# How to Create Value through Aggregation: A Business Model Review for Multiple Regulatory Environments in Europe


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*Abstract*—**The rising share of distributed generation is having a profound impact on European electricity markets. Increased variability and price volatility require a more robust power system that allows alternative forms of production and consumption. Aggregation of renewable energy sources in a combined portfolio can significantly accelerate their market integration by diversifying revenue mechanisms, offering alternative ownership options and increasing asset valorisation. Today we see a variety of business models for aggregation, which are largely driven by the national regulatory framework and the distributed resources available for which aggregation can create value. This paper reviews three aggregator business models that were conceived by commercial aggregators in different regulatory environments in Europe. On the theoretical side, the business models are simulated using a business economic optimisation model. The practical implementation is monitored and the aggregators' implementation experiences are discussed. The paper identifies and documents how the business models can create value for the aggregators, their customers and for society in the different regulatory environments.**


## I. Introduction

In a changing electricity market, where the share of variable renewable generation is rising, system flexibility requirements are becoming crucial. European electricity markets were designed around centralised fossil-fuel generation along national or regional borders, yet they are now facing a rising share of distributed generation. This energy transition demands a more robust power system, both in a technical and economic regard, that can cope with increased variability and price volatility.

A possible solution is aggregating distributed generation and demand, a method that can yield higher market value for the aggregated portfolios as compared to their individual elements. An aggregator is an emerging market role that "aggregates" electrical load and generation of various assets in a single portfolio in order to optimise their market participation. The aggregated pool can include generators and consumers and can participate on one or multiple electricity markets. Being facilitators between the different sides of the electricity value chain, this activity can play an important role in market optimisation.

Aggregators are relatively new in European electricity markets and their role is expected to become increasingly important in the coming years. Market design, both on regional and European level, is starting to consider aggregation as an important facilitator of system flexibility. However, the industry is still facing several teething problems that need to be overcome before this new market position can be consolidated. Problems are present both on the regulatory side, in the form of barriers to market entry, and the operational side, where best practices have not been established. A wide variety of aggregation business models exists and it remains a question which business models create sufficient value in the long term to justify an aggregator's existence in European power markets.

This paper reviews three aggregator business models (BMs) that were conceived by commercial aggregators in different regulatory environments in Europe and identifies in which ways they create value. The following BMs and aggregators have been reviewed:

- Supplying mid-scale customers with time variable tariffs including peak-load optimisation by Next Kraftwerke Germany,
- Trading of aggregated renewable electricity on spot markets by Next Kraftwerke Belgium,
- Valorising distributed generation of customers in apartment buildings by oekostrom Austria.

The BMs are assessed through a detailed theoretical simulation [1]. Furthermore, their practical implementation is monitored [2].

## II. Aggregation: Overview of an Emerging Market Role

### A. Market roles for energy aggregators

Six market roles for aggregators can be identified, as shown in Figure 1 [3]. A major distinction is drawn between aggregators with a combined role and those with an independent role. Combined aggregators are existing market actors that carry out aggregation in addition to their normal operations. An example is an incumbent energy supplier that offers aggregation services to its existing client base. Since combined aggregators do not require fundamentally different frameworks to be developed, this form of aggregation avoids regulatory changes and is thus more compatible with the existing electricity market design. Independent aggregators, on the other hand, act independently from the electricity supplier and the supplier's balance responsible party (BRP). An

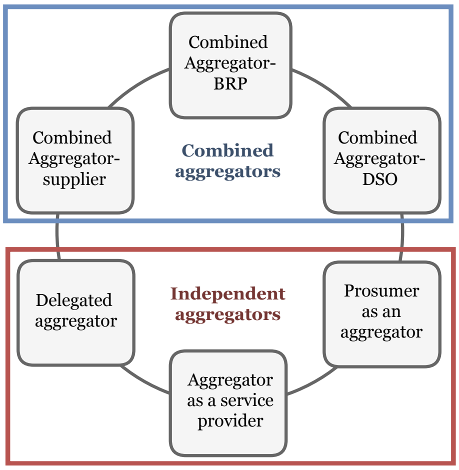


Fig. 1. Aggregator market roles

important advantage of independent aggregators is that their presence can create more competition on electricity markets. However, a clear framework for independent aggregators in Europe is still under development and relationships between independent aggregators, BRPs and suppliers are not always well-defined [4].

