Smart Grids and Aggregators

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About Me

- Professor, Information Systems
- Research on smart cities, smart energy systems, emerging business models, sustainability.
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Most of this keynote is based on a book chapter from the book Sustainable Smart Cities – A Vision for Tomorrow (2023).

The Role of Aggregators in Smart Grids
Lasse Berntzen and Qian Meng

https://www.intechopen.com/chapters/83490

Background

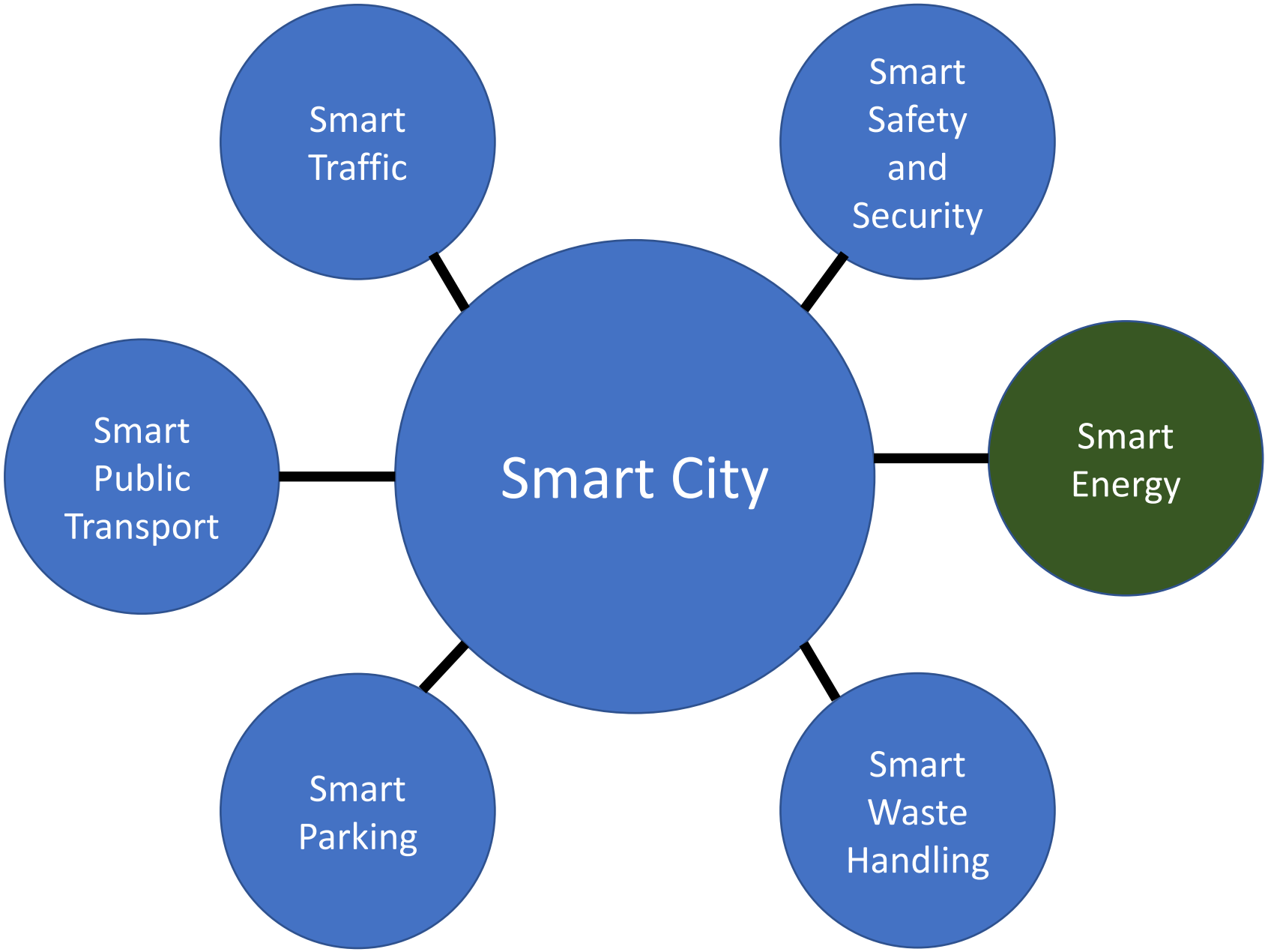
University of South-Eastern Norway have been partner in two European projects where we have worked on renewable energy and the role of the aggregator in the smart grid

- Smart MLA (Multi-Layer Aggregator)
  - Era-Net Smargrid+
  - 2018-2022
- Cloud-based analysis and diagnosis platform for photovoltaic (PV) prosumers
  - Manu-net
    2021-2022

Smart Multi-Layer Aggregator

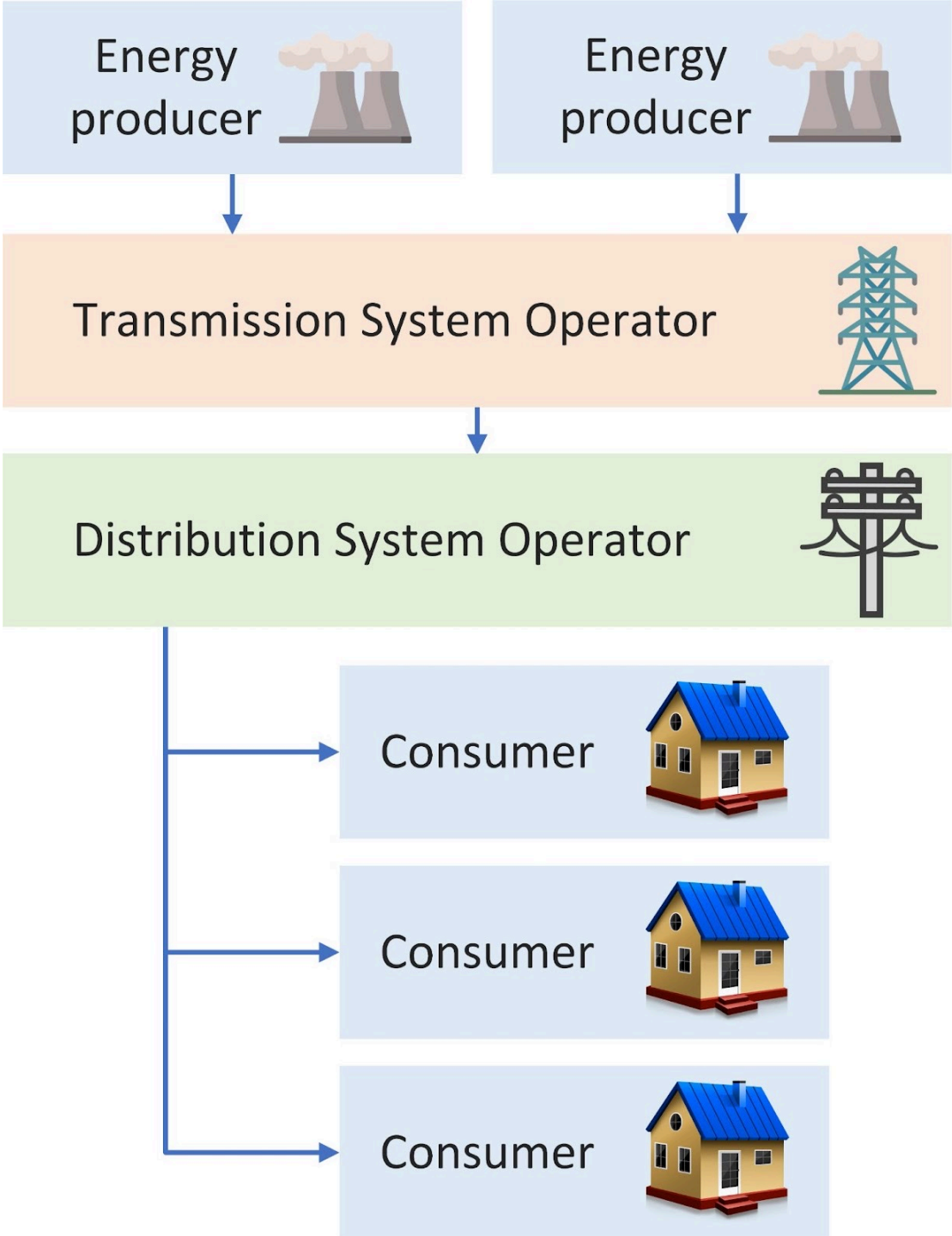
- ERA-NET project with with partners from Denmark, Norway, Romania, Sweden, and Turkey
- Period: November 2018 – January 2022
- Scope: Develop cloud-based multi-layer aggregator ICT solutions to facilitate optimum demand response (DR) and grid flexibility to energy systems to utilize up to 100% renewable energy.
- The project includes investigating possible business models for **aggregators** and **prosumers**.

