# SUB-AGGREGATOR BUSINESS MODELS FOR DEMAND RESPONSE

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## Abstract

Global efforts for decarbonizing electricity production have led to the rise of renewable energy sources that are intermittent by nature. Electricity demand will need to become more flexible to support the integration of renewables into the power system. Aggregators are companies specialised in combining distributed energy resources into larger entities that can be controlled based on power system needs. In this paper we are going to first define the flexibility value chain and the required pieces to this puzzle to make it work. Then we will explain why we feel that sub-aggregators need to be recognized as key enablers for harnessing flexibility in a cost-efficient manner. The main output of this paper are chapters that clearly define the roles and responsibilities needed to form fair and sustainable business models for aggregators and sub-aggregators.

## 1 Introduction

Countries replacing fossil fuels in their electricity production with weather dependent renewables face risk related to availability of electricity. Renewable power production is stochastic in nature and therefore there will always be a risk that power production capacity on windless and cloudy days isn't enough to cover demand [1]. To cope with this issue, countries have generally three options: they can import the missing power from neighbouring countries if there are enough available interconnections, they can use stored energy if there is any or they can reduce demand. Reducing demand can happen by incentivising consumers to use less energy or by forcing the shut-down of consumption units [2]. In this paper we are focusing on the demand side management solutions, more specifically on the voluntary schemes where compensation is provided for the activation of flexibility.

Sub-aggregator is a role that can be adopted by companies that govern large amounts of distributed flexible assets. The concept of a sub-aggregator was refined and tested in real life during a project called Aggregator Business Pilot. The project is part of a Finnish innovation ecosystem called Smart Otaniemi where research, business and regulators are brought together to innovate new smart energy solutions. The project goal was to find cost-efficient ways for aggregating distributed energy resources within different domains and to test this flexibility on markets. Another goal for this project was to develop innovative business models for aggregators and sub-aggregators for managing that flexibility. The creation of these new sustainable business models supports the green transition and the cost-efficient utilisation of the existing electricity grid. [3]

## 2 Flexibility in Power Systems

Demand Side Management (DSM) will have an increasing role in the future of power system management. Traditionally the necessary balance between power consumption and production has been managed by controlling the production side but the trend of replacing controllable power generation units with intermittent sources of electricity has flipped the operation logic upside down. Increasing share of power production is either base load like nuclear power or weather dependent like wind and solar power. This trend is forcing power systems around the world to renew their operation logics. In practice this often means a wider use of demand side flexibility or Demand Response (DR), which are both covered by the wider term Demand Side Management [2].

Managing flexibility from demand side is substantially more challenging than managing the supply side. Traditional production of electricity is typically designed to be as flexible as possible, to match varying level of demand with intermediate storages and controllable power plant processes. Whereas demand of electricity is formed by the individual habits of humans and fine-tuned industrial processes which are used to receive electricity always on demand. Significant efforts are needed to rethink the human behaviour and industrial process patterns to support the clean power production of tomorrow.

Another driver for flexibility is the shortening of balancing period from 1 hour to 15 minutes in 2023 in Nordics [4]. This change will force balance responsible parties to activate flexibility more often and closer to real time resulting in greater value of resources that can react fast and reliably. In Finland there has also been serious discussions whether household consumers would also be subject to power tariffs



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by the DSOs, meaning that a major component of distribution fees would be determined by the peak power they consume over a certain period [5]. These are additional reasons for demand side to start thinking how the use of electricity could be more flexible.

*2.1 Management of Flexibility*

Flexible resources are naturally the key ingredient in DR schemes since they are the physical part of the power system that provides the flexibility. The resources themselves can differ almost in all features. What they have in common is that they either consume or produce electrical energy and that the power can be controlled to some extent.

The changes in power production are believed to result in much higher price volatility [6]. In practice, this means that those who can schedule the time of electricity consumption will pay lower prices than those that have no flexibility. Scheduling consumption based on production availability will require a change in the mindset of consumers who are used to consume electricity without minding the current situation in the system. In the future, it will be essential to know when and how much electricity use can be rescheduled to more profitable times and the risks associated to it.