Two types of aggregators and their respective BMs are analysed in this paper. The first is the case of a **combined aggregator-supplier** in which supply and aggregation are offered as a single package. The customer only interacts with one actor for both electricity supply and aggregation services. The main benefits of this scheme are reduced complexity and the absence of financial settlements between suppliers and aggregators. This model faces as a result the least barriers for implementation in European electricity markets compared to the other market roles. The second market role analysed in this paper is that of a **delegated aggregator** in which the aggregator only provides aggregation services to other market actors. It is an example of an independent aggregator. The aggregator sells at its own risk to potential buyers such as the TSO, the BRP and the wholesale electricity markets and can be liable for incurred costs due to inadequate trading, imbalance, etc. The actions of the aggregator can have a significant impact on the position of other market players so interactions with these market players need to be contractually formalised.

The reviewed BMs are classified according to the presented market roles. The resulting conclusions allow to make abstraction for particular use cases and to extrapolate the findings to other scenarios.

### B. Benefits and beneficiaries to aggregation

Several potential benefits of aggregation can be identified, such as market integration, prosumer and consumer empowerment and boosting of both competition and innovation [5]. Specifically for distributed generation and renewable energy sources, aggregation can improve integration and facilitate market opening to a large number of participants. This can lead to new revenue models that result in increased competition and innovation on retail, whole-sale and reserve markets. Aggregators, as specialised actors, can also be better placed to deal with rapidly changing technologies. Furthermore, by acting as mediator between market actors and volatile markets, aggregators can provide risk hedging solutions.

Some benefits are already visible in European markets since a number of aggregation providers have been building up significant portfolios in recent years. However, in determining the benefits of aggregation it is important to identify for whom the aggregation activities create value: for the power system as a whole or only for an individual agent. System value is created if the operation of the power system as a whole is improved. Private value refers to added value that is created on markets, but does not necessarily reflect an improved system. In this regard, three types of aggregation can be distinguished [6]. **Fundamental aggregation** creates permanent value that does not depend on regulation and market awareness of technologies. **Transitory aggregation** can temporarily contribute to better functioning of the power system but may disappear when technical, managerial and regulatory conditions evolve. Apart from these 2 categories, aggregation can also be purely **opportunistic** when aggregators benefit from imperfect or asymmetric information, technology constraints, political interferences and conflictive regulatory principles. The created value by each of the reviewed BMs is classified according to these categories.

## III. BM1: SUPPLYING MID-SCALE CUSTOMERS WITH TIME VARIABLE TARIFFS INCLUDING PEAK-LOAD OPTIMISATION (GERMANY)

The first reviewed BM aims to add additional value to flexible electricity supply contracts by considering the impact of both the wholesale price and the capacity component of the grid charges on the customer's electricity price. An established aggregation product is wholesale price optimisation, in which the time of an asset's electricity consumption is controlled to reduce the sourcing price on spot markets. Flexible power consumption that considers the capacity component of the grid charges (the peak-load price) can lead to an additional cost reduction. By jointly reducing the wholesale price as well as the peak-load price, all components of electricity costs that can be influenced by load shifting through demand response are addressed. This is shown in Figure 2. This BM is implemented by Next Kraftwerke Germany (Next Kraftwerke DE).

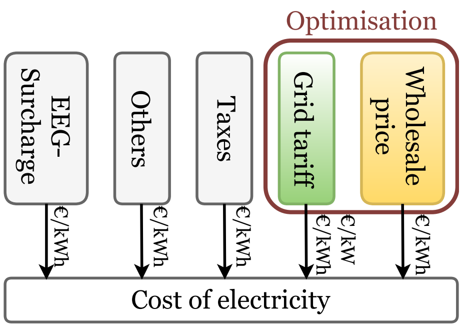


Fig. 2. Diagram of cost of electricity

TABLE I
SIMULATION RESULTS FOR BM1

| Optimisation | Spot | Grid | Spot | Grid |
|---|---|---|---|---|
| Peak-load-pricing | Yearly | Yearly | Monthly | Monthly |
| Electricity cost (€/MWh) | 91.42 | 87.39 | 119.75 | 106.80 |
| Peak load (MW) | 55.00 | 43.37 | 55.00 | 44.10 |
| Flex. activation (GWh) | 45.42 | 32.61 | 45.42 | 30.38 |

### A. *Economic analysis*

The BM is analysed through a case study of an aggregated portfolio of water pump installations with a total capacity of 55 MW, a total annual consumption of 155 GWh and a flexibility availability of 32 MW. The optimisation algorithm aims to minimise the portfolio's annual electricity cost by temporally shifting loads. It is assumed that the total daily consumption is not altered by the optimisation; only intraday shifts are allowed. The three following control scenarios are simulated:

1) An optimised consumption profile considering the instantaneous spot price.
2) An optimised consumption profile considering the instantaneous spot price and a peak-load component that is calculated yearly. This represents the current situation in Germany.
3) An optimised consumption profile considering the instantaneous spot price and peak-load component that is calculated monthly. This represents a possible future scenario.