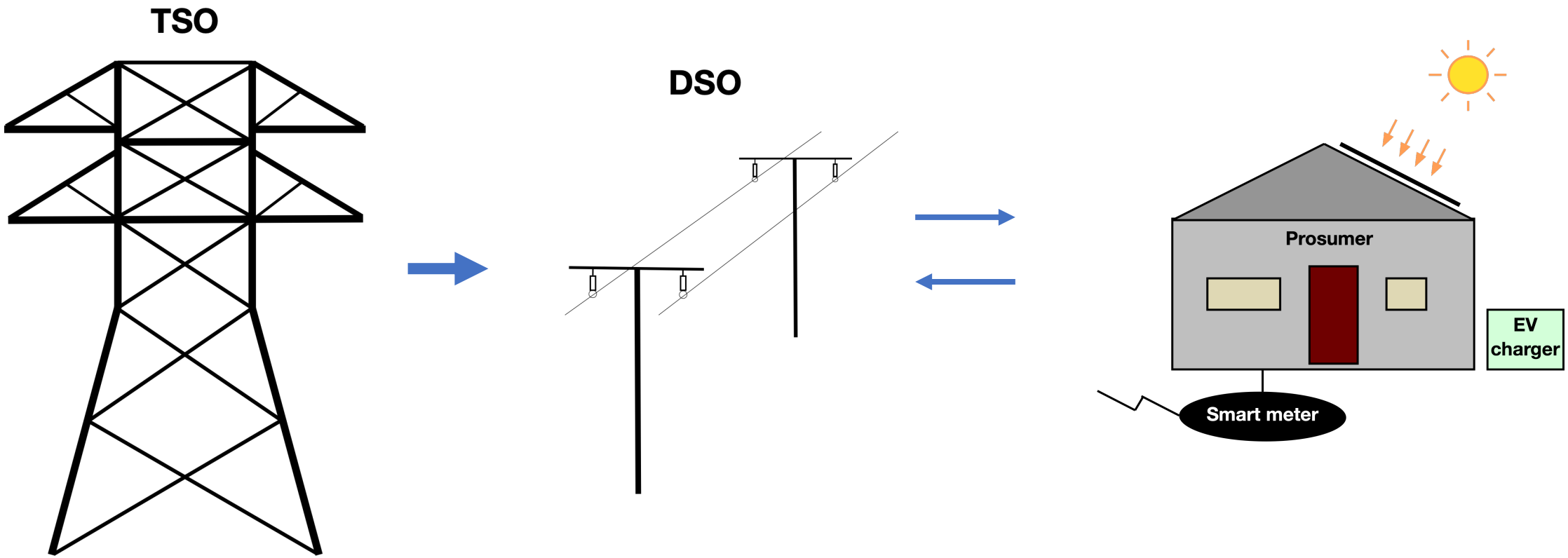
Smart City


Smart Traffic
Smart Safety and Security
Smart Public Transport
Smart City
Smart Energy
Smart Parking
Smart Waste Handling

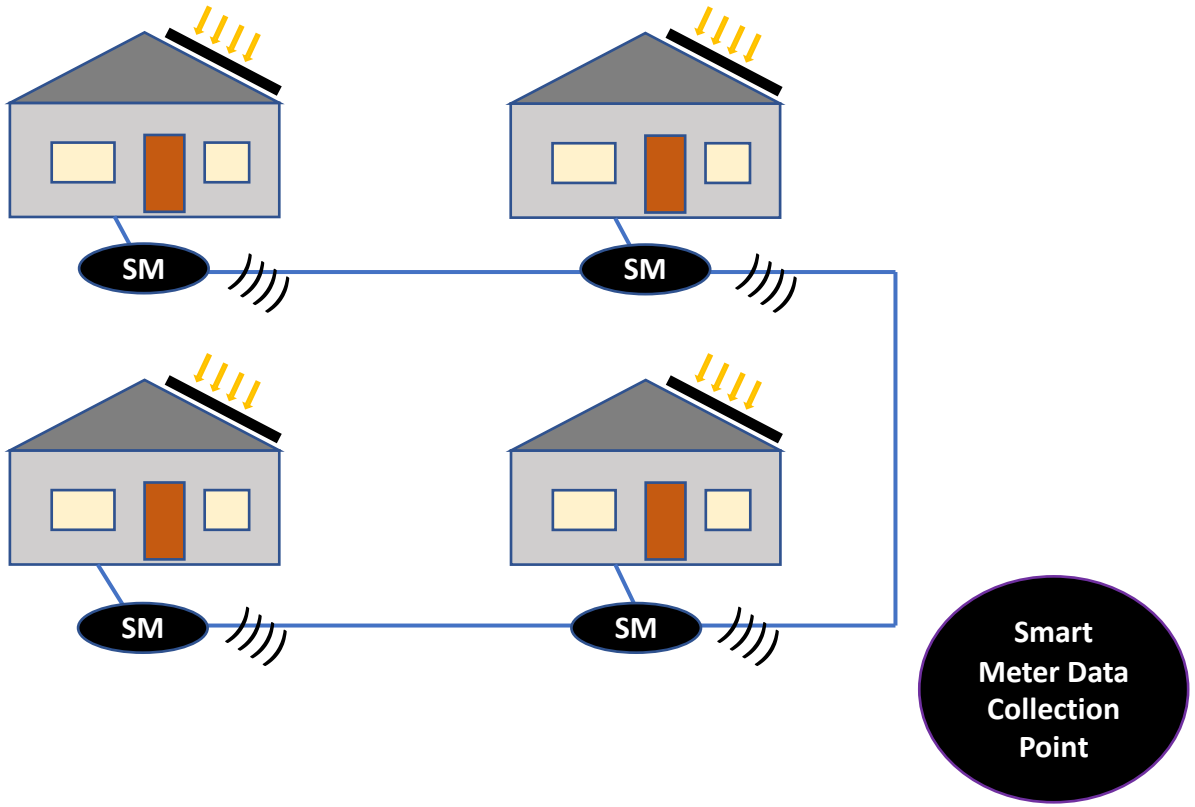
The Consumer

- Traditional model
- Buys energy from the grid
- Deregulated market (since 1991)
- Two components:
  - Consumed power
  - Infrastructure (grid)





