BestRES

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

Analysis of RES Competitiveness in the improved business models

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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 at the website: www.bestres.eu

This report has been written by Carlo Corinaldesi (TUW-EEG). The author thankfully acknowledge the valuable contributions from all project partners.

Disclaimer

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The legislative proposals presented by the European Commission on 30th November 2016 in its package "Clean Energy for All Europeans" (covering energy efficiency, renewable energy, the design of the electricity market, security of electricity supply and governance rules for the Energy Union) are expression of its exclusive right of legislative initiative. The Package was the starting point for the still ongoing ordinary legislative procedure, which gives the same weight to the European Parliament and the Council of the European Union. At the end, the European Parliament and the Council will adopt the proposals of the Commission – each in a more or less modified form – jointly as European laws. The concrete proposals cited in this study still might change during the legislative process and shall be understood rather as a general description of an issue to be regulated than a finalized legal setting.

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List of abbreviations and acronyms

aFRR	Automatic Frequency Restoration Reserve, see R2
BM	Business Model
DSM	Demand Side Management
EC	European Commission
FiT	Feed-in-Tariff
GPRS	General Packet Radio Service
IEM	Internal Energy Market
mFRR	Replacement reserve see R3
MSD	Ancillary Services Market in Italy
R1	Primary reserves also frequency containment reserve (FCR)
R2	Secondary reserves also frequency restoration reserve (aFRR)
R3	Tertiary reserves also replacement reserve (mFRR)
RES	Renewable energy sources
RES-E	Electricity generation from renewable energy sources
RTP	Real-time-pricing
ToU	Time-of-Use
TSO	Transmission System Operator
VPP	Virtual Power Plant
GPC	Grid Procurement Costs
ICT	Information and Communication Technology
ESCO	Energy Service company

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Executive summary

Within the BestRES project, business models identified in the report "*Existing business models for renewable energy aggregators*" [1] have been further improved allowing aggregators to offer new products and services. The improved business models for each aggregator are presented in the report "*Business Models of selected aggregators in target countries*" [2] and their quantitative analyses are studied in the report "*Quantitative analysis of improved BMs of selected aggregators in target countries*" [3]. These analyses took into account multiple aspects, such as a more competitive trading of renewable generation, better customer relationships and more integrated energy service provision (e.g. energy management, maintenance, etc.). The core of all improved aggregator business models is to create value by aggregation. The aggregated components, in general, comprise generators and consumers and their flexibility is used to create value on multiple energy markets.

Figure 1 illustrates, the relationships of the aggregator with the components it aggregates.

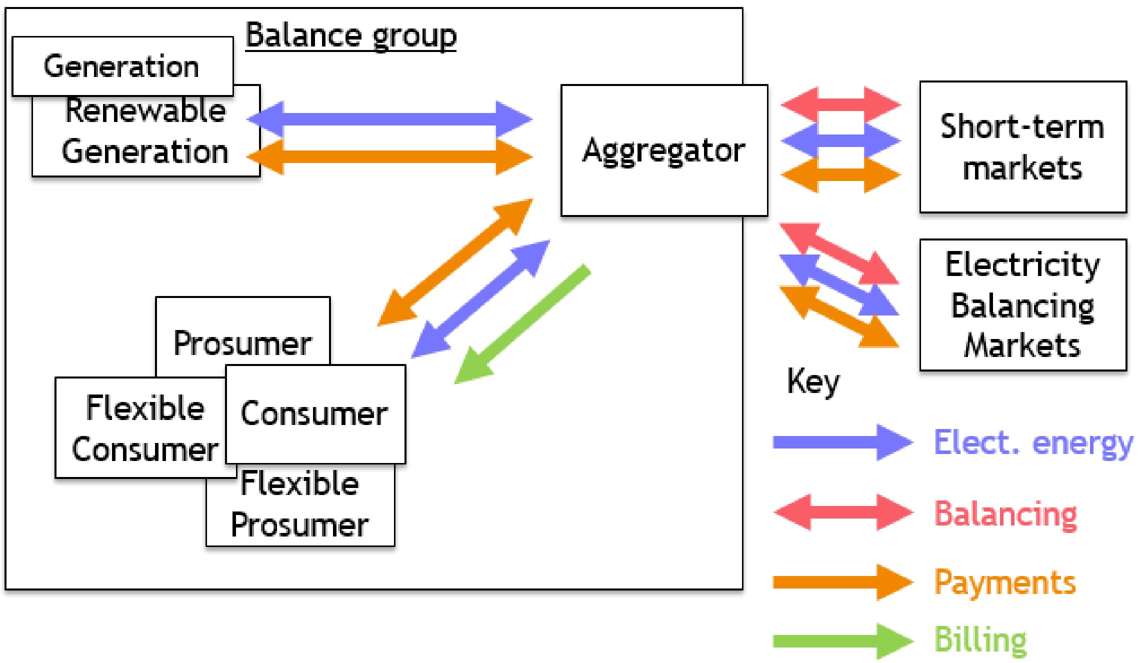

Figure 1: Schematic representation of the aggregator's connections

In this analysis, we differentiate between two types of generators: renewable- and conventional generators. In this context, the present report focuses on how the improved business models, presented in the report "*Quantitative analysis of improved BMs of selected aggregators in target countries*", increase the competitiveness of renewable generation. Table 1 summarizes the different RES technologies that are directly used by the aggregator to create value in the improved business models in the BestRES project.