For this purpose, two optimisation models – with and without the consideration of peak-load prices – are set up, solved and compared. A baseline scenario with the original load profile is simulated as a reference.

Time series of the resulting annual load profiles are shown in Figure 3. Subfigure 3.1 shows the baseline load profile, which has irregular peaks up to 55 MW. Under spot optimisation, shown in Figure 3.2, the peak load is increased and the load profile shows intermittent behaviour: either maximum power is consumed or no power at all. This reflects the algorithms tendency to consume as much electricity as possible during the hours when electricity prices are low. If peak-load pricing is considered in the optimisation (Subfigures 3.3 and 3.4), the peak load is reduced. In the case of yearly peak-load pricing, the peak load is uniform throughout the year. This reflects the algorithm's trade-off between using the flexibility either to reduce the peak load or shift consumption to times with low spot prices. Under the monthly peak-load pricing, shown in Figure 3.4, this trade-off is optimised for each individual month.

Table I shows the numerical simulation results for a tariff with annual peak-load pricing and for a tariff with monthly peak-load pricing using both optimisation techniques. The reported economic KPI is the annual operation costs due to electrical consumption of the portfolio. The optimisation results in a reduction of 4.4% of the electricity cost under yearly peak-pricing and a 10.8% reduction under monthly peak-pricing. The peak load is respectively reduced by 21.1% and 19.8% for the yearly and monthly charges. Furthermore, the flexibility activation is affected by the

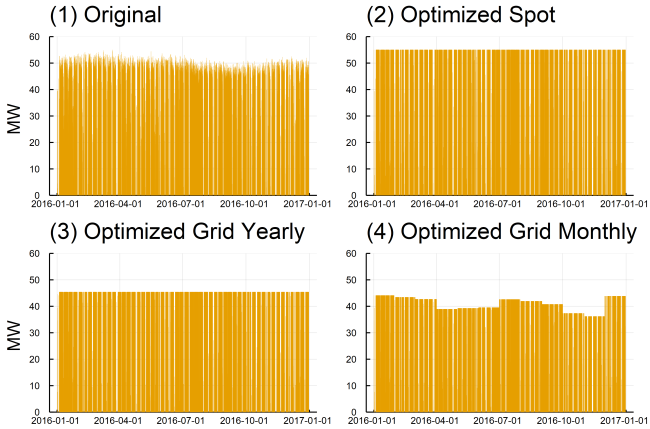


Fig. 3. Simulation Results for BM1

different operational routines. Remarkable is that the peak-load optimisation is responsible for less flexibility activation. This can be explained by the fact that the peak load is lower, and therefore the amount of flexibility employed for spot price optimisation is smaller.

### B. *BM Implementation and Results*

Next Kraftwerke DE reports that customer acquisition for this BM was ongoing by October 2017. Water pumps were identified early in the implementation process as a customer segment with a high potential; inherent storage of connected water basins and fast reaction times of water pumps create ideal conditions to valorise flexibility. Some water management companies already consider grid charges and optimise their consumption profile by based on peak load periods. This has the advantage that these potential customers are familiar with the idea of optimisation of consumption through load flexibility. Furthermore, Next Kraftwerke DE has previous experience with this customer group through their product 'flexible power supply' so they are aware of the technical restrictions of the installations. For these reasons, water management companies that already perform peak-load optimisation were targeted as the first customers for this BM. The implementation KPIs are summarised in Table II

The flexible power supply concept entails the implementation of several interfaces and processes. The implementation consists of both a yearly and a daily optimisation component.

As a first step in the yearly optimisation, the power demand and technical constraints of the customer are mapped. Next Kraftwerke DE forecasts the long term supply and fixes a maximum price level per customer. This assures that flexible power supply customers are not put at risk of a long-term electricity price increase. Peak load already plays a crucial role in this stage since peak load optimisation

TABLE II
IMPLEMENTATION RESULTS FOR BM1

| | Reported | Reported | Target |
|---|---|---|---|
| | Feb. 2018 | Jul. 2108 | Dec. 2018 |
| Portfolio size | | | |
| - Water pumps | 32 MW | 32 MW | 36 MW |

is influenced by the hedged profile. The long-term profile is further optimised taking into account long-term price forecasts for the day-ahead and intra-day market.

In the daily optimisation, Next Kraftwerke DE makes a detailed forecast of the electricity price for the following 96 fifteen-minute intervals and supplies these values to the pump's central control system on an hourly basis. The pump's controller generates a short-term demand schedule considering the price forecast and operational restrictions such as the minimum fill limits of the water reservoirs, the anticipated water delivery, and the peak load. Finally, Next Kraftwerke DE receives the optimised operational timetable and trades the adapted schedule on short-term markets.

