FORT COLLINS 2019 SYMPOSIUM ON MICROGRIDS

Colorado State University

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INVADE

*Smart system of renewable energy storage based on **IN**tegrated E**V**s and b**A**tteries to empower mobile, **D**istributed and centralised **E**nergy storage in the distribution grid*

The Sandbakken Microgrid and the Inspiria Charging Court
Two R&D Exploitation cases

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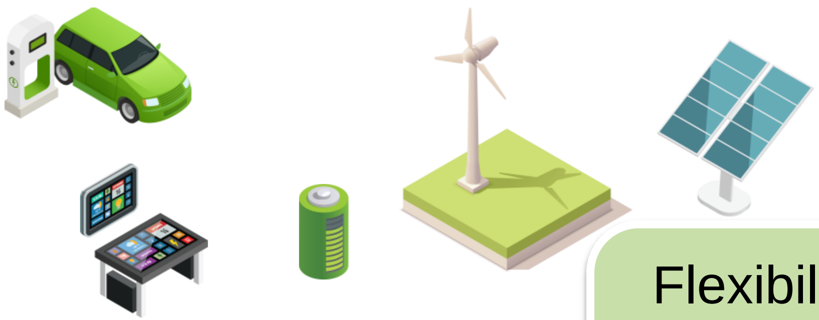
Content

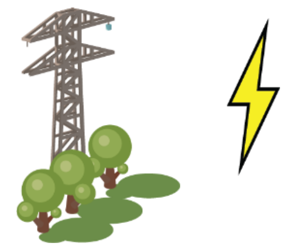
- The INVADE project & concept
- The Sandbakken Microgrid
- The Inspiria Charging Court
- Some take-aways

Market setting

Growing share of distributed energy resources

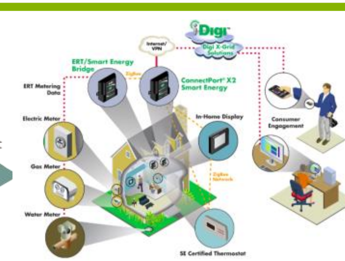


Grid challenges



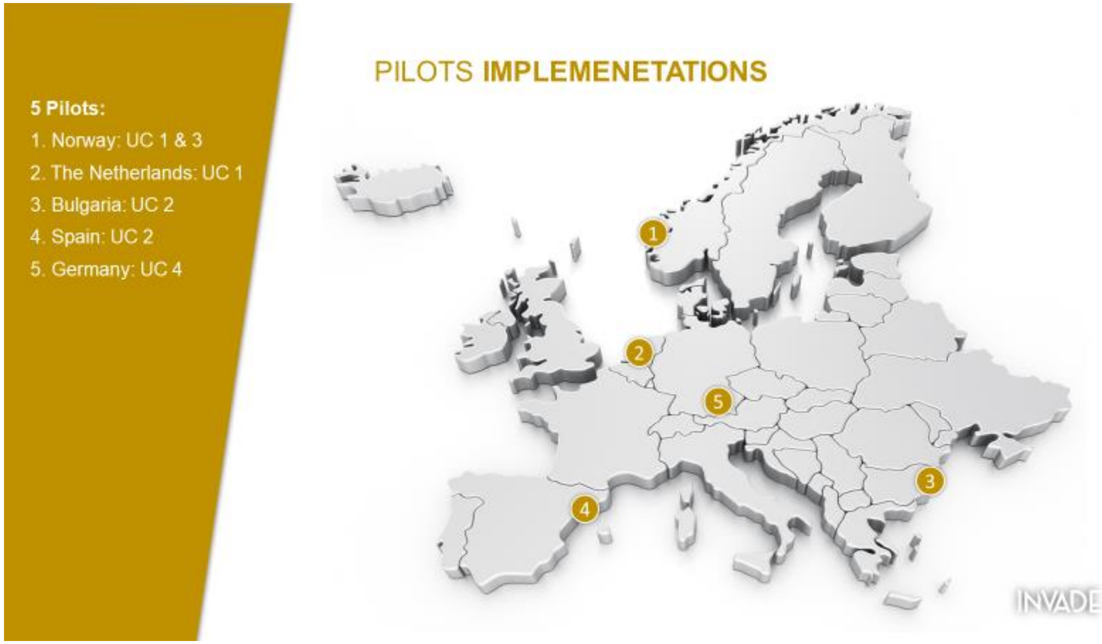
Flexibility trading as an attractive and efficient solution