The Smart Grid



The Smart Grid

FLEXIBILITY

The Importance of Flexibility

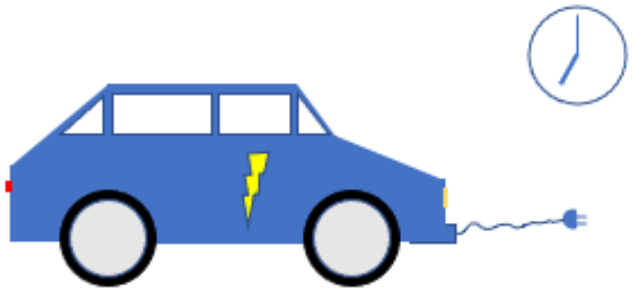
Flexibility

- Flexibility is important.
  - Delay or avoid infrastructure investments
  - Stabilize grid operations
- What are the barriers from the prosumer side?
  - Lack of trust in the energy market actors

Marius Rohde Johannessen, Lasse Berntzen, Boban Vesin, Qian Meng, Thomas Brekke, and Inessa Laur
User Sentiments Towards Smart Grid Flexibility - A survey of early adopters' attitude towards allowing third parties to control electricity use in households
CENTRIC 2021, The Fourteenth International Conference on Advances in Human-oriented and Personalized Mechanisms, Technologies, and Services
https://www.thinkmind.org/index.php?view=article&articleid=centric

Introduction

- Flexibility can be transferred to an aggregator.
- The customer can define some constraints:
  - The electric vehicle should be fully charged at 7 am
  - The temperature should not get below 16^{O}C
  - The water in the water heater should be above 70^{O}C



- The aggregator can then use algorithms to decide when to turn appliances on and off to fulfill the constraints, while getting the most beneficial rates from the energy market.
- The flexibility is essential for grid management since it can reduce the chances of overloading the grid and delay investments in upgraded electric power infrastructure.

The customer is rewarded for giving up control, either by favorable pricing or a discount on the electricity bill.

Load Shifting and Peak Shaving

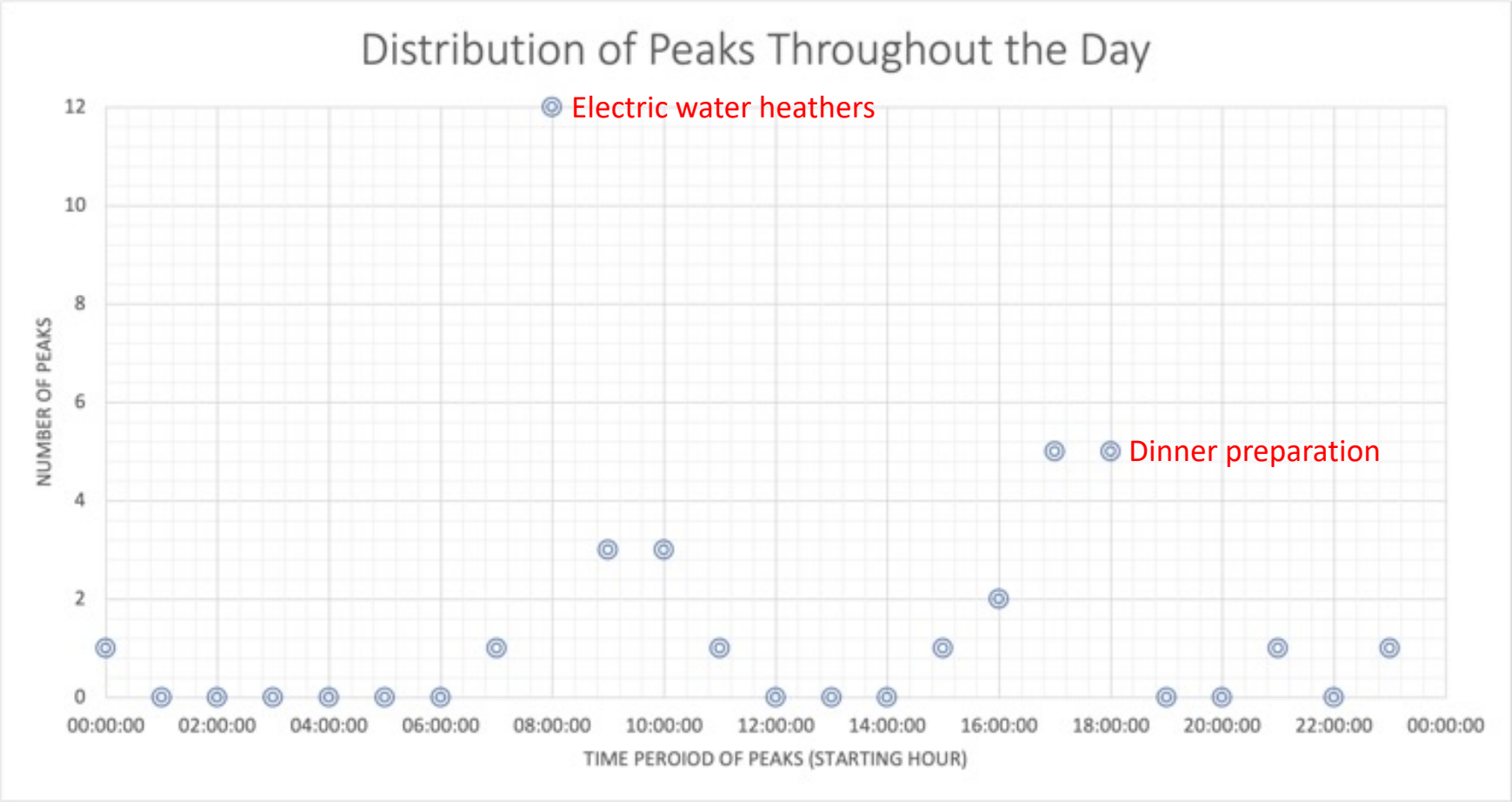
Load shifting and peak shaving are two important techniques to improve energy use.

The consumption of electricity varies throughout the day.