Large industrial players in Nordic countries are typically providing ancillary services already for the national TSOs, but in future also smaller players are likely to be seen on flexibility markets as the need for flexibility increases. Aggregators will have a key role in bringing more flexibility to the markets. They combine the flexible potential of smaller players into products for the wholesale or flexibility markets. The aggregation provides economies of scale and helps reduce the uncertainties through forecasting. More importantly for small or even medium players, to combine forces with others is a necessary action to enter the markets in the first place. In the current flexibility markets, such as Fingrid’s reserve markets, a minimum bid size of 100 kW is required to participate [7].

Household consumers are also able to participate in the flexibility markets with some of their electrical appliances such as electric vehicles, hot water boilers and air conditioning units. Flexibility management from households also requires aggregation since there is generally not enough flexible capacity in individual households to make it feasible to be managed alone. People also tend to value a high level of comfortability in their living conditions and a low level of complexity which further limit the potential for flexibility. Attitudes are however changing as recent study finds out that almost half of household consumers in Finland are willing to let a third party to manage their flexibility if the households get some compensation for it [8].

Demand forecasting in the future will still have a critical role in power system management, but for a slightly different reason than today. In future it will be used more for estimating the need for flexibility whereas today it is used to schedule the power production. Power system management will also need more accurate and closer to real time monitoring of the system in future so that problems like congestion can be avoided. Transition to cleaner power system is already ongoing and the pace will most likely increase as the cost of emissions increases. Harnessing the flexible potential in a cost-efficient and sustainable manner from industry and households will be essential for nations moving towards low carbon power systems.

Virtual Power Plants (VPP) are at the core of future flexibility management. They are virtual entities that consist of multiple distributed energy resources that can be used together to create desired impact on power system. This aggregated portfolio can be offered to different markets based on the technical capabilities and assessed profits. Aggregation also enables market access for assets that might not be suitable on the markets otherwise in terms of capacity or activation time. Portfolio management in VPPs enable flexible resources to be used in a more efficient manner by combining available assets dynamically to ensure maximum yield from the most beneficial market [9].

*2.2 Value of Flexibility*

Following the trend of decarbonisation, it is expected that flexible use of electricity will play a bigger role in the following decades. Those who can utilize flexibility can create value by providing flexible capacity for the use of system operators and balance responsible parties. Utilizing flexibility to schedule consumption based on SPOT prices will also bring added value by lowering the electricity bill. Also, the electrification of mobility as well as many industrial processes will impose greater requirements for the power system.

Based on our discussions with commercial aggregators during the project, smaller units than 50 kW were not regarded as profitable in DR schemes unless there would be practically no need for hardware investments to enable DR. This is because estimated savings or earnings from DR must be larger than the investments in a reasonable time scale. How long a time is regarded as reasonable is not something that could be generalized but based on initial surveys from industry it could be as short as one or two years which makes investments challenging. On top of hardware costs, operating on flexibility markets might require educating personnel about the changes that will result from DR. System updates and reconfigurations might also be needed once in a while, for example setting up the DR parameters again. For some industries, integrating DR into the daily operation is seen as overwhelmingly difficult because it requires a holistic understanding of the consequences of mixing internal operations and the flexibility markets. This is somewhat understandable as complex industrial processes might be sensitive to disturbances. For example, regulating ventilation too much in a paper mill might have unexpected effects on the quality of the paper that is produced.



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Forecasting the future value of flexibility is challenging since it depends on multiple things, such as the share of renewables in the power mix and the amount of grid scale energy storages. On one hand, the share of wind power in Finland is estimated to grow from 7% to 17% of the total consumption within a few years [10], which will increase the need for flexibility and thus its value. On the other hand, flexibility is available more and more as new players enter the market. In summer 2020 the first grid scale battery storage unit in Finland was announced sizing 30 MW / 30 MWh [11]. Another aspect to consider is the impact that the new balancing period will have on the value of flexibility. Moving to shorter balancing period will require balance responsible parties to manage their balance more actively, which could increase the value of flexibility at least in the short term.