This BM combines several optimisation systems and is therefore quite complex in terms of marketing and technical implementation. Its roll out requires a large customer commitment to electricity price reduction that supports the lengthy installation process and facilitates the necessary coordination between the different departments within the same company. These have been major barriers to the development and extension of this BM to other customer segements. Next Kraftwerke DE initially started as an independent aggregator. However, in order to facilitate advanced BMs such as the one under discussion, Next Kraftwerke DE has moved towards the combined role of aggregator-supplier. A combined approach reduces the required coordination between market players and lowers the necessary commitment from the customer.

Next Kraftwerke DE reports that this BM can reduce the sourcing cost of electricity by about 10%. This confirms the simulation results in the previous section (Table I). Furthermore, the peak load of the aggregated portfolio has seen a decrease of 20-25%. This result also confirms the simulation results from the previous section.

The 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 benefit is therefore classified as transitory aggregation with signs of fundamental aggregation. However, 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 can therefore not be classified as fundamental aggregation. 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 non-reflective of the instantaneous system state. This limits Next Kraftwerke DE's potential to develop a commercial BM that contributes to a more resilient power system. While the BM causes peaks that are lower than those under spot price reduction, the BM primarily leads to private value and does not necessarily bring overall system benefits. However, the technology that is developed in this BM can significantly increase the system value of demand side management once dynamic peak-load components are introduced in Germany.

## IV. BM2: TRADING PV AND WIND POWER ON SPOT MARKETS (BELGIUM)

The main activity in this BM is to trade power from weather dependent electricity sources such as solar PV and wind power on the different power markets in Belgium. The assets in the portfolio are connected in a virtual power plant that collects large amounts of data from the variable power sources. Algorithms use this data to determine the optimal trading strategies on the day-ahead, and intra-day market. This includes imbalance optimisation. Using advanced communication technologies and forecasting methods the BM aims to add value to the aggregated portfolio by optimising its revenue. This BM is implemented by Next Kraftwerke Belgium (Next Kraftwerke BE).

### A. *Economic analysis*

The BM is analysed through a theoretical case study of three different portfolios. A first portfolio (Solar BE) consists of the total installed capacity of solar PV in Belgium (2.953 GW). The second portfolio (Wind BE) covers the total installed capacity of onshore wind power in Belgium (1.249 GW). The third portfolio (Solar NK) concerns a single PV plant in Next Kraftwerke BE's current Virtual Power Plant (2.003 MW). The following trading scenarios are simulated:

1) The *baseline* scenario considers the portfolio's revenue on the day-ahead market including the incurred imbalance costs due to the deviations between the forecast and production.
2) The *improved* scenario markets the forecast deviation on the intra-day market instead of bearing the incurred impact of the imbalance.
3) The *optimal* scenario markets the deviations on the intra-day market, but only in case that its prices increase the revenue compared to the imbalance tariffs. This scenario assumes perfect market knowledge.

The financial performance of the different trading strategies, measured in turnover per produced electricity (€/MWh), is shown in table III. The *optimal* trading strategy gives the highest turnover per MWh for each of the portfolios. Surprising is that the *improved* strategy, in which forecast deviations are marketed on the intra-day market, does not result in a higher turnover than the baseline. This means that in the *optimal* scenario, a significant amount of electricity production is still settled through imbalance mechanisms. This result opposes one of the principles behind the intra-day market: that it offers market participants the opportunity to settle electricity production and consumption near real-time to reduce the amount of cost-intensive ancillary services that are required to keep the power system in balance.

It is important to note that both the portfolios Solar BE and Wind BE have a significant size relative to the total Belgian production capacity. This can have several effects that can help to explain the results. First of all, the portfolio size can affect production forecast accuracy. A larger portfolio will have a more pronounced aggregation effect and can be forecasted more accurately. An indicator for the accuracy of the generation forecast is the mean average percentage error

TABLE III

ECONOMIC SIMULATION RESULTS FOR BM2

| Portfolio | **Baseline** €/MWh | **Improved** €/MWh | **Optimal** €/MWh |
|---|---|---|---|
| Solar BE | 36.40 | 36.01 | 38.49 |
| Solar NK | 33.44 | 33.20 | 37.57 |
| Wind BE | 31.05 | 31.02 | 33.55 |

TABLE IV

TECHNICAL SIMULATION RESULTS FOR BM2

| Portfolio | **MAPE** | **Imbalance** MWh/year | **Intraday** MWh/year |
|---|---|---|---|
| Solar BE | 1.93 | 124 | 104 |
| Solar NK | 3.27 | 197 | 173 |
| Wind BE | 3.84 | 227 | 202 |

(MAPE). Values for MAPE for the different portfolios are given in Table IV. The revenue from electricity production increases with decreasing MAPE, regardless of the trading strategy. Forecast accuracy alone can thus not explain the witnessed results. A second implication of the portfolio size is that a large portfolio can play an important role in price setting on electricity markets. Electricity production from the total PV or wind capacity will impact the instantaneous bid ladders of both the day-ahead and intra-day market. The simulation results of optimised trading of a sufficiently large production profile based on fixed market prices might be distorted by the effect that the specific production profile had on the market prices. However, the independent Solar NK portfolio equally results in a slight decrease between the *Baseline* and *Improved* scenarios, which indicates that the described effect does not entirely explain the simulation results.