Load Shifting and Peak Shaving

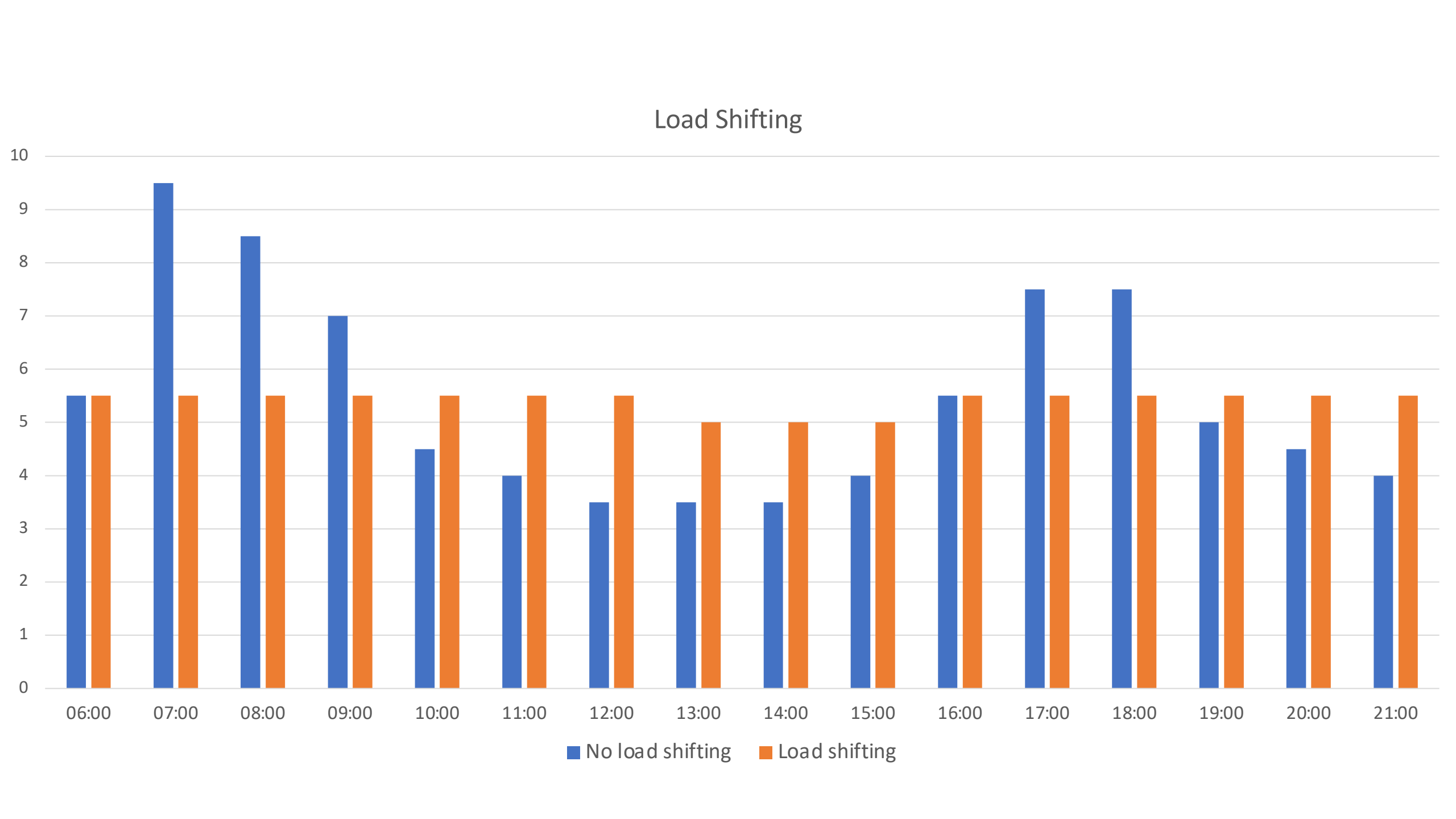
- In Norway, we have one peak in the morning and one in the afternoon.
  - The peak in the morning is mainly caused by electric water heaters kicking in after morning showers.
  - The afternoon peak happens when most are coming home from work, cooking dinner, etc.

Energy Consumption Peaks



Load Shifting and Peak Shaving

- Load shifting can simply be explained as moving the load to other time periods.
- One example is to spread the load from water heaters
- Another example is to charge electric vehicles during the night.

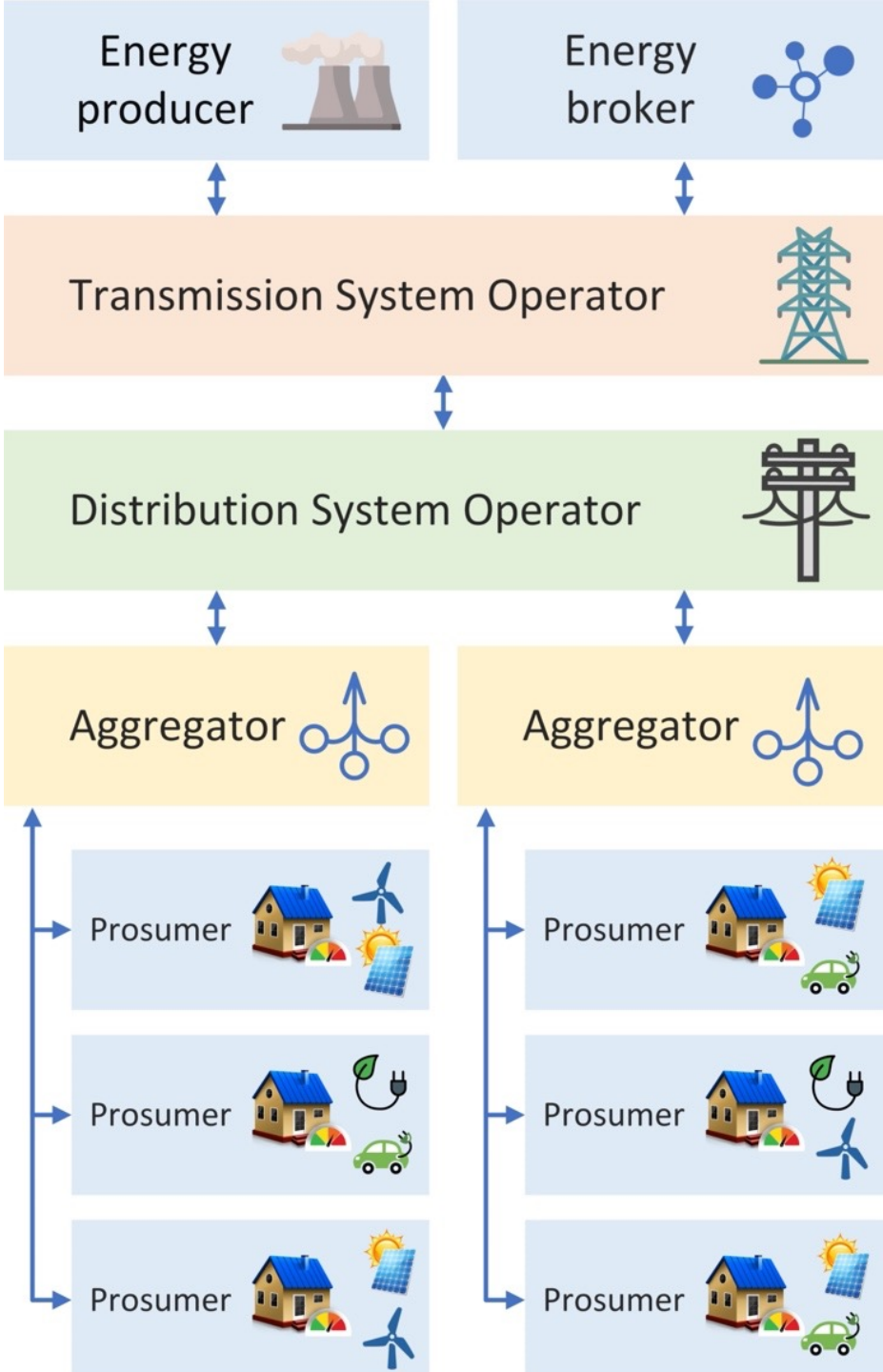

Load Shifting
10
9
8
7
6
5
4
3
2
1
0
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
No load shifting
Load shifting

Load Shifting and Peak Shaving

- Peak shaving has to do with storage. If electricity can be stored somewhere in the facilities, this stored energy can be used to shave the peaks.
- Tesla has introduced its power wall as a household battery storage system.
- Storage can also be centralized (will get back to that).
- Load shifting and peak shaving are important since the grid needs to be dimensioned to handle the peaks.

The Prosumer

- Emerging
- Both producer and consumer
- Mostly photovoltaic (solar), but some geothermal and wind
- Renewable energy sources
- Can sell to the grid



Business Model

Identifies product or services to sell, target market, and anticipated expenses.