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Table 1: Directly used RES in the improved business models in the BestRES project

Aggregator	Improved business model	Directly used RES technology
Good Energy (UK)	Automation and control	None
Next Kraftwerke (Germany)	Dispatch flexible generation under changing market design on multiple markets	**Biogas**
	Suppling „mid-scale“ customers with time variable tariffs including grid charges optimization	None
Next Kraftwerke (France)	Providing decentralized units access to balancing markets	**Biogas**
Next Kraftwerke (Italy)	Market renewables on multiple market places	**Photovoltaic, Wind Onshore farm and Wind Offshore farm**
Next Kraftwerke (Belgium)	Trading PV and Wind power	**Photovoltaic, Wind Onshore farm and Wind Offshore farm**
	Using flexibility of customers as third party	None
Oekostrom AG (Austria)	Demand Side flexibilization of small customers	None
	Valorize distributed generation of customers in apartment houses	**Photovoltaic**
EDP (Portugal)	Activation and marketing of end user’s flexibility.	None
EDP (Spain)	Activation and marketing of end user’s flexibility.	None
FOSS (Cyprus)	Pooling flexibility for local balancing market and energy service provision.	None

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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 because a rising share of distributed generation increases intermittency and price volatility in the system. This requires a more flexible system with more flexible 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 single 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 information and communication technology (ICT) to directly control consumption at lower costs. For this reason, there is an important role for 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 last case, the player downstream and upstream could potentially be the same entity.[1]

[1] Guidelines on State aid for environmental protection and energy 2014-2020

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1.1 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 Life Cycle Analysis (LCA). These improved business models have then been 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 entered into force on 1st March 2016 and will end until 28th February 2019.

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

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

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

The improved business models provided during the project are based on on-going business models available in Europe and adapted to the future market design by research institution and energy expert partners such as the Energy Economic Group of the Technical University of Vienna (TUW-EEG) and 3E. The consortium includes also a legal expert, SUER (Stiftung Umweltenergierecht / Foundation for Environmental Energy Law), which provided 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 will be carried out by WIP with the support of Youris.

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

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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 analyze 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 analyzed systematically with regard to their interdependencies. Interdisciplinary questions, e.g. technical and economical questions, are of particular importance. Website: http://stiftung-umweltenergierecht.de/

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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 Kraftwerke'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/

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

The Research Centre for Sustainable Energy of the University of Cypruss (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. To sum up, 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

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1.2 Purpose of the document

This document provides an analysis of how the improved business models for the aggregators in the BestRES project, developed in the document *"Improved Business Models of selected aggregators in target countries"* [2] and analyzed in *"Quantitative analysis of improved BMs of selected aggregators in target countries"* [3], increase the competitiveness of different RES technologies. Subsequently, this document investigates, whether and under which conditions aggregation can increase the competitiveness of specific RES technologies.

The analyses are divided into two sections: Impact of the direct use of RES technologies in the improved business models (chapter 3) and indirect impact of the improved business models on RES technologies (chapter 4).
Table 2 presents the business models that are analyzed in this document and differentiates between those that have a direct impact on RES technologies and those that have an indirect impact on RES technologies.

Table 2: Direct and Indirect impact on the RES competitiveness

	Indirect impact on RES technologies	Direct impact on RES technologies
Aggregator	**Improved business model**	
Good Energy (UK)	Automation and control	
Next Kraftwerke (Germany)		Dispatch flexible generation under changing market design on multiple markets
	Suppling „mid-scale“ customers with time variable tariffs including grid charges optimization	
Next Kraftwerke (France)		Providing decentralized units access to balancing markets
Next Kraftwerke (Italy)		Market renewables on multiple market places
Next Kraftwerke (Belgium)		Trading PV and Wind power
	Using flexibility of customers as third party	
Oekostrom AG (Austria)	Demand Side flexibilization of small customers	
		Valorize distributed generation of customers in apartment houses
EDP (Portugal)	Activation and marketing of end user’s flexibility.	
EDP (Spain)	Activation and marketing of end user’s flexibility.	

With improved business models with direct impact on RES we mean all those improved business models that modify the use and / or exchange of renewable energy. The improved business models with indirect impact on RES competitiveness are those that use electrical flexibility of the demand side in

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order to create value and/or reduce the costs. The change of the demand side can significantly change indirectly the market value of RES.

In Chapter 3, the competitiveness of RES technologies is evaluated through their economic values in the improved business models compared to their economic values on the Day-Ahead spot market.

The first improved business model analysis of Chapter 3, “Dispatch flexible generation under changing market design on multiple markets” for the aggregator Next Kraftwerke (Germany), consists in pooling flexible renewable generation from a biogas power plant. Here, we investigate the competitiveness of a biogas power plant on the German energy market.

The improved business model “Providing decentralized units access to balancing markets” for the aggregator Next Kraftwerke (France) is studied in Section 3.2. This improved business model analysis investigates how the generation of energy can be used to enhance market participation through flexibility provision. In this section we determine the competitiveness of a biogas power plant on the French Rapid Reserve market.

The improved business model analysis for the aggregator Next Kraftwerke (Italy) in Section 3.3, investigates the RES competitiveness of different renewable technologies on the six different Italian energy market areas.

Section 3.4 presents the analysis of the improved business model “Trading PV and Wind power” for the aggregator Next Kraftwerke (Belgium). In this improved business model analysis, from the report *"Quantitative analysis of improved BMs of selected aggregators in target countries"* [3], it has been investigated how the generation of energy by solar, wind onshore and wind offshore plants can be optimally traded in Belgium. Here, we investigate if the optimal trading strategy also increases the competitiveness of those technologies.

The last analysis of the third chapter is on the improved business model “Valorize distributed generation of customers in apartment houses” for the aggregator Oekostrom AG (Austria). This improved business model investigated the most economical way of investing and operating of Photovoltaic plants on residential buildings. In this section, we focus on the competitiveness of shared photovoltaic plants on residential buildings.

In the fourth chapter, the improved business models that have an indirect impact on RES technologies are considered. The models taken into account in this section are those that use demand side flexibility of end users in order to create value. Here, we investigate if the use of the demand side flexibility in the improved business models improves the RES competitiveness, comparing the percentage of renewable energy taken from the electrical grid in the baseline case and in the improved business model.

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2 Methodology

The main objective of all improved business models is to create value and generate profits by aggregation of generators, consumers and energy markets. This report focuses on how the improved business models developed in [2] and analyzed in [3], to increase the competitiveness of different RES technologies using the aggregation of multiple units that are significant for energy management, as illustrated in Figure 2.