To investigate the optimal division between trading on the intra-day and through imbalance in greater detail, the traded volumes on each market in the optimal strategy are shown in Table IV. The traded volumes at the different markets are almost equally divided between the intra-day market and imbalance power market. These results indicate that optimal trading strategies cannot be easily determined based on historical data and differences in technology.

### *B. Implementation results*

The implementation of this BM started in October 2017. In the first phase a market analysis was carried out to analyse the available value on the different markets. As the simulation results show, this is an important step: markets can exhibit immature and counter-intuitive behaviour. Next Kraftwerke BE's study showed that the imbalance prices in Belgium are low compared to neighbouring countries. Several large market players therefore prefer to keep settling forecast deviations through imbalance instead of trading them on the intra-day market. This has as a result that the Belgian intra-day market is illiquid, which can help to explain the theoretical simulation results presented in the previous section.

TABLE V

IMPLEMENTATION RESULTS FOR BM2

| | **Reported** Feb. 2018 | **Reported** Jul. 2108 | **Target** Dec. 2018 |
|---|---|---|---|
| Portfolio size | | | |
| - Solar PV (MW) | 0 | $50 - 100$ | $> 100$ |
| - Wind power (MW) | $0 - 10$ | $100 - 150$ | $> 150$ |

The implementation KPIs at different times are shown in Table V. The portfolio size can be broken down between PV and wind. In both cases the values for February 2018 are between 0 and 10 MW. By July 2018 this has grown to respectively 50 - 100 MW and 100 - 150 MW for solar PV and wind power.

Several aspects play a role in client acquisition. An important requirement is the size of the asset. Next Kraftwerke BE has identified a minimum system size for both solar and wind assets based on the fixed costs that they face when integrating a unit in their virtual power plant. These costs include setting up a production data interface, staffing the 24/7 trading team, invoicing, administration and customer service. Next Kraftwerke BE uses in-house developed communication hardware which they pre-finance for most customers. If an installation is too small then the revenue is not able to pay back this investment.

During discussions with the first potential clients for solar power PPAs, Next Kraftwerke BE found that asset owners are not only interested in selling their solar or wind electricity. They are also looking to sell their Guarantees of Origin (GO), since those cannot be sold to the regulator against a minimum price (as is the case for belgian green power certificates). Next Kraftwerke BE worked out a strategy that included acquiring market access to these commodity markets. Preferably, a bilateral agreement is made with one or more energy suppliers that are looking for GOs from Belgium. Electricity suppliers that offer local renewable energy products must deliver GOs to the regulator to indicate the source of the electricity. As there is an increasing demand from end consumers to be supplied with local renewable energy, suppliers often cannot fulfil the demand with their own renewable production assets and buy the GOs on commodity markets. Market prices for GOs in both Belgium and the Netherlands are therefore rising. Before, the low market prices for GOs meant that the additionally generated revenue did not outweigh the costs of trading on these markets. Nowadays, bundling PPAs for electricity and GOs can streamline trading service and bring additional value to renewable energy sources.

Business development for large wind and solar farms has proven to be more challenging. Tendering parties for large-scale projects are interested in Next Kraftwerke BE's trading services that use day-ahead indexed prices, but they additionally want to secure payback of their investment even when long-term prices in the electricity markets drop significantly. This requires long-term hedging securities including risk premiums for which in-depth financial risk management is necessary. The BM is marketed through a Power Purchase Agreement in which Next Kraftwerke BE is liable for the trading risk and takes the role of delegated aggregator. As a delegated aggregator whose strengths are short-term valorisation on spot markets and through imbalance optimisation, long term hedging is outside the scope of Next Kraftwerke

BE's current operation. Next Kraftwerke BE is actively looking at different ways to expand their market role in order to solve this problem. They report that they will collaborate with a financial institution to be able to offer a long-term product.

This BM exhibits several aspects of fundamental aggregation: it offers economies of both scale and scope. By using a single IT infrastructure to market a large pool of assets, fixed transaction costs associated with participating in a market can be brought down. Furthermore, by bundling several services, in this case trading both electrical power and GOs, the available business knowledge and technologies can be used more efficiently compared to the case of multiple aggregators delivering a single service. This creates value both for the aggregator and the power system as a whole. The BM also shows signs of transitory value. By offering a specialised service that optimally markets assets on multiple markets it can close potential information gaps between asset owners and market signals.