Prosumers have changed:				
value propositions	revenue models	market opportunities	competitive advantages	strategies

The Prosumer

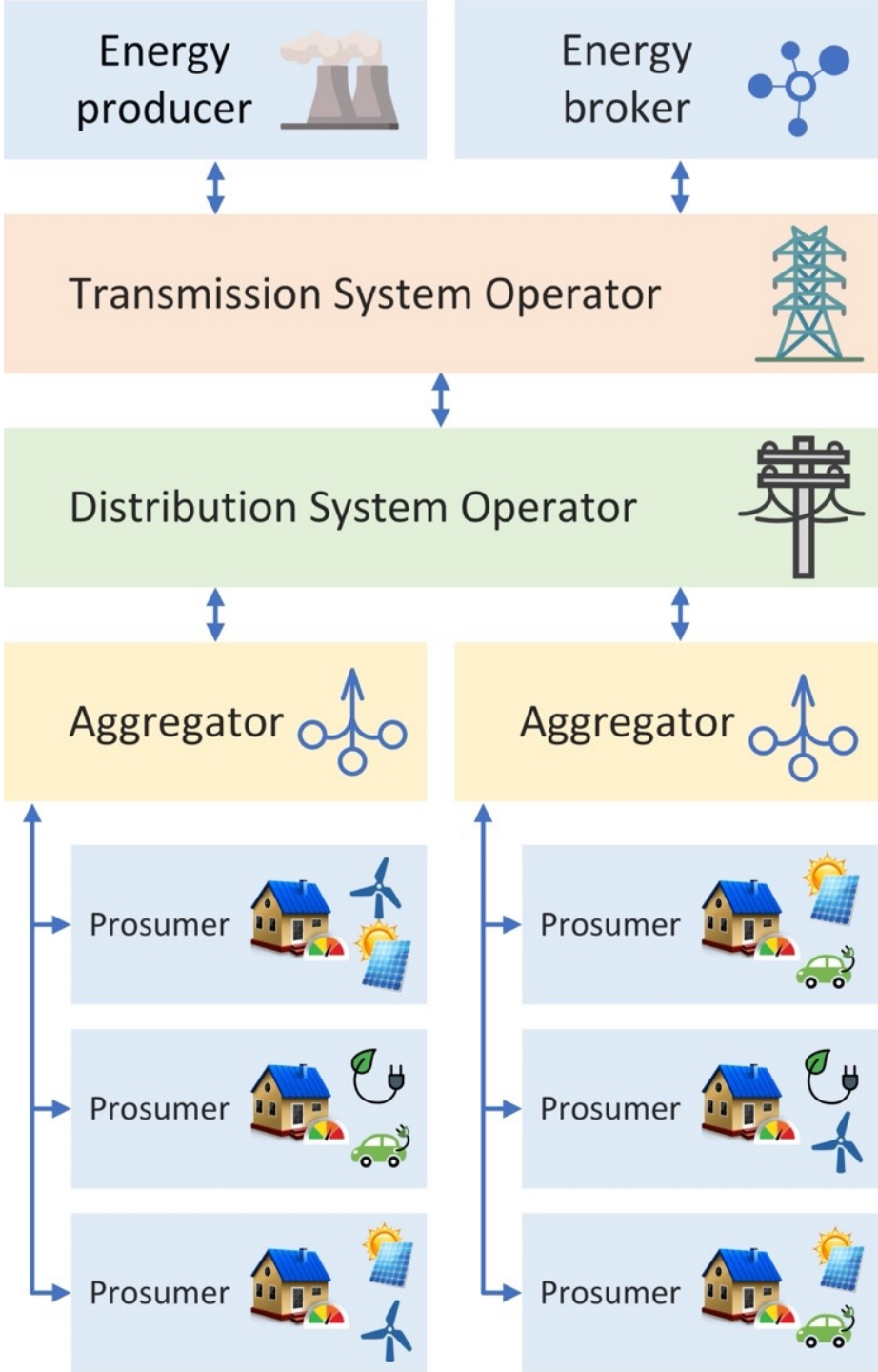
- A prosumer can produce and sell surplus energy in the energy market.
- In Norway, a prosumer can sign an agreement (energy customer plus agreement) with an energy provider.
- The distribution system operator is obliged to facilitate energy transfer to and from the customer.
- The prosumer cannot produce more than 100 kW per hour in Norway. If production exceeds this limit, the prosumer must seek a license as an energy producer.
- The tariffs for selling energy to the market are generally not beneficial.
- A prosumer will seek to use its own produced energy before selling to the market.

The Aggregator

- To facilitate collaboration among a group of prosumers, an aggregator is necessary.
- The EU 2019/944 Electricity Directive defines aggregation as a “function performed by a natural or legal person who combines multiple customer loads or generated electricity for sale, purchase, or auction in any electricity market”.

The Aggregator

- The aggregator operates on behalf of prosumers.
- Negotiates with energy brokers and distribution system operators.
- Market power.
- Create value for the prosumers, create profit.
- Can also create an internal market.

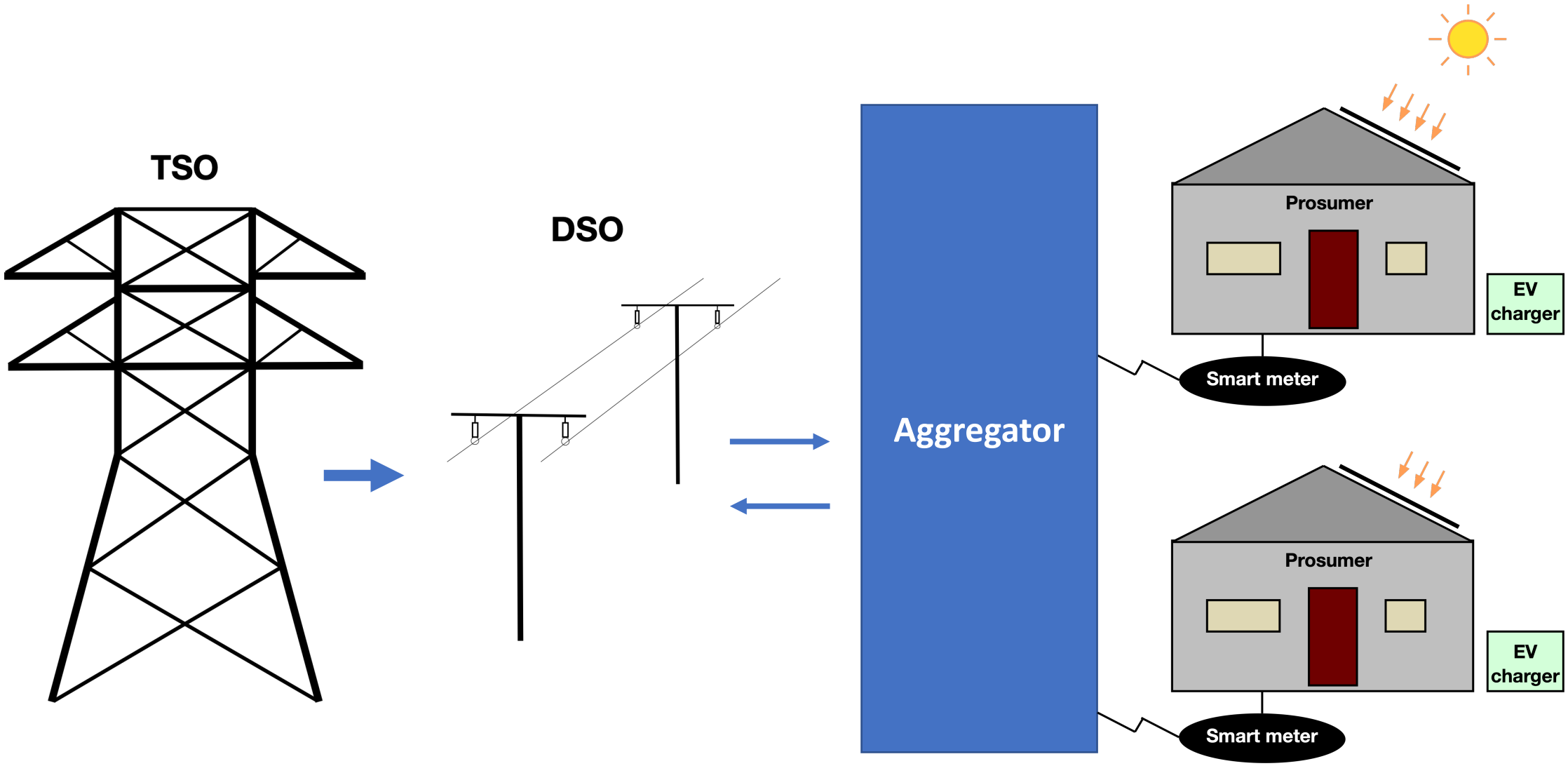


The Aggregator

- As the number of prosumers grows, the business opportunities for a new energy ecosystem actor, the aggregator, emerge.
- As earlier mentioned, flexibility may be important to shift or shave peaks caused by differences in consumption during the day.
- The aggregator is a business entity that can aggregate energy from a group of prosumers.
- A higher volume benefits the aggregator when negotiating with the distribution system operators and energy providers.
- The aggregator can also provide services, such as settlements, etc.