Prosumers/consumers who choose to be flexible with respect to non-time dependent electricity consumption/production can help to reduce grid problems



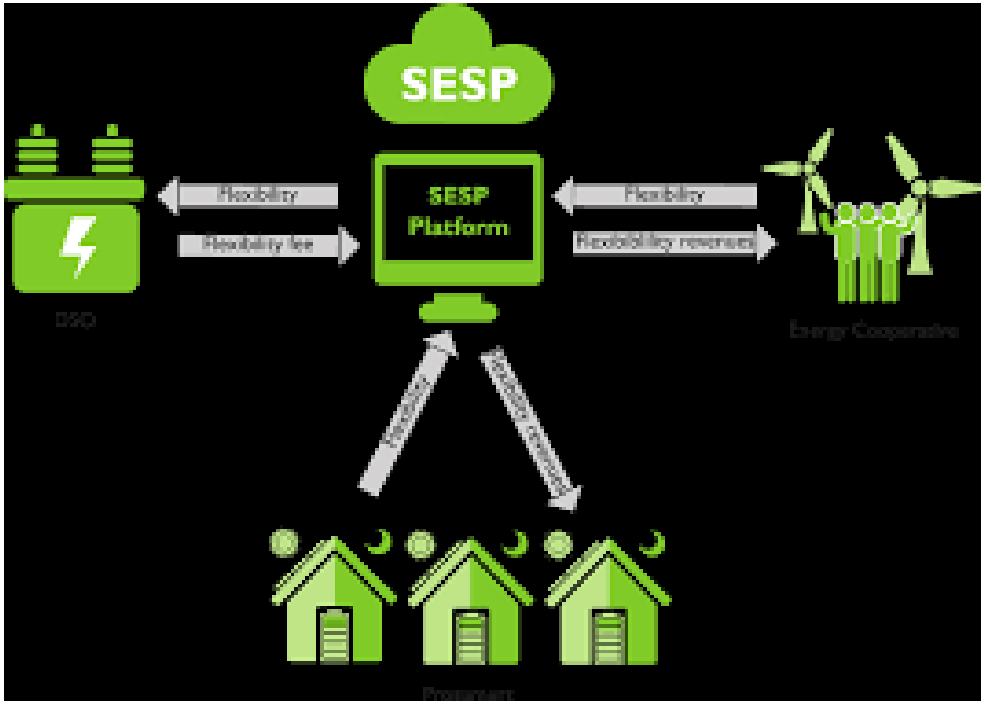
Other key drivers: changing customer behavior, energy community initiatives, advances in technological development

INVADE



The INVADE project aims to provide a **cloud-based flexibility management system integrated with EVs and batteries** empowering energy storage at **mobile, distributed and centralized levels** to increase renewables share in the smart distribution grid.

History



EMPOWER Local Electricity Retail Markets For Prosumer Smart Grid Power Services

Price incentives to consume and produce locally and to achieve local balance between supply and demand

INVADE

Consolidation of flexibility resources using price incentives for local and central power management