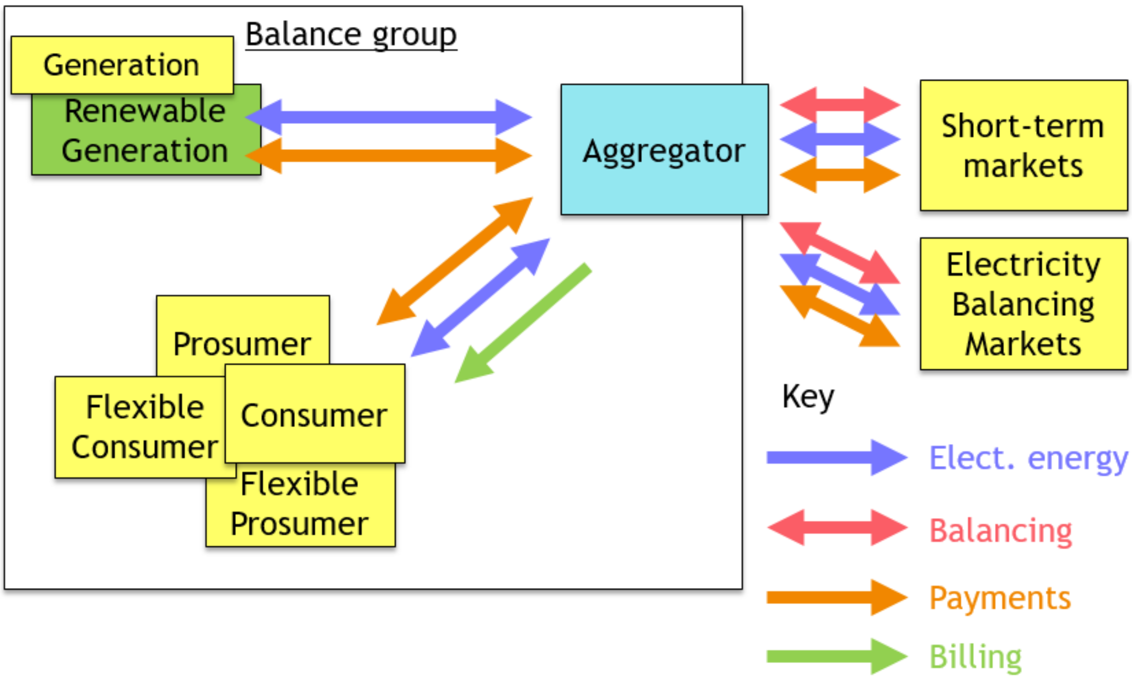

Figure 2: Aggregation of electricity markets, Generation and Customers

In the first section, in which the improved business models with a direct impact on RES technologies are considered, the question of RES competitiveness is investigated through the **economic value in the improved business models** of the different RES technologies compared to their **market value on the Day-Ahead spot market**.

In the fourth chapter, the indirect impact of the improved business models on RES technologies is analyzed. In these improved business models, there are load shifts of the demand side, aiming to reduce the end consumers costs. We assume that more demand during hours of variable renewable energy production increases its market value. Hence, we suppose that shifting demand to hours of more renewable production has a positive indirect effect on renewable generation. To quantify this impact, we calculate the weighted average share of variable renewable energy production in the target country in the electricity consumed by flexible demand in different scenarios for the improved business

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models. The renewable share in energy production is calculated from the energy production per power plant type data available for each target country on the ENTSOE transparency platform[2].

Moreover, specific and detailed analyses aim to identify, whether and under which conditions aggregation can increase the competitiveness of specific RES technologies.

[2] https://transparency.entsoe.eu/

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3 Impact of the direct use of RES technologies in the improved business models

3.1 RES Competitiveness in the improved business model of Next Kraftwerke (Germany)

Dispatch flexible generation under changing market design on multiple markets

In this business model analysis, we simulated the operation of a subsidized flexible biogas power plant on the German aFRR balancing market and on the day-ahead market. Here we want to compare the economic value of the biogas power plant in this business model to its market value. The market value for intermittent RES producers, such as solar PV and wind, is defined as the average price they receive on the wholesale market [4], i.e. the market price weighted by the variable generation profile.

Here, however, we consider a flexible renewable generation plant. Hence, there is no variable production profile available. Furthermore, we want to account for the short-run marginal cost, i.e. the assumed production cost in the report "*Quantitative analysis of improved BMs of selected aggregators in target countries*" [3]. Hence, we consider only the times, when the income from the market are higher than the production cost of the biogas unit. We use the average difference of market income and production cost, i.e. the profit, in EUR/MWh as market value and compare it to the achieved profit in EUR/MWh in the business model.

As production cost we assumed 100 EUR/MWh and 140 EUR/MWh, respectively, in [3]. Hence, the biogas power plant would barely be operated, considering the wholesale market prices, illustrated in Figure 3. In that case, it would also not receive subsidies, as described in the quantitative business model analysis [3]. Hence, we also want to consider the market value with subsidies to make a more consistent comparison to the business model.

The subsidies, for renewable power plants, are auctioned based on a targeted value[3]. The auction winners then receive the difference of this targeted value to the average monthly market price as market premium. We used the production cost of 100 EUR/MWh and 140 EUR/MWh, respectively, as targeted value in our analysis. However, with this subsidy scheme, the number of hours, when the profit of the power plant is non-negative is independent of the targeted value: Let p_h and p_m denote the hourly and average monthly wholesale market price. The market premium mp is the difference of the targeted value tv and the monthly average price:

[3] https://www.bmwi.de/Redaktion/DE/Gesetze/Energie/EEG.html last accessed in 11/2018