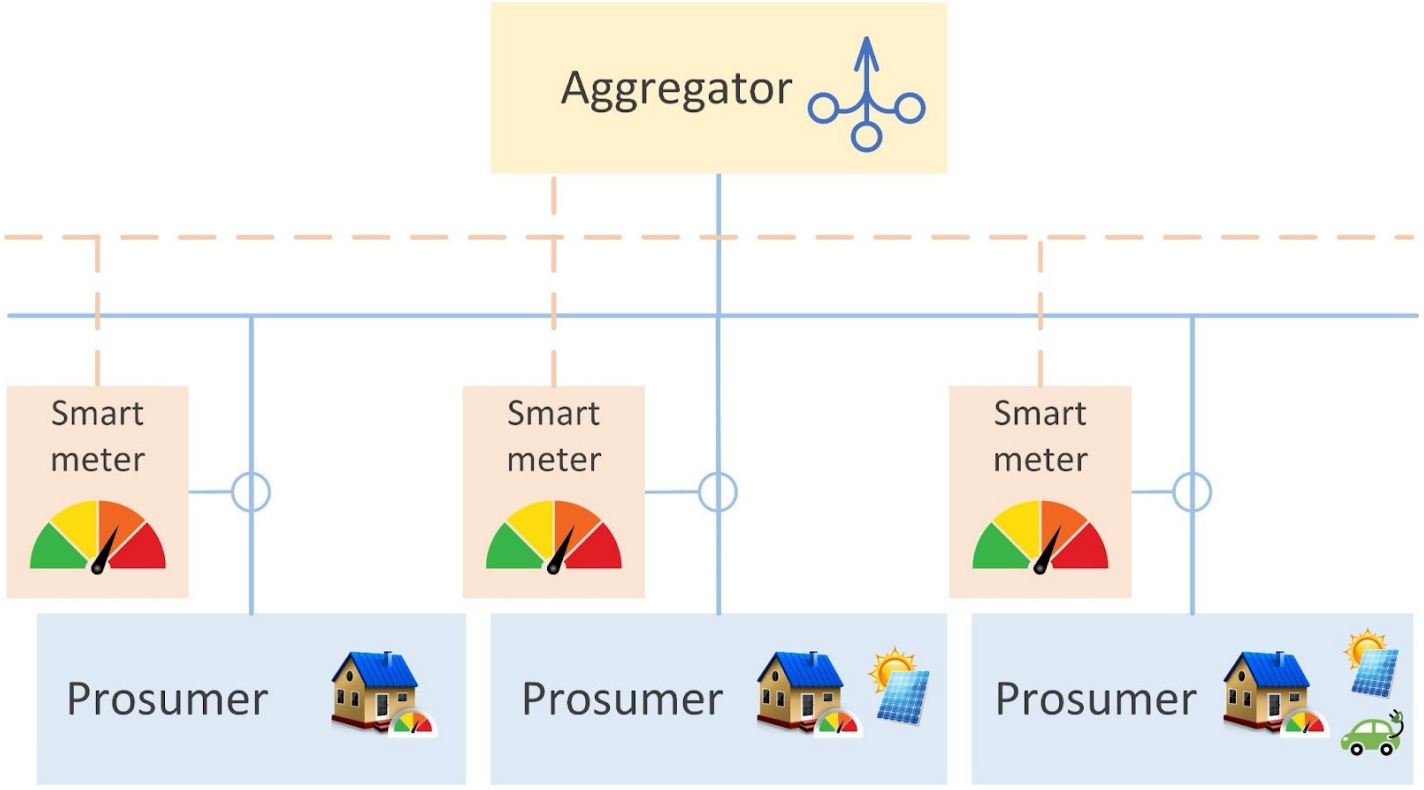
Aggregator Business Model

- Demand-side response (industrial and commercial customers adjust to signals from the distribution system operator).
- Residential customers (prosumers) have not received the same interest (due to low production).
- The aggregator plays an important role to organize individual prosumers into one entity that can trade flexibility and negotiate tariffs.


TSO
DSO
Aggregator
Prosumer
EV charger
Smart meter
Prosumer
EV charger
Smart meter

Virtual Power Plant

- The aggreagtor may take the role as a virtual power plant.
- Smart meters are essential for tracking production and consumption by individual prosumers



Business Opportunities

1) Energy efficiency services provider
2) Information value-added services provider
3) Integrated energy services provider
4) Extended services provider for zero-emission

Energy Efficiency Services Provider

The aggregator offers the customers an energy-saving plan by installing high efficiency equipment.

The aggregator can monitor and control the equipment to participate in the demand response in the power market.

E.g., at the peak of the power consumption, the aggregator helps users to reduce their demand and consume electricity later when the power price is low.

Information Value-added Services Provider

The aggregator provides their consumers a value-added service through IoT and big data technologies that provide data and analysis for real-time electricity prices, electricity demand and consumption at a household, and power distributed generation nearby.

Then the prosumers can take control of their electricity consumption in real-time and decide when to sell their own generated power at a peak in the grid.

Integrated Energy Services Provider

- With the demand for green transition and access to various smart terminals like electric vehicles, charging stations, smart home appliances, and distributed energy generation, the aggregator can develop the business to cooperate with other service suppliers (like heating) to deliver integrated energy services, optimize the integrated energy solution to maximize the benefit for the users.
- With many assets and a wide range of businesses, the aggregator may behave in the dual role of an energy supplier and an energy service provider.