## V. BM3: VALORISING DISTRIBUTED GENERATION OF CUSTOMERS IN APARTMENT BUILDINGS (AUSTRIA)

The aim of this BM is 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. This 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 residential buildings is through self-consumption. Aggregating the consumption of an entire apartment building can increase the self-consumption of the locally produced PV power and thus improves the asset's economic performance. The analysis investigates how the solar PV potential of apartment buildings can generate the most value. This BM has been put forward by the Austrian electricity supplier oekostrom.

### *A. Economic analysis*

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 of a typical apartment building in Vienna and each household is characterised by its average electric load profile. The building's total annual consumption is 34.5 MWh. Three different scenarios are considered:

1) The *baseline* scenario considers the situation in which there is no PV plant installed.
2) The *static* scenario considers the situation in which each individual flat owns a photovoltaic installation and PV power cannot be traded between the different flats.
3) 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.

The main difference between the *static* and the *dynamic* scenario is that in the former, in case an individual household has an excess of produced power, this power will be sold to the utility grid. In the *dynamic* scenario, this is only the case if the total produced solar power is higher than the building's total electricity consumption.

The case studies have been formulated as optimisation problems that minimise the building's overall electricity cost depending on the installed solar power and the traded electricity per household. The connected capacity of the individual flats remains unchanged. The tariffs for electricity and grid costs are based on oekostrom's current offer for residential customers.

The evaluated economic parameter is the annualised total cost of ownership including the annualised investment cost. The effect of the different scenarios is shown in Figure 4 and Table VI. Under the *static* scenario, the total electricity cost decreases by 10.4% compared to the Status Quo scenario. The case with the lowest cost is the *dynamic* case, where the annual cost is 13.7% lower compared to the status quo scenario. The produced power by the PV-system is the same in both the *static* and *dynamic* case: 28.9 MWh. The auto-consumption increases from 11.5 MWh in the *static* case to 13.5 MWh in the *dynamic* case. These results confirm that aggregating residential load in apartment buildings can increase auto-consumption and decrease the cost of electricity from renewable sources.

As the capacity of the grid connection is assumed to remain the same regardless of the simulated scenarios, the results give a conservative estimate of the potential benefits. Electrical peaks of the individual households are not all simultaneous and only the aggregated net difference between the building's production and consumption is exchanged with the utility grid. This means that the collective PV installation could result in a reduction of the building's required grid connection. As grid capacity is a cost-driver in electricity tariffs, this could result in larger benefits than those calculated in this simulation.

Figure 5 shows that both the *static* and *dynamic* case

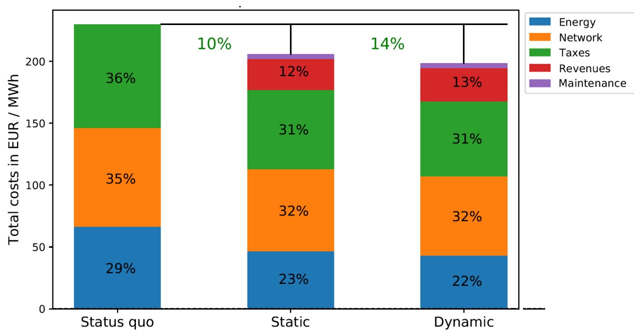


Fig. 4. Breakdown of electricity cost in BM3

TABLE VI
BREAKDOWN OF ELECTRICITY COST IN BM3

| | Baseline | Static | Dynamic |
|---|---|---|---|
| Energy | € 66.5/MWh | € 46.63/MWh | € 43.13/year |
| Grid | € 79.62/MWh | € 66.26/MWh | € 63.91/MWh |
| Taxes | € 83.77/MWh | € 64.2/MWh | € 60.75/MWh |
| Investments | € 0/year | € 1374.4/year | € 1374.4/year |
| Maintenance | € 0/year | € 134.2/year | € 134.2/year |
| Total | € 229.89/MWh | € 205.9 /MWh | € 198.39/MWh |