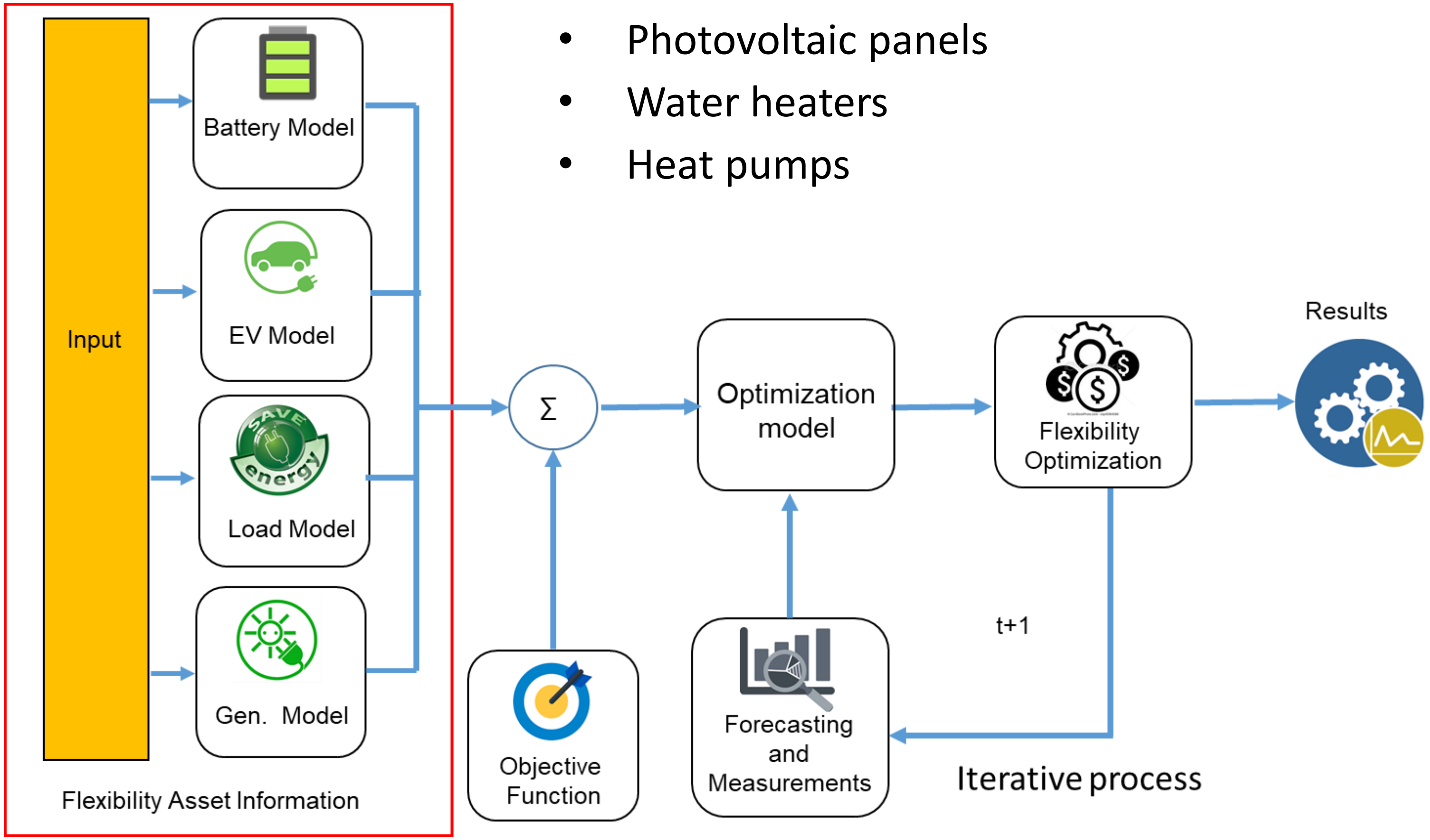
Use-Cases to be tested

Flexibility customer	Flexibility services INVADE	Description (Flexibility usage)
DSO	Congestion management	Avoiding the thermal overload of system components by reducing peak loads where failure due to overloading may occur.
	Voltage / Reactive power control	Using load flexibility by increasing the load or decreasing generation is an option to avoid exceeding the voltage limits. Voltage control is typically requested when solar PV systems generate significant amounts of electricity.
	Controlled islanding	Preventing supply interruption in a given grid section when a fault occurs in a section of the grid feeding into it
BRP	Day–ahead portfolio optimization	Shifting loads from a high-price time interval to a low-price time interval before the day-ahead market closure. It enables the BRP to reduce its overall electricity purchase costs
	Intraday portfolio optimization	Enabling value creation on intraday market, equivalent to the day-ahead market
	Self-balancing portfolio optimization	Reducing imbalance by the BRP within its portfolio to avoid imbalance charges. The BRP does not actively bid on the imbalance market using its load flexibility, but uses it within its own portfolio.
Prosumer	ToU optimization	Flexibility from high-price intervals to low-price intervals or even complete load shedding during periods with high prices.
	KWmax control	Reducing the maximum load (peak shaving) that the Prosumer consumes within a predefined duration (e.g., month, year), either through load shifting or shedding.
	Self-balancing	Value is created through the difference in the prices of buying, generating, and selling electricity (including taxation if applicable).
	Controlled islanding	during grid outages.