Extended Services Provider for Zero-emission

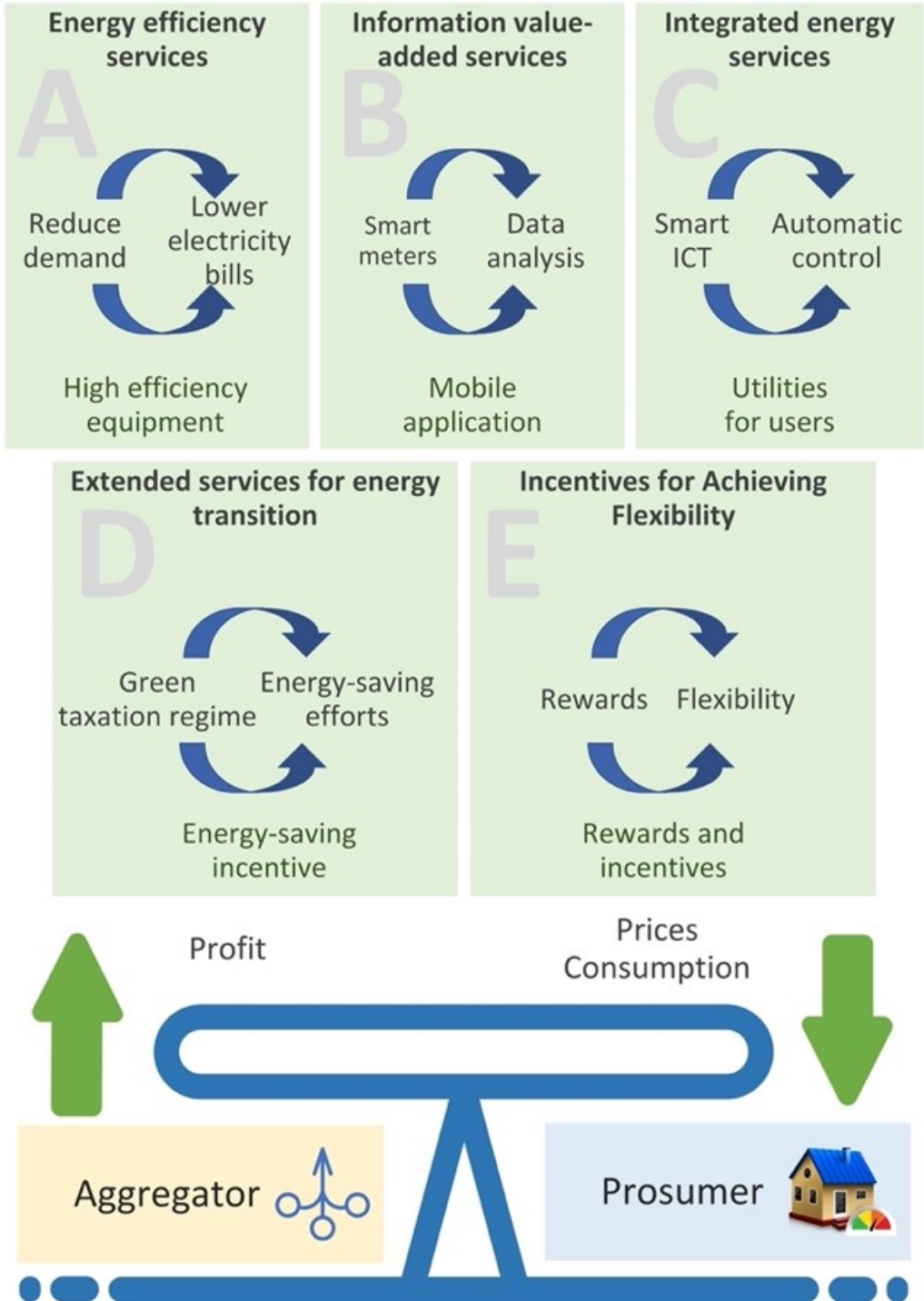
- For the EU zero-emission target, many countries have implemented policies and measures to replace fossil fuel cars with electric cars.
- In practice, Norway's electric vehicle policy has proven effective by reducing taxes and fees for electric vehicles while fossil fuel cars are heavily taxed.
- Thus electric vehicles have become much cheaper than fossil fuel cars.

Extended Services Provider for Zero-emission

- As a result, by the end of 2021, there were 460,734 electric cars registered among a total of 2,893,987 private passenger cars.
- This clearly shows how incentives shape consumer choice by a combination of taxes and rewards.
- The aggregator can then expand their customer channels through cooperation with the electrical vehicle sellers and benefit prosumers with their energy-saving, information, and integrated energy services.

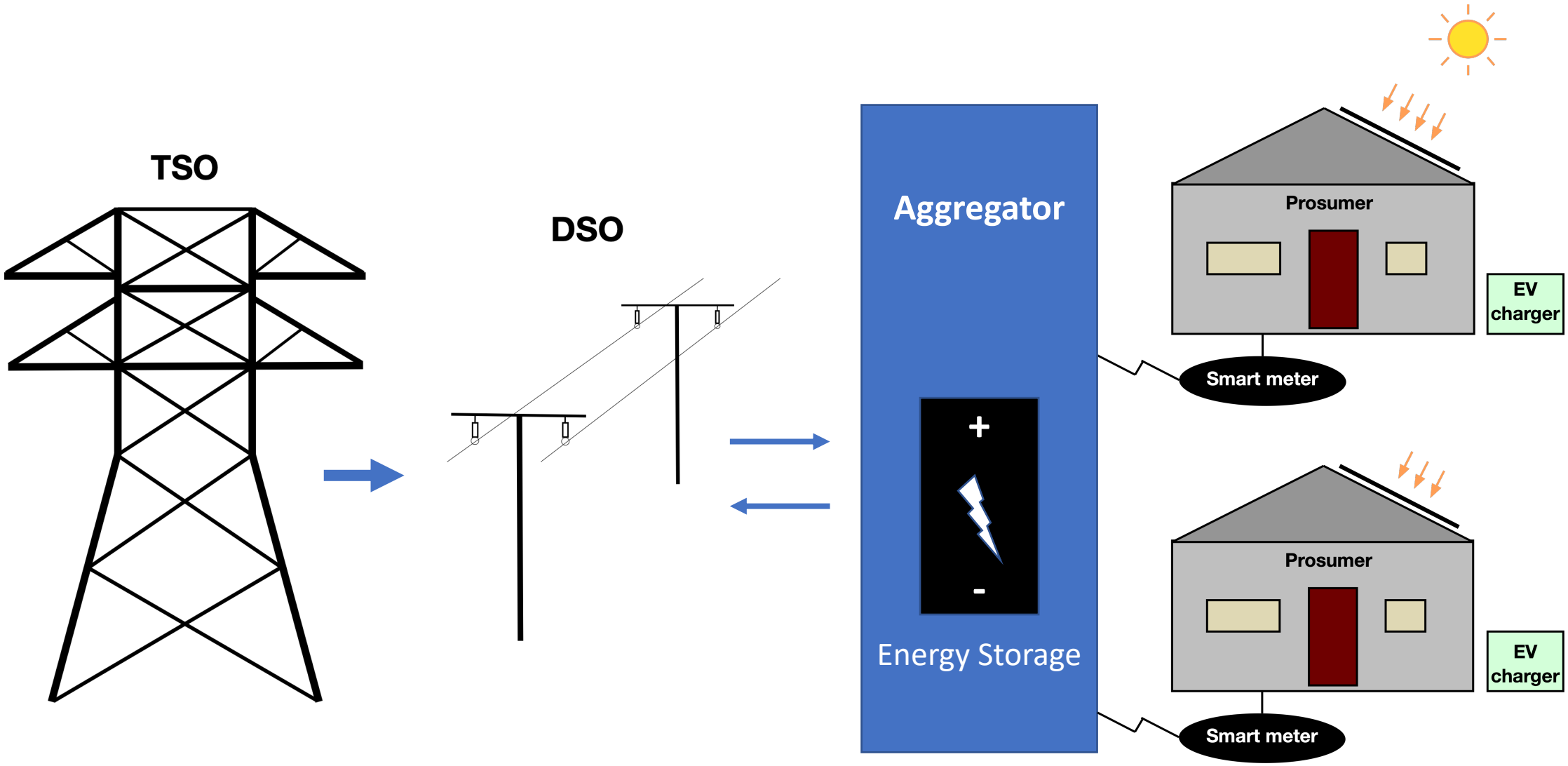
Aggregator Business Models

- Energy efficiency services
  - Profit sharing, subscription, smart home
- Information value-added services
  - Inform the prosumers, profit from big data
- Integrated energy services
  - Combine different energy sources
- Extended services for energy transition
  - Reduce energy consumption by better insulation etc.
- **Incentives for achieving flexibility**
  - **Monetary, non-monetary**



The Aggregator as a Storage Provider

- In the smart grid, the intermittent and random output of solar energy has brought challenges to the balance of demand, supply, and grid stability.
- As to prosumers, solar energy is stored for self-consumption in most cases.
- While from the perspective of energy efficiency and management efficiency, storing energy by the aggregator will be a more feasible solution.