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$$mp = tv - p_m$$

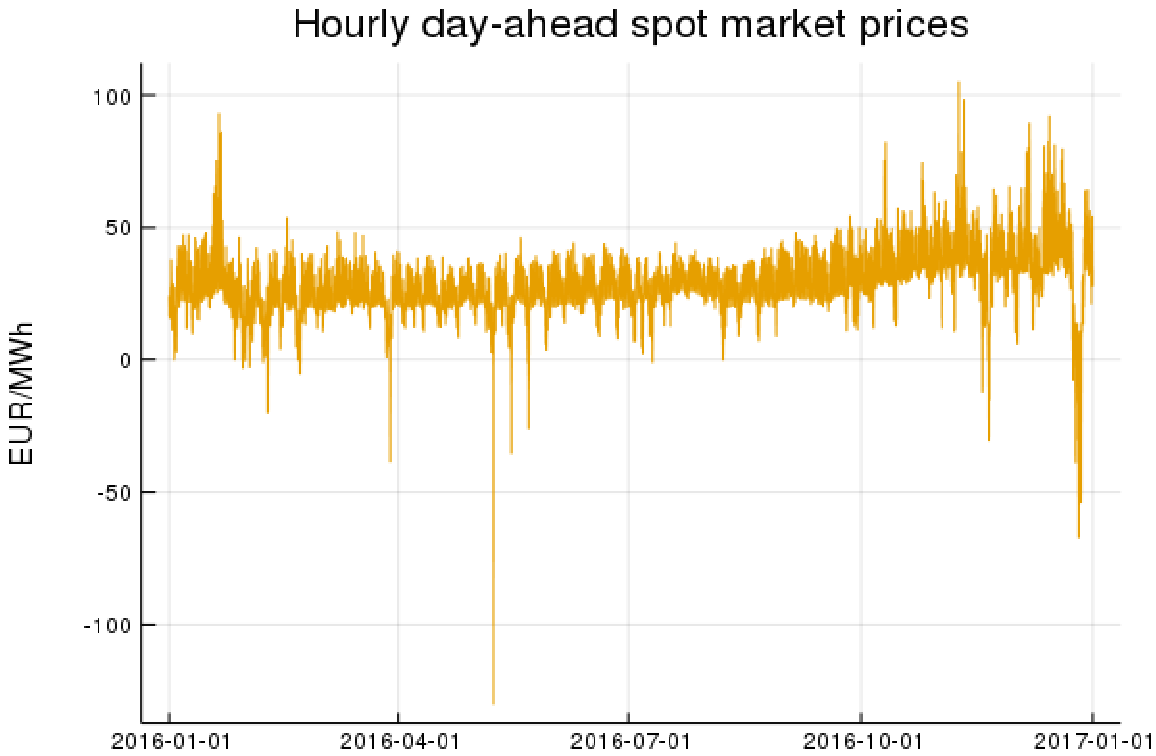

Figure 3: Wholesale market prices for Germany, 2016[4]

The market revenue at a given hour is the sum of the market price and the market premium $p_h + mp$ and the power plant only operates if these earnings exceed the production cost tv:

$$p_h + mp > tv$$

Inserting the formula for the market premium yields the condition:

$$p_h > p_m$$

This is independent of the production cost tv. Hence, neglecting other parameters such as start-up cost, the biogas plant would be operating whenever the hourly wholesale market price is above the average.

The market values and the economic value in the business model of the biogas power plant are listed in Table 3 for production cost of 100 EUR/MWh and in Table 4 for production cost of 140 EUR/MWh. We note a significant increase of profit in EUR/MWh in the business models compared to the wholesale market profit. The improved business model with four-hour products provides more hours of operation and higher total profit. The relative profit in EUR/MWh however is lower than for the baseline business model with weekly reserve market products.

[4] https://transparency.entsoe.eu last access 06.12.2018

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Table 3: Economic value in the business model compared to market value for production cost of 100 EUR/MWh.

Production cost	Market profit without subsidies	Market profit with subsidies	BM profit with weekly products	BM profit with four-hour products	Impact of the improved business model
Profit in € / MWh	4.96	7.8	25.4	19.6	+ +
Hours of operation in h	1	4256.8	1969.3	3030.5	o
Produced energy in MWh	1.3	5533.8	2559.9	3939.7	o

Table 4: Economic value in the business model compared to market value for production cost of 140 EUR/MWh.

Production cost	Market profit without subsidies	Market profit with subsidies	BM profit with weekly products	BM profit with four-hour products	Impact of the improved business model
Profit in €/MWh	0	7.78	23.4	19.3	+ +
Hours of operation In h	0	4256.8	2130.8	3077.5	o
Produced energy in MWh	0	5533.8	2770	4000.5	o

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3.2 RES Competitiveness in the improved business model of Next Kraftwerke (France)

Providing decentralized units access to balancing markets

This improved business model analysis investigated how the generation of energy can be used to enhance market participation through flexibility provision. The report "*Quantitative analysis of improved BMs of selected aggregators in target countries*" [3] in particular aimed to evaluate the participation of a flexible biogas power plant generator in further flexibility markets.

This analysis aims to determine the competitiveness of a biogas power plant using the methods described in Section 2. The RES competitiveness is investigated comparing the **economic value** of the biogas power plant on the French Rapid Reserve market to its **market value** on the Day-Ahead spot market.

The tertiary reserve is divided into two different reserves. The fast reserve (capable of being activated in less than 13 minutes) and the complementary reserve (capable of being activated in less than 30 minutes). The Rapid Reserve (RR) is composed of 1000 MW and can be activated in less than 15 minutes and for two hours. The Complementary Reserve (CR) is composed of 500 MW and can be activated in less than 30 minutes and for 1.5 hours. The balancing mechanism is a market mechanism, in which generators and consumers can offer to increase or decrease their output or consumption. Depending on the need of the power transmission network, the energy offered can be used, or not. In [3], we analyzed the case, in which two biogas power plants with two different energy generation costs, sold their flexibilities at the Rapid Reserve (RR) market. The biogas power plants are activated only if the Rapid Reserve market price is higher than their energy production cost and we assume that they are remunerated with this price.

The revenues of the biogas power plant trading energy at the Rapid Reserve market were calculated with energy generation costs of 60 and 120 €/MWh. In the quantitative analysis [3] we assumed an offered volume of 1 MW. Here, the profits of the biogas power plant trading energy at the Rapid Reserve market are compared with the value of the biogas power plant trading energy at the Day-Ahead spot market optimally. It has to be noted, that depending on the need of the power transmission network, the energy offered on the reserve market can be used, or not. This means that the Day-Ahead spot market certainly represents less risk factors than the rapid reserve market. Table 5 shows the differences between the profits from trading the flexible energy production of a biogas power plant on the Rapid Reserve market (**Economic value** in the improved business model) and the Day-Ahead spot market (**Market value**).