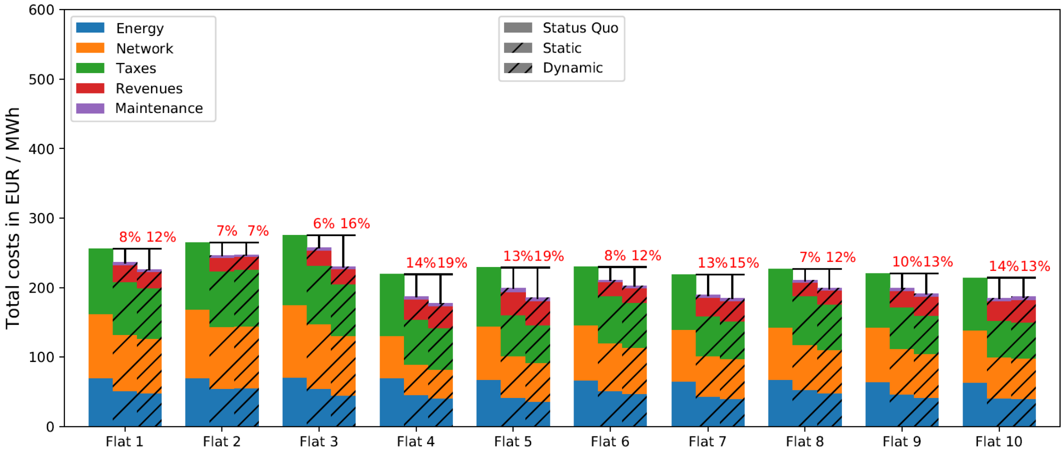


Fig. 5. Electricity cost for individual households in BM3

reduce the cost of electricity for all the inhabitants of the apartment building. The dynamic case is more profitable than the static case for almost all the inhabitants of the apartment building. The *Static* case only creates more value for flats with a large individual consumption, as in the case of Flat 10. As the figure clearly indicates, the costs reductions and the investment & maintenance costs are not equally distributed between the flats: some flats have higher benefits than others. The allocation of benefits of collective PV systems on apartment buildings is studied in detail in [7].

### *B. Implementation results*

Unlike in the case of the other BMs, the market conditions in Austria for this BM were not positively evaluated and oekostrom has not started its implementation. Until recently, several barriers to the implementation of this BM existed. However, recent changes in the legislative framework have changed this situation. The Amendment of the Electricity Management and Organisation Act 2010 from 26th July 2017 includes several provisions to promote community production facilities. It is explicitly included that network access beneficiaries shall have the right to operate collectively owned generation assets as long as the free choice of suppliers to the end consumers is not restricted.

Even though the amendment opens up viable options for the rollout of this BM, oekostrom identifies several barriers 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 the PV installation has to be included in a long-term contract between the owner and occupier. In case an occupier decides to move, there is the uncertainty whether the new tenant will be willing to take over this contract. Even when the respective property-owner inhabits the dwelling there can be complications to this BM's implementation: it is possible that mortgage lenders do not accept a third-party or collectively owned installation on the mortgaged property.

Several organisation schemes exist to finance and operate collective rooftop PV systems on apartment buildings in Austria: the installation can, for example, be financed and operated by the building owner, a resident association or an external company. In their preferred ownership scheme, oekostrom takes the combined role of aggregator-supplier. They finance and operate the installation and the residents can benefit from the collective PV installation by paying a fixed price for the self-consumed PV electricity (in €/kWh). This price lies below the price of electricity from the grid. As the economic performance of the PV relies on the participation of as many customers as possible, oekostrom identifies that an incumbent local supplier can be in a preferential position to offer this service.

This leads to the question of which share of the created value can be granted to the aggregator-supplier (here abbreviated as supplier). A collective PV installation will reduce the apartment building's electricity consumption from the grid, which reduces the supplier's revenue from electricity supply. The simulation results presented in the previous section are used to analyse how the created value can be distributed to compensate this loss. In this example, the supplier makes profit through three activities: selling the produced PV power to the building's residents and trading the excess on wholesale markets, supplying the building's remaining demand by sourcing the electricity on wholesale markets, and trading the guarantees of origin of the produced PV power. The calculation results are shown in Figure 6. The *Static* case results in a profit reduction of €135 and the *Dynamic* case results in a profit reduction of €185. The supplier recuperates this lost profit, together with the PV investment cost and the annual maintenance cost, through a charge on

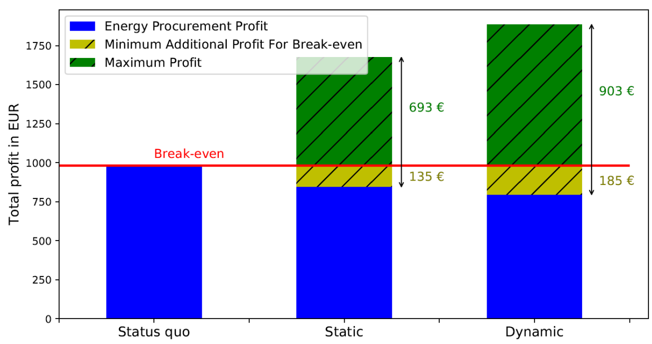


Fig. 6. Total profit for the Aggregator in BM3

the auto-consumed PV power. In the break even case, in which the supplier charges the minimum price to cover these cost, the households pay respectively €98.65/MWh and €96.47/MWh in the *Static* and *Dynamic* scenario. This is less than half of the electricity price in the *Baseline* scenario. The supplier makes maximum profit if PV power is charged at the same rate as regular electricity supply, €230/MWh. This case leads to a profit of €1683/year in the *Static* case and €1893/year in the *Dynamic* case, as presented by the green bars in Figure 6.