## 3 Sub-aggregator concept

Sub-aggregator, as the name suggests, is an aggregator managing lots of distributed energy resources. However, it is distinguished from a traditional aggregator due to its purpose in business. Traditional aggregator exists to fulfil tasks related to energy markets, such as managing flexibility to provide auxiliary services for power system balancing whereas sub-aggregators exist for completely other reasons. A sub-aggregator is a natural aggregator in the sense that it's capability to monitor and control distributed energy resources is a result from purposes other than those related to energy markets. For example, charging point operators for electric vehicles exist for providing charging services for EV owners and heat pump manufacturers exist because household consumers want to heat their houses. They can exist and fulfil their purpose without having anything to do with electricity markets.

The novelty here is to understand that these service providers can extend their value offering by adopting the role of sub-aggregator and becoming more or less active player on the electricity markets on top of their primary business. This should be done in a way that new value that is created is equally divided between the whole value chain. The value is created by harnessing the flexible potential that these distributed energy resources hold and using sub-aggregator's existing ICT connections to do this without any need for installing hardware for this. For example, electric vehicle can be charged in a flexible manner if the vehicle is plugged in for longer time than would be needed, which is typical in household and office parking. The charging could be scheduled or in real time controlled using charging point operator's interfaces to do this.

For a sustainable and fair business model, the end-user i.e. the owner or user of the flexible asset should be included in the business model for at least two reasons. End-user should be able to define how much flexibility can be activated and on what terms. Also, the end-user should be able to benefit from the flexibility activities in some way. It doesn't necessarily have to be a share of the compensation that is yielded from activated flexibility, it can also be something else, for example improved services or lowered charging tariffs.

In the project Aggregator Business Pilot we had several companies that were identified as potential sub-aggregators. These companies had varying reasons to be interested in adopting the role of sub-aggregator, the most common having an interest in extending their business towards providing flexibility. Another reason was that their own customers had been asking them to provide access to flexibility markets. In the first mentioned case the companies were thinking to play more central and thus "active" role in the demand response schemes while in the latter the intent was to enable their customers to join flexibility markets by providing a gateway for them to connect with commercial aggregators. In addition to companies interested in becoming sub-aggregators we had one already established and seasoned commercial aggregator, e2m, which is German based but acquired by the French EDF during the project. In Figure 1 below, the key project partners are mapped in the DR value chain. The research was led by VTT Technical Research Centre of Finland and valuable support for the project was received also from the Finnish TSO - Fingrid.

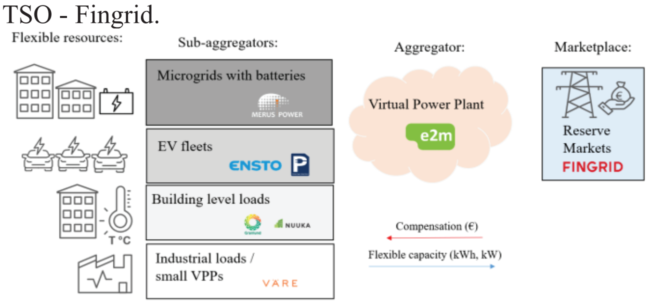


**Figure 1. Participating companies in the project mapped in DR value chain.** ***Modified from [3]***

On the edges in Figure 1 there are the demand and supply for DR and in the middle the actors that enable them to connect. Also presented in the figure are the project partners who had important role in defining the key elements for the proposed business model. [3]

### *3.1 Sub-aggregator business models*

The companies included in this study had varying reasons to become involved in demand response and adopt the role of sub-aggregator. Some wanted to provide the opportunity to commercialise their flexible capacity for their customers while others wanted to become active on electricity markets themselves. In the former case the company would do no more than open the interfaces for the remote monitoring and controlling for their customers and a third party e.g. aggregator, while in the latter case their goal would be to utilize those capabilities themselves and manage the entity as a virtual power plant. Naturally their business models would look completely different from each other.