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Table 5: Comparison between the generated value of a biogas power plant on the Rapid Reserve and on the Day-Ahead spot market

Comparison between the generated value of a biogas power plant on different market places	Market value (Day-Ahead spot market)		Economic value in the improved business model		
	Generator with energy generation costs of 60 €/MWh	Generator with energy generation costs of 120 €/MWh	Generator with energy generation costs of 60 €/MWh	Generator with energy generation costs of 120 €/MWh	Impact of the improved business model
Profits in €	36,253	7,324	101,355	20,985	+ +
Traded Volume	1838	68	2960	444	+ +
Profit in €/MWh	19.72	107.7	34.24	47.26	+ -

As we can see from the results, the profits in "€" of the generator in the improved business model are greater both with low and high energy generation costs compared to the market value. This is due to the fact that the generator in the improved business model sells a greater volume of energy, since the prices on the French rapid reserve market are averagely higher, than those on the Day-Ahead spot market. The volume sold in the improved business model with low energy generation costs is 2960 MWh, while if the energy production price is doubled, the traded volume is 444 MWh. Compared to the case in which the energy is traded on the Day-Ahead spot market, the traded volumes are increased by 61 % and 552 % respectively. It is interesting to note the fact, that the profits in €/MWh are higher in both cases, when the energy generation costs are 120 €/MWh.

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3.3 RES Competitiveness in the improved business model of Next Kraftwerke (Italy)

Market renewables on multiple market places

In the improved business model analysis of Next Kraftwerke (Italy), analyzed in the report *"Quantitative analysis of improved BMs of selected aggregators in target countries"* [3], we investigated the potential profit of different renewable sources in the different Italian Day-Ahead market areas. In this document the question of RES competitiveness is analyzed through the economic value of the RES technologies in the improved business model compared to their market value on the Day-Ahead spot market. For this reason, in this section there is no distinction between economic value of the improved business model and market value. Hence, the economic value in the business model is exactly the market value listed in Table 6.

Table 6: Market value of RES technologies in different Italian market areas

Potential Profit in € / MWh per year	North market	Central North market	Center South market	South market	Sicily market	Sardinia market	Impact of the improved business model
Solar	39.8	38.2	37.0	35.1	41.2	36.9	0
Wind Onshore	42.3	41.7	41.1	40.1	47.1	41.1	0
Wind Offshore	42.7	42.3	41.6	40.6	47.6	41.6	0

3.4 RES Competitiveness in the improved business model of Next Kraftwerke (Belgium)

Trading PV and Wind power

In the analysis of this improved business model developed in *"Improved Business Models of selected aggregators in target countries"* [2] and analyzed in *"Quantitative analysis of improved BMs of selected aggregators in target countries"* [3], we investigated how the forecast error of energy generation by solar, wind onshore and wind offshore plants can be traded in Belgium in order to avoid or reduce the imbalance costs. Here, the RES competitiveness is evaluated through the comparison between the **economic value** of RES in the improved business models and their **market value** on the Day-Ahead spot market. Figure 4 shows the hourly day-ahead spot market prices in Belgium in 2015 and 2016.

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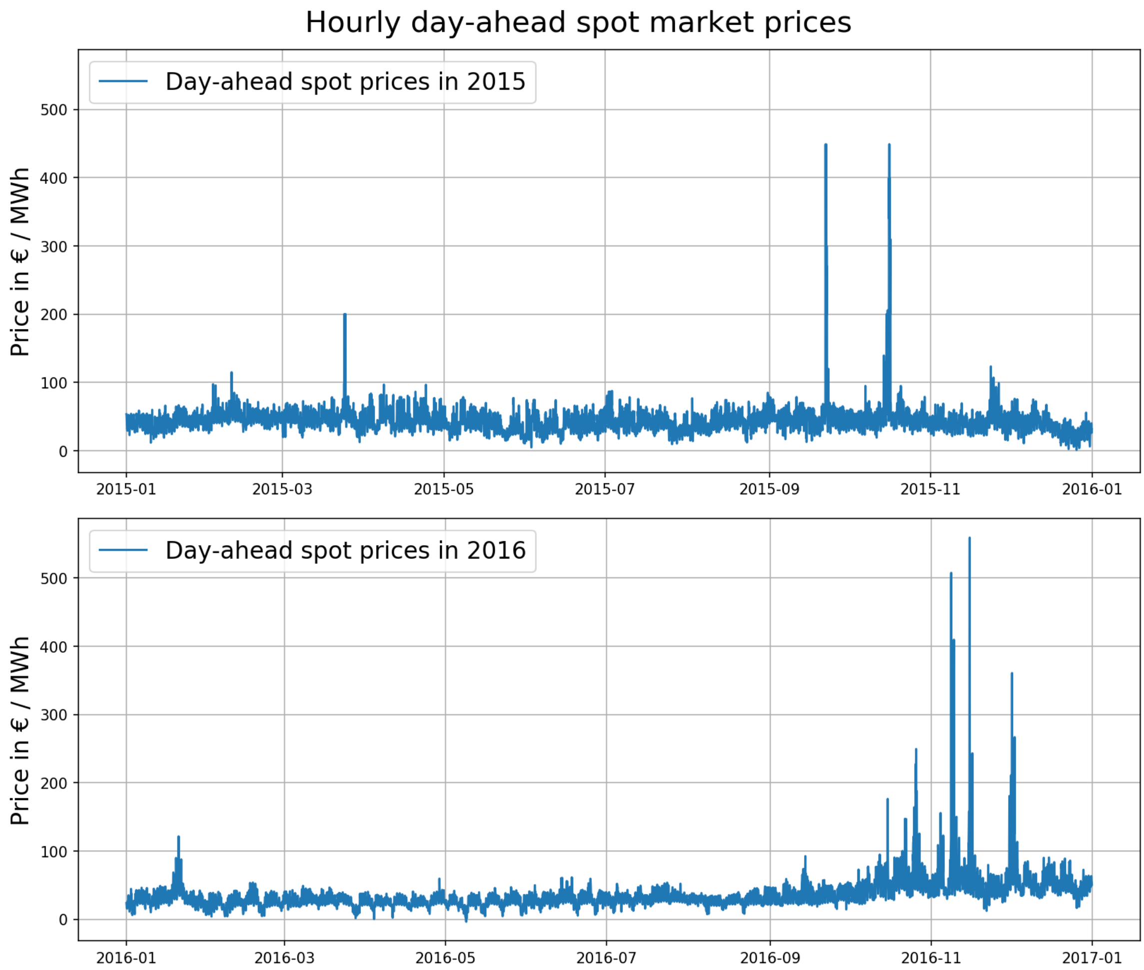