## VI. Best practices

Several practices are reviewed through the economic simulation and the practical implementation of the BMs. Both practical issues and successful strategies are identified. This leads to the following best practices.

### A. Value creation and distribution

The implementation experiences show that an effective strategy in aggregation BMs is to offer the aggregated assets the opportunity to benefit from all possible revenue streams. This is exemplified by combined trading of electricity and guarantees of origin (Belgium), optimisation of electricity sourcing costs and peak-load prices (Germany) and bundling electricity supply from power markets with self-consumed PV production (Austria). The aggregator-supplier market role is an evident way to combine revenue streams, though it is also possible through the delegated aggregator role. This strategy creates in both cases a 'one stop shop' that satisfies the customers' need for electricity supply as well as aggregation services.

### B. Client Acquisition

A challenge in client acquisition for aggregation BMs is to overcome the technical complexity of the aggregation activities and offer the clients a value proposition that they can understand. At the same time, market pull mechanisms towards the aggregator are decisive in the acquisition of aggregation clients. The challenge lies in developing a BM that captures the complexity of electricity markets to generate enough value, while being tailored to the customers' understanding of power systems.

### C. Revenue

Complex BMs require a substantial amount of set-up costs at the initial stage with uncertainty about later revenue streams. In the early implementation phases there is a learning curve in which the aggregator gains insights into the BMs revenue streams. This makes it complicated to balance the services provided by the aggregated assets with the correct remuneration. Value created through aggregation requires carefully built portfolios and the optimisation needs detailed risk management that considers the customers' appetite to risk exposure.

### D. Technology

In many cases there is no ready-made solution to provide the technology for aggregation activities. Due to the multitude of existing assets and control systems, a completely standardised interface between the customer and the aggregator is impossible to develop. Aggregators can choose between either an in-house solution or an external technology provider. In any case, the anticipated revenue streams have to cover development costs for any specific interface.

## VII. Conclusion

This paper presents a business model review of 3 aggregation business models that were conceived by commercial aggregators in 3 different European markets. The analysis combines the results of detailed economic modelling and real-life implementation experiences. The analysed business models are: "Supplying mid-scale customers with time variable tariffs including peak-load optimisation" implemented by Next Kraftwerke Germany, "Trading PV and wind power on spot markets" by Next Kraftwerke Belgium and "Valorising distributed generation of customers in apartment buildings" by oekostrom Austria. The results of the simulations indicate that each of the presented business models can create additional value for renewable energy sources. These results are validated by the implementation experiences from the commercial aggregators. However, the amount of value created at a system level differs between the business models. As a best practice it is identified that commercially successful aggregation business models generate a diverse income from multiple revenue streams. Furthermore, the results indicate that aggregators can make complex aggregation business model more appealing to potential customers by combining several market roles.

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## References

[1] 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, Tech. Rep. BestRES D3.3, 2018.

[2] R. Verhaegen and R. Beaumont, "An assessment of the economics of and barriers for the implementation of the improved business models," Grids & Markets, 3E, Tech. Rep. BestRES D4.4, 2017.

[3] S. USEF, "USEF: The Framework Explained," Universal Smart Energy Framework, Tech. Rep., Nov. 2015. [Online]. Available: http://www.globalsmartgridfederation.org/wp-content/uploads/2016/10/USEF_TheFrameworkExplained-18nov15.pdf

[4] R. Verhaegen and C. Dierckxsens, "Existing business models for renewable energy aggregators," Grids & Markets, 3E, Tech. Rep. BestRES D2.1, 2016.

[5] R. Verhaegen, C. Dierckxsens, and P. Joseph, "Technical, market, environmental and social benefits of aggregation BMs within the consortium," Grids & Markets, 3E, Tech. Rep. BestRES D2.2, 2016.

[6] S. Burger, J. P. Chaves-Ávila, C. Batlle, and I. J. Pérez-Arriaga, "The Value of Aggregators in Electricity Systems," MIT Center for Energy and Environmental Policy Research, Tech. Rep. CEEPR WP 2016-001, Jan. 2016.

[7] A. Fleischhacker, H. Auer, G. Lettner, and A. Botterud, "Sharing solar PV and energy storage in apartment buildings: resource allocation and pricing," *IEEE Transactions on Smart Grid*, Jun. 2018.