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The role of sub-aggregator is quite essential for cost-efficient demand response since most of the initial costs for harnessing new flexibility goes in the hardware needed to gain monitoring and controlling capabilities. However, the aggregator business requires much more than the physical connections to the flexible resources. In order to successfully operate a virtual power plant consisting of several distributed energy resources one needs to have dedicated software for that, and proper understanding of both ends connected to that, i.e. flexible resources and electricity markets. It is by no means self-evident how flexibility is harnessed from the electricity consuming process or which market is the most suitable for the harnessed flexibility.

Fair and sustainable business model for demand response scheme should reflect the cost of the operation as well as the risks included. The costs include investment costs for the hardware and software as well as the operational costs e.g. personnel costs for the contract making. Risks include market risk from not being able to deliver and risk associated with harm that the resource owner might feel if flexibility activations are not well planned or executed.

*3.2 Roles and Responsibilities*

Operating on flexibility markets requires certain tasks from participating actors, such as pre-qualification of the individual energy resources in order to validate their performance according to technical requirements of the market. Some tasks need to be carried out only once, but others need to be conducted every time flexibility is offered to the market. Tasks related to utilizing flexibility is divided here into *market processes* and *energy resource processes.*

*Market processes* include all tasks related to markets, such as pre-qualification, multimarket optimization, bidding, verification and so on. *Energy resource processes* include tasks related to monitoring and controlling of flexibility resources and end-user engagement. In Figure 2 an example of demand response scheme is presented where the needed information flow between needed actors is shown.

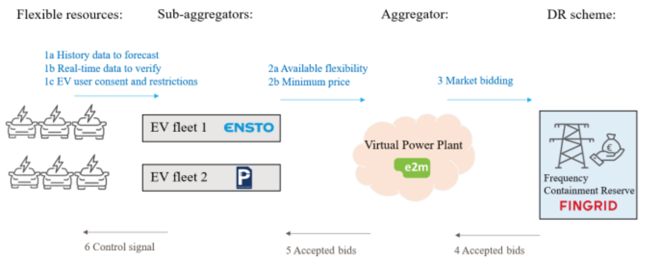


**Figure 2. Information flow of a demand response scheme between actors when operation on frequency regulation markets.** ***Modified from [3]***

In the Figure 2 above, the roles are divided so that EV fleet operators, i.e. sub-aggregators, have the responsibility for the *energy resource process* and Virtual Power Plant operator, i.e. aggregator, has the responsibility for *market process*.

*3.3 Value sharing between aggregator and sub-aggregator*

The sub-aggregator concept assumes that the costs for harnessing flexibility can significantly be reduced by using existing monitoring and controlling capabilities compared to situation where a commercial aggregator installs additional hardware on-site. Using existing interfaces enables smaller units to participate in demand response since managing a virtual power plant, at least ideally, can be fully automated which means the operating costs are not increased when new units are introduced to the pool.

The division of income from flexibility markets between aggregator and sub-aggregator should reflect the total effort that is put in play. In addition, a proper weight should be placed on the risks that result in operating in flexibility markets. For example, if the flexible capacity that is accepted on frequency regulation fails to deliver, a fine need to be paid. It should be clearly defined in the contract who is responsible for example if the failure is due to a communication connection failure or if the energy resource breaks down.