Figure 4: Hourly day-ahead spot market prices in 2015 and 2016

In the analysis of this improved business model four different RES technologies were investigated: Two solar plants and two wind plants (onshore and offshore)[5]. In this case, we defined the market value of the RES technologies as the value of their energy generation at the Day Ahead spot market, considering also the imbalance costs, caused by the deviations from their schedules. In the improved business model, we investigate the case, in which the forecast deviation is entirely marketed at the intraday spot market.

Table 7 illustrates the differences between the **economic value** of the improved business model and the **market value** of a RES Portfolio in the Belgian market. It has to be noted, that in this improved business model, the production of the renewable power plants is not changed and the Portfolio taken into account is the same. Hence, different scenarios do not affect CO_2-Emissions.

[5] The considered production data are taken from http://www.elia.be/e last access 13.11.2018

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Table 7: Comparison between the economic value of the improved business model and the market value of a RES Portfolio

Comparison of the generated value of a RES on different markets	Renewable Technology	Market value (Day-Ahead spot market) in € / MWh	Economic value in the improved business model in € / MWh	Impact of the improved business model
2015	Solar (BE)	**46.4**	**45.8**	-
	Solar (NKW)	**45.89**	**46.72**	+
	Wind Onshore	**36.51**	**36.07**	-
	Wind Offshore	**43.41**	**42.15**	-
2016	Solar (BE)	**36.4**	**36.01**	-
	Solar (NKW)	**33.44**	**33.2**	-
	Wind Onshore	**31.05**	**31.02**	-
	Wind Offshore	**34.01**	**34.72**	+

The comparison shows, that the improved business model does not increase the value of the RES Portfolio. We can state that marketing the forecast deviations on the intraday spot market does not offer a concrete way to avoid the balancing costs and subsequently to increase the economic value of renewables.

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3.5 RES Competitiveness in the improved business model of Oekostrom AG (Austria)

Valorize distributed generation of customers in apartment houses

The improved business model, analyzed in [3], investigated the most economical way of investing and operating of Photovoltaic plants on residential buildings. Thereby PV generation is used instead of consuming electricity from the grid. In the business model analysis we investigated, how the energy potential of operating Photovoltaic plants on buildings can be exploited to the fullest. In this section, the competitiveness of photovoltaic plants on residential buildings at the Austrian energy market is evaluated. We considered one apartment house with 10 different flats. Figure 5 shows the average day-ahead spot prices, the daily average photovoltaic generation and the daily average consumption of the apartment house.

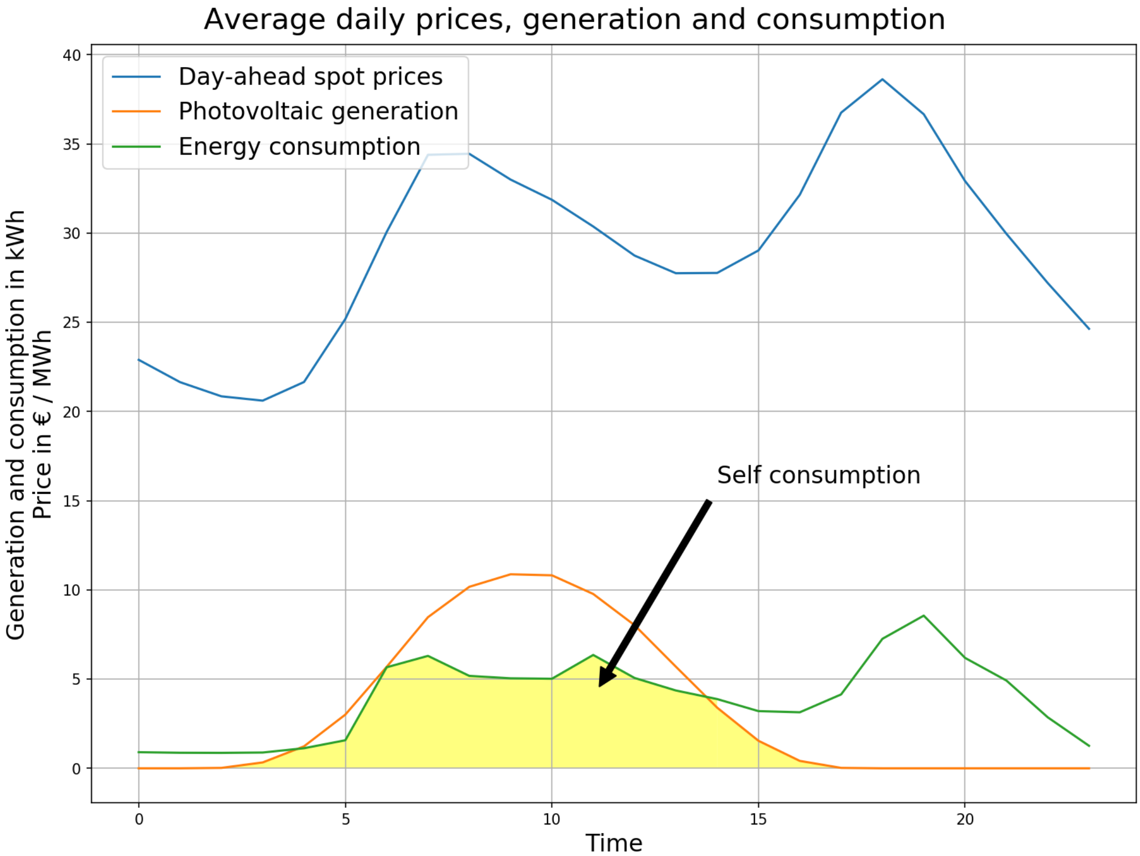

Figure 5: average day-ahead spot prices, photovoltaic generation and the consumption of the apartment house

In [3] two different scenarios were analyzed: The **Static** and the **Dynamic** scenario. In the static scenario, every participant owns a fixed share of the PV system. The produced energy is allocated among the inhabitants statically according to these fixed shares. The dynamic scenario considers a more flexible case, in which every participant owns a part of the photovoltaic panel. In this case, the PV plant generation can be traded among the inhabitants of the

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apartment house and not only via the grid. Hence, by trading the photovoltaic generation among the residents, the aggregation reduces the network charges, fees, taxes and energy supply cost. To find the optimal solution, an optimization problem was solved minimizing the overall costs for energy procurement.

The improved business models analyzed [3] give the photovoltaic plant an increased economic value, because it allows using PV generation, instead of consuming electricity from the grid and so to maximize the self-consumption of the building, reducing the energy supply costs. Moreover, the possibility of exchanging solar energy between the inhabitants of the apartment house with low additional costs reduces significantly the network charges, the fees and the taxes.

Table 8 illustrates the comparison between the **economic value** and the **market value** of the photovoltaic generation in the improved business model for both, the static and the dynamic case.

Table 8: economic value and the market value of the photovoltaic generation

Aggregator	Photovoltaic for residential buildings	Market value of the PV plant in € / MWh	Economic value of the PV plant in the improved business model in € / MWh		Impact of the improved business model
Oekostrom AG (Austria)	Energy value of the Photovoltaic	29.1	Static	67.1 (+130 %)	+
			Dynamic	107.4 (+268 %)	+

It has to be noted, that the reduced procured electricity via the grid consequently reduces the CO_2-Emissions by 0.11 tCO_2 / MWh. In conclusion, we can state, that this improved business model increases the economic value of photovoltaic plants for residential buildings and together reduces the CO_2-Emissions.

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4 Indirect impact of the improved business models on RES technologies

In this chapter, the indirect impact of the improved business models analyzed in [3] on renewable generation is investigated. The business models taken into account in this section are those that exploit electrical flexibility of the demand side in order to create value and/or to reduce costs. Table 9 summarizes the aggregators and the improved business models investigated in this chapter.

Table 9: BMs with an indirect impact on renewable generation

Aggregator	Improved business model
Good Energy (UK)	Automation and control
Next Kraftwerke (Germany)	Suppling „mid-scale“ customers with time variable tariffs including grid charges optimization
Next Kraftwerke (Belgium)	Using flexibility of customers as third party
Oekostrom AG (Austria)	Demand Side flexibilization of small customers
EDP (Portugal)	Activation and marketing of end user’s flexibility.
EDP (Spain)	Activation and marketing of end user’s flexibility.

4.1 Methods

In business models with demand side flexibility, we shift parts of the electric loads to different times. This results in a changed load profile. We assume that increasing demand during times of renewable energy production increases the market value of renewables. To quantify this impact we use the average share of renewable energy in electricity production at each time step and calculate the weighted average share of renewable energy production in the electricity consumed by the loads.

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4.2 Results

Table 10 illustrates the indirect impact of the considered improved business models on renewable generation. The change of the employment of renewables is measured in percentage points.

Table 10: Indirect impact of the improved business models on renewable generation

Aggregator	Improved business model	Percentage employment of renewable energy sources in the Baseline scenario	Percentage point change of the employment of renewable energy sources in the improved business model		Impact of the improved business model
Good Energy (UK)	Automation and control	29.4 %	- 0.07 %		-
Next Kraftwerke (Germany)	Suppling „mid-scale“ customers with time variable tariffs including grid charges optimization	32.08 %	Grid yearly	-0.25 %	-
			Grid monthly	-0.37 %	-
Next Kraftwerke (Belgium)	Using flexibility of customers as third party	16.57 %	Spot	-0.04 %	-
			Reserve	+0 %	o
Oekostrom AG (Austria)	Demand Side flexibilization of small customers	80.2 %	+0.08 %		+
EDP (Portugal)	Activation and marketing of end user’s flexibility.	50.67 %	Spot	-0.37 %	-
			Imbalance	+0.08 %	+
			Optimal	+0.1 %	+
EDP (Spain)	Activation and marketing of end user’s flexibility.	41.98 %	Spot	+0.05 %	+
			Imbalance	+0 %	o
			Optimal	+0.05 %	+

In the improved business model analysis for the British aggregator Good Energy in the report "*Quantitative analysis of improved BMs of selected aggregators in target countries*” [3], we investigated, how automated flexible devices react on market price signals to reduce the energy bill of the end consumers. The use of electrical flexibility implies the consumption of electricity via the grid at different times than those of the baseline. This may have an effect on the market

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value of renewables sold on the wholesale market. The results in Table 10 show that the share of renewables in electricity consumption in the improved business model decreases by 0.07 percentage points. Even if lower spot market prices typically correspond to lower average CO_2-emissions and so to higher renewable generation, in this case the renewable share in electricity consumption is reduced.

The improved business model analysis for Next Kraftwerke (Germany) analyzed in [3] investigated how considering grid charges in load schedule optimization affects the energy bill of mid-scale consumers. A yearly and a monthly peak-load-pricing component were investigated. Table 10 shows that neither the yearly nor the monthly peak-load-pricing options increase the RES competitiveness. Grid charges are not related to the employment of renewables and so considering them in an optimization strategy does not ensure an increase of RES competitiveness.

The improved business model “Using flexibility of customers as third party” for Next Kraftwerke (Belgium) developed in [2] investigated, how to valorize as aggregator the flexibility of customers that have a different supplier on different market places. To analyze the effects of third party flexibility activations, we defined two different scenarios: Spot- and Reserve scenario. In the first one, the flexibilities are used on the Day-ahead spot market and in the second one on the reserve market in order to reduce the overall costs. As Table 10 illustrates, the Spot scenario has a weak negative impact on the share of renewables in electricity consumption, while the Reserve scenario does not affect it. However, participating in the reserve market can be considered helpful to the energy system and, in particular, to integrate more variable renewables into the system, because the imbalance in the network is also affected by renewable feed-in.

