - Status Quo and What Lies Ahead," presented at the Germand Trade & Invest, Sep-2016.

[15] R. Verhaegen and R. Beaumont, "An Assessment of the Economics of and Barriers for the Implementation of the Improved Business Models," Grids & Markets, 3E, BestRES D4.1, 2017.

[16] M. C. E. S. GmbH, "Balancing energy," *Balancing energy*. [Online]. Available: https://www.mwm.net/mwm-chp-gas-engines-gensets-cogeneration/newsletter-mwm-newsflash/newsflash-07-december-2014/balancing-energy/. [Accessed: 12-Jul-2018].

[17] Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, *Profile of the German Water Section 2015*. Bonn: Wirtschafts- u. Verlagsges. Gas u. Wasser, 2015.

[18] "Punktediagramme zur Stromproduktion | Energy Charts." [Online]. Available: https://www.energy-charts.de/scatter_de.htm?source=loadAP&year=2017. [Accessed: 12-Jul-2018].

[19] E. Tröster, R. Kuwahata, and T. Ackermann, "European Grid Study 2030/2050," *BrusselsLangen Study Comm. Greenpeace Int. EU Bank*, 2011.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

[20] eclareon GmbH, "RES Legal - Feed-in tariff France," 12-Apr-2018. [Online]. Available: http://www.res-legal.eu/search-by-country/france/single/. [Accessed: 30-Oct-2018].

[21] "Présentation de l'observatoire du biogaz en France," *Atee - Association Technique Energie Environnement*. [Online]. Available: http://atee.fr/biogaz/observatoire-du-biogaz-en-france. [Accessed: 24-Oct-2018].

[22] "RTE Customer's area - Rapid and Complementary Reserve." [Online]. Available: https://clients.rte-france.com/lang/an/clients_producteurs/services_clients/reserves_rc.jsp. [Accessed: 30-Oct-2018].

[23] "Communal biogas at the Moulin Guérin farm | Case Studies | Thermaflex." [Online]. Available: https://thermaflex.com/en/case-studies/communal-biogas-at-the-moulin-guerin-farm. [Accessed: 30-Oct-2018].

[24] "Éteignières, commune à bioénergie positive avec le bois et le biogaz | MAGAZINE ET PORTAIL FRANCOPHONE DES BIOÉNERGIES." [Online]. Available: https://www.bioenergie-promotion.fr/49673/eteignieres-commune-a-bioenergie-positive-avec-le-bois-et-le-biogaz/. [Accessed: 30-Oct-2018].

[25] GSE, "Solare Fotovoltaico - Rapporto Statistico," Gestore Servizi Energetici, 2017.

[26] GSE, "Rapporto statistico - Energia da fonti rinnovabili in Italia," Gestore Servizi Energetici, 2016.

[27] CREG, "Study on the functioning and price evolution of the Belgian wholesale electricity market – monitoring report 2016," Sep. 2017.

[28] Federaal Planbureau and FOD Economie, "Aanvullend verslag Elektriciteit - Monitoringverslag van de bevoorradingszekerheid." Dec-2017.

[29] "Supply, transformation and consumption of electricity - annual data," *Eurostat Dataset nrg_105a*. [Online]. Available: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_105a&lang=en. [Accessed: 23-Aug-2018].

[30] Elia, "Beschikbaar Regelvermogen." [Online]. Available: http://www.elia.be/nl/grid-data/balancing/beschikbaar-regelvermogen. [Accessed: 11-Feb-2014].

[31] "Electricity prices for household consumers," *Eurostat Dataset nrg_pc_204*. [Online]. Available: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204&lang=en. [Accessed: 10-Sep-2018].

[32] "Statistik Austria," *Die Informationsmanager*. [Online]. Available: http://www.statistik.at/web_de/statistiken/index.html. [Accessed: 11-Sep-2018].

[33] L. Kranzl, A. Toleikyte, Z. Moravac, and A. Müller, "The challenges, dynamics and activities in the building sector and its energy demand in Austria," D2.1 of WP2 from Entranze Project.

[34] GfK Belgium consortium, "Residential Prosumers in the European Energy Union," JUST/2015/CONS/FW/C006/0127, May 2017.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

[35] Bundesverband Photovoltaic Austria, “Umsetzungsvarianten,” *PV-Gemeinschaft*. [Online]. Available: http://pv-gemeinschaft.at/umsetzungsvarianten/. [Accessed: 23-Aug-2018].
[36] “Unser Eigenstrom,” 2017. [Online]. Available: http://www.bewo.at/storage/news/Presseaussendung_Unser_Eigenstrom_12%202017.pdf. [Accessed: 22-Aug-2018].
[37] “IKB und NHT präsentierten innovatives Mieterstrommodell.” [Online]. Available: https://www.ikb.at/newsdetail/ikb-und-nht-praesentierten-innovatives-mieterstrommodell/. [Accessed: 22-Aug-2018].
[38] “Electricity prices for non-household consumers,” *Eurostat Dataset nrg_pc_205*. [Online]. Available: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_205&lang=en. [Accessed: 10-Sep-2018].
[39] “PORDATA - Electricity consumption: total and by type of consumption.” [Online]. Available: https://www.pordata.pt/en/Portugal/Electricity+consumption+total+and+by+type+of+consumption-1124-9091. [Accessed: 02-Oct-2018].
[40] “The Spanish Electricity System 2017,” Red Eléctrica de España, 2017.
[41] “Annual Report on the Electricity and Natural Gas Markets in 2017,” Entidade Reguladora dos Serviços Energéticos.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 691689.

14. Technical references

Project Acronym	BestRES
Project Title	Best practices and implementation of innovative business models for Renewable Energy aggregators
Project Coordinator	Silvia Caneva WIP – Renewable Energies silvia.caneva@wip-munich.de
Project Duration	1st March 2016 – 28th February 2019

Deliverable No.	D3.5
Dissemination level*	PU
Work Package	WP 3 - Testing of improved business models
Task	T3.5 - Life Cycle Analysis (LCA) of the improved Business Models
Lead beneficiary	2 (3E)
Contributing beneficiaries	3 (TUW-EEG), 5 (Good Energy), 6 (NKW BE), 7 (NKW DE), 8 (oekostrom), 10 (EDP CNET), 12 (FOSS)
Due date of deliverable	31 December 2018
Actual submission date	20 December 2018

* PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

v	Date	Beneficiary	Author
1.0	19/11/2018	3E	Simon De Clercq and Carlos Guerrero Lucendo
1.2	28/11/2018	3E	Review by the project partners
1.3	13/12/2018	3E	Ruben Baetens and Achim Woyte
1.4	13/12/2018	WIP	Silvia Caneva
2.0	20/12	3E	Simon De Clercq

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.

BestRES This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 691689.