TSO
DSO
Aggregator
+
-
Energy Storage
Prosumer
EV charger
Smart meter
Prosumer
EV charger
Smart meter

The Aggregator as a Storage Provider

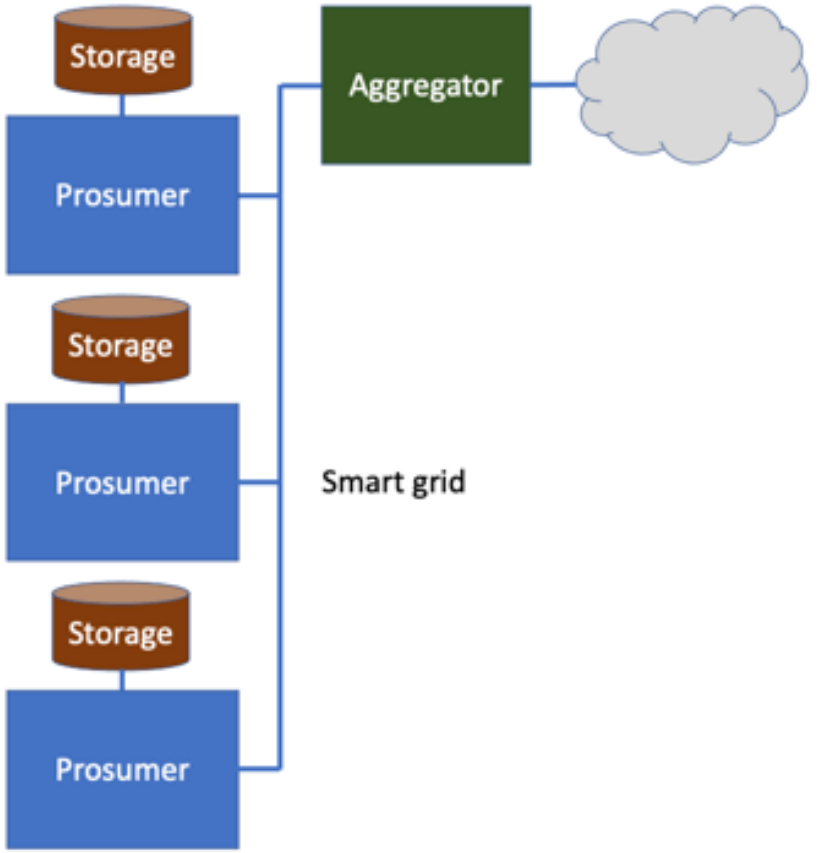
- In storage service, prosumers store energy mostly for self-consumption.
- Even if they make a profit out of the outrage of storing produced energy in the battery and selling energy at peak time to maximize their own profit, this could be inefficient when taking many prosumers as a system.
- Scale effect also works with aggregation of many prosumers than respectively.
- For prosumers, it is not only the cost of batteries but also the additional hardware to handle the charging and discharging of the batteries and the installation cost that need to be considered when investing in battery storage.

The Aggregator as a Storage Provider

- If an aggregator supplies a storage service, the aggregator could use a larger facility and not be overly concerned about the compactness of the installation.
- In addition to achieving the outrage goal, aggregators storing electricity is also a key mechanism for supplying electricity reliably, increasing security and economic value, and decreasing carbon dioxide emissions.
- Aggregator storage also plays a significant role in keeping a balance between supply and demand, avoiding electric fluctuations, contributing to the stability of the low voltage DSO grid, and making the DSO grid system more efficient, especially for the weak low voltage grid in Norway.

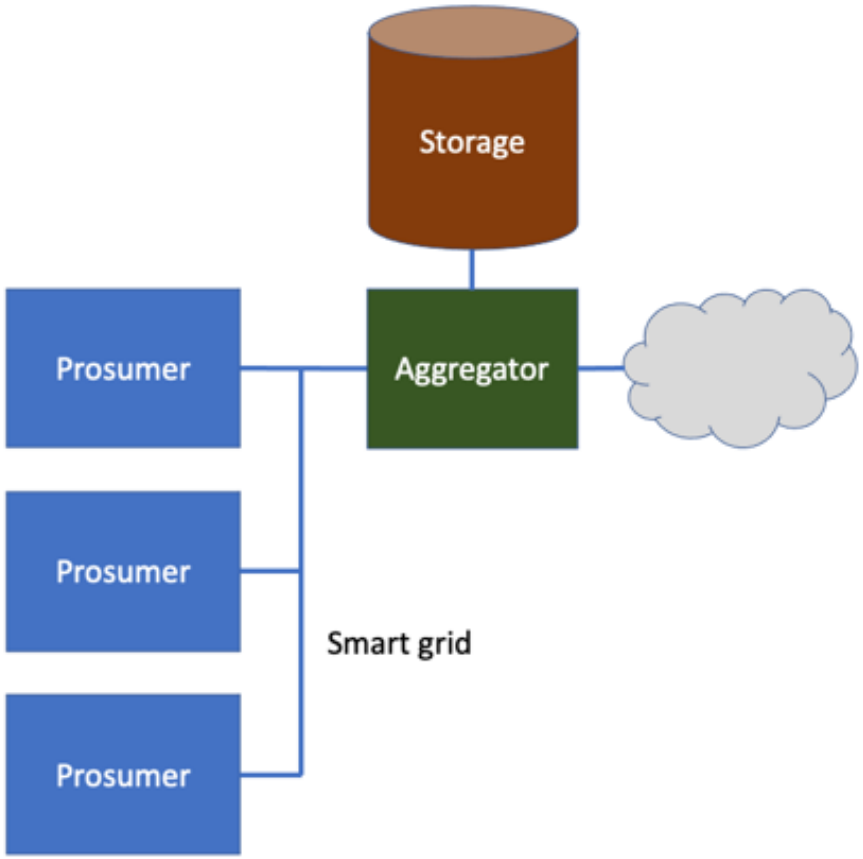
Prosumer Energy Storage

- Using batteries to shave peaks.
- Tesla Powerwall
- 50% for packaging and control system



Aggregator Energy Storage

- Assumption: It is better to have one large battery maintained by the aggregator than many batteries spread among the prosumers.
- Space and maintenance
- Packaging and control system
- But also improved business opportunities



Aggregator Revenue Opportunities

- To buy energy from prosumers at market price when production is available and sell it later at a higher price. The aggregator is making its revenues from the fluctuations in electricity prices throughout the day.
- To offer storage as a service to prosumers. The aggregator would provide Energy Storage as a Service (ESaaS). This would be like a Dropbox™ for electric energy. The prosumers can then choose to sell it to the market or use it for its own purposes. In this case, the aggregator gets revenues from either renting out storage or charging a subscription fee, or both.
- Bundling EaaS (energy as a service) and ESaaS. The aggregator in companions with other companies could provide a complete package of services and utilities based on specific customer demands.

Conclusions

Smart energy is an important part of smart cities. Smart cities need to be energy efficient.

The role of prosumers refers to buildings and households that can produce renewable energy.

The **aggregator** is a new role in the energy ecosystem.

Conclusions

The aggregator can represent a group of prosumers dealing with the energy market.

The aggregator may also offer additional services to help its prosumers achieve more energy efficiency.

While fulfilling the balance between the energy demand and supply, especially for load shifting and peak shaving, energy storage is an important component.

Conclusions

Prosumer storage is efficient for self-consumption mode, but from the perspective of scale effect for many prosumers, storage provided by an aggregator is more feasible and sustainable.

New business opportunities for the aggregators have been identified, and aggregators will play a significant role under the EU framework to achieve the green transition goals.

Electric vehicles will also contribute to smart traffic and smart energy when their worldwide adoption increases.

Thank you for your attention

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