In the business model analysis for Oekostrom “Demand side flexibilization of small customers”, we investigated, how flexibilities of loads can provide monetary benefits for both, consumers and supplier. In this model high and low price intervals, fixed by the supplier incentivize the customers to shift their demand to low cost times. As we can see from the results in Table 10, shifting the load to lower cost times leads to increase the share of renewables in electricity consumption.

For the business models of EDP “Activation and marketing of end user’s flexibility” in Portugal and Spain similar analyses were done. In these analyses the flexible loads of end users were shifted to reduce the energy and the imbalance costs. We investigated three different scenarios for each country. The Spot scenario, in which exclusively the energy costs are minimized; The Imbalance scenario, in which the flexibilities are used only to reduce the imbalance of EDP’s portfolio; The Optimal scenario, in which the optimal marketplace for the flexibilities is chosen. Table 10 resumes the changes of the employment of renewables, when those scenarios are applied. As we can see, the costs optimization increases weakly the RES competitiveness on the Iberian Peninsula.

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5 Conclusions

The main objective of this report was to provide an analysis of how the improved business models for the aggregators in the BestRES project, developed in the report "*Improved Business Models of selected aggregators in target countries*" [2] and investigated in the report "*Quantitative analysis of improved BMs of selected aggregators in target countries*" [3], increase the competitiveness of RES. The question of RES competitiveness was analyzed distinguishing between two cases: The case in which the improved business models have a direct impact on RES technologies and the case in which the improved business models have an indirect impact on renewables.

The direct impact on RES technologies was investigated comparing the economic value of renewables in the improved business models of the different RES technologies with their market value on the Day-Ahead spot market. The indirect impact on RES technologies was analyzed, considering the demand side variations and subsequently comparing the percentage of renewable energy taken from the electrical grid in both cases: using and without using the demand side flexibility. These analyses took into account multiple aspects, such as a more competitive trading of renewable generation, better customer relationships and more integrated energy service provision (e.g. energy management, maintenance, etc.).

Table 11 provides an overview of the results of the analyses about the RES competitiveness of the improved business models. The results show that three of four improved business models with direct impact on RES technologies increase their competitiveness. These improved business models directly valorize the renewable generation, giving it a higher value than the one of the wholesale market. This is the reason, why the economic value in the improved business models of different RES technologies is higher, compared to their market value on the Day-Ahead spot market.

The improved business models with an indirect impact on RES technologies do not always improve the KPI we have chosen to measure RES competitiveness in the target country. These business models focus on the demand side and, thus, their impact on renewables cannot directly be quantified in a straightforward way. In general, we assumed that increasing demand during hours of renewable energy generation would increase the market value of renewables. Hence, we evaluated as KPI for the impact on RES competitiveness the weighted average share of renewables in the electricity consumption of flexible loads. We find mixed results for this KPI. Some business models increase the share of renewables, others decrease it. The reason for this is that all business models optimize their flexibility with respect to market prices. Market prices, however, do not only depend on renewable production, but also on the demand. Hence, shifting load to times of lower prices does not necessarily imply a shift to times of higher renewable shares. Regardless of these quantitative case study results, we can say that providing flexible distributed demand access to electricity

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markets by aggregation increases system flexibility and a more flexible energy system is better suited to integrate higher shares of variable renewable energy production.

Table 11: Summary of the resulting RES competitiveness in the improved business models

<table>
<tr><th>Competitiveness of renewables in the improved business models</th><th>Aggregator</th><th>Improved business model</th><th colspan="2">Impact of the improved business model</th></tr>
<tr><td rowspan="4"><u>Direct</u> impact on RES technologies</td><td>Next Kraftwerke (Germany)</td><td>Dispatch flexible generation under changing market design on multiple markets</td><td colspan="2">+ +</td></tr>
<tr><td>Next Kraftwerke (France)</td><td>Providing decentralized units access to balancing markets</td><td colspan="2">+ +</td></tr>
<tr><td>Next Kraftwerke (Belgium)</td><td>Trading PV and Wind power</td><td>o</td><td>-</td></tr>
<tr><td>Oekostrom AG (Austria)</td><td>Valorize distributed generation of customers in apartment houses</td><td colspan="2">+ +</td></tr>
<tr><td rowspan="6"><u>Indirect</u> impact on RES technologies</td><td>Good Energy (UK)</td><td>Automation and control</td><td colspan="2">-</td></tr>
<tr><td>Next Kraftwerke (Germany)</td><td>Suppling „mid-scale“ customers with time variable tariffs including grid charges optimization</td><td colspan="2">- -</td></tr>
<tr><td>Next Kraftwerke (Belgium)</td><td>Using flexibility of customers as third party</td><td>-</td><td>o</td></tr>
<tr><td>Oekostrom AG (Austria)</td><td>Demand Side flexibilization of small customers</td><td colspan="2">+</td></tr>
<tr><td>EDP (Portugal)</td><td>Activation and marketing of end user’s flexibility.</td><td>-</td><td>+ +</td></tr>
<tr><td>EDP (Spain)</td><td>Activation and marketing of end user’s flexibility.</td><td>o</td><td>+ +</td></tr>
</table>

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Technical references

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Contributing beneficiary/ies	Carlo Corinaldesi, Daniel Schwabeneder, Andreas Fleischhacker, Georg Lettner (TUW-EEG)
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* 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)
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v	Date	Beneficiary	Author
1.0	13/11/2018	TUW-EEG	Carlo Corinaldesi, Daniel Schwabeneder, Andreas Fleischhacker
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3.0	17/12/2018	WIP	Silvia Caneva
4.0	18/12/2018	WIP	Cathal Cronin
5.0	19/12/2018	WIP	Silvia Caneva
6.0	20/12/2018	TUW-EEG	Carlo Corinaldesi

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