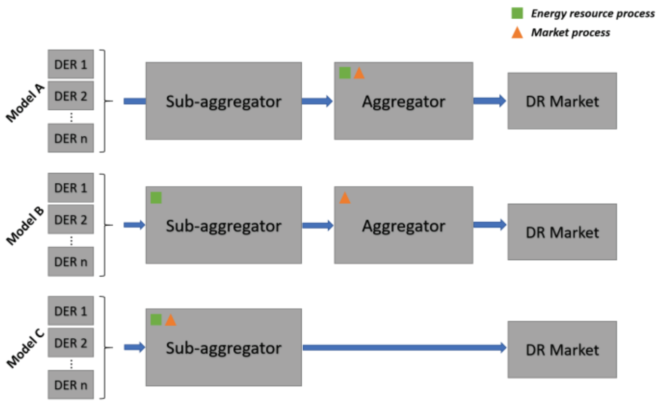


**Figure 3. Proposed business models for aggregator and sub-aggregator**

In Figure 3, three business models are presented, leading to the following proposed value sharing model. In model A, the sub-aggregator is totally passive meaning it acts only as a gateway between the end-users and the aggregator. This might be beneficial for the sub-aggregator even if it misses its shares from the DR actions. Only by enabling participation to DR markets for their customers, a sub-aggregator improves its service offering among its competitors. Passive sub-aggregator is responsible only for maintaining the communication connections and so a fixed fee for that might be proper compensation for it in this model.

In model B, the sub-aggregator has a more active role in the DR scheme. It is responsible for the energy resource process while the commercial aggregator is used to manage the market processes. This might be the most natural division of responsibilities, as both are now covering the part of DR scheme that is better known to them. It is not possible for us



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to propose any general division of the DR income between sub-aggregator and aggregator in this kind of model since the applications where the flexibility is harnessed vary so much. However, during the project it became clear that the most challenging part was to forecast the available flexible capacity and so perhaps most of the compensation should be appointed to one responsible for that.

In model C, the sub-aggregator alone governs a large enough portfolio of flexible resources and goes to the market without a third-party aggregator. This way it gets 100% of the aggregation income but is also responsible for the whole DR scheme. This model might be more common in the future when sub-aggregators mature in this business and assisting tools, such as virtual power plants as a service (VPPaaS) develop and become more available.

Business models presented here are still a novelty and taking shape as more experience is gained by all participants. In addition to concrete tasks, there are also immeasurable responsibilities related to flexibility trading for which no static value can be appointed to. These include for example forecasting the flexible capacity, which might be relatively easy if the flexible resources behave predictably but very challenging if the behaviour is stochastic as it is to some extent with electric vehicles.

## 4 Conclusions

Sub-aggregators are a gateway to masses of flexibility, but so far, their participation into electricity or flexibility markets is hindered by the lack of lucrative business models. Aggregators are willing to include the flexible capacity provided by sub-aggregators to their portfolio, but research is needed to find sustainable business models where risk and reward are balanced for all participants.

The research on potential sources of flexible capacity typically focuses in specific fields of industry and tries to answer 'where' to find new sources. In this research the focus was on the concept of utilizing sub-aggregators' interfaces to harness large numbers of DERs without initial investments and thus answering the question of 'how'. Typically, a sub-aggregator already has monitoring and control capabilities for its resources based on other needs, for instance maintenance or remote management purposes. This way the needed capabilities in remote monitoring and controlling the devices is not built for flexibility purposes only, promoting cost-efficiency.

Sub-aggregator in general is someone who has the ability to monitor and control DERs with low, or zero, investment cost and it is a role to be adopted on top of company's primary business, e.g.

- Charging Point Operator for Electric Vehicles
- Home Automation System Providers
- Hardware manufacturers (air conditioners, freezers, hot water tanks etc.)
- Microgrid System Operators (for energy communities, smart factories etc.)
- Industrial consumers (paper mills, chemical factories, metal industry)

In this paper, we have first defined the main characteristics that are general for all sub-aggregators. We then pointed out the differences that we found between the sub-aggregators participating in this research, highlighting the great variety of primary businesses these actors might have. In the end we concluded that utilizing existing interfaces to flexible assets provided by sub-aggregators would minimize the investments needed in harnessing the flexible potential. More research should be focused on finding the technical capabilities of these existing interfaces to ensure they are reliable, secure and safe to use in demand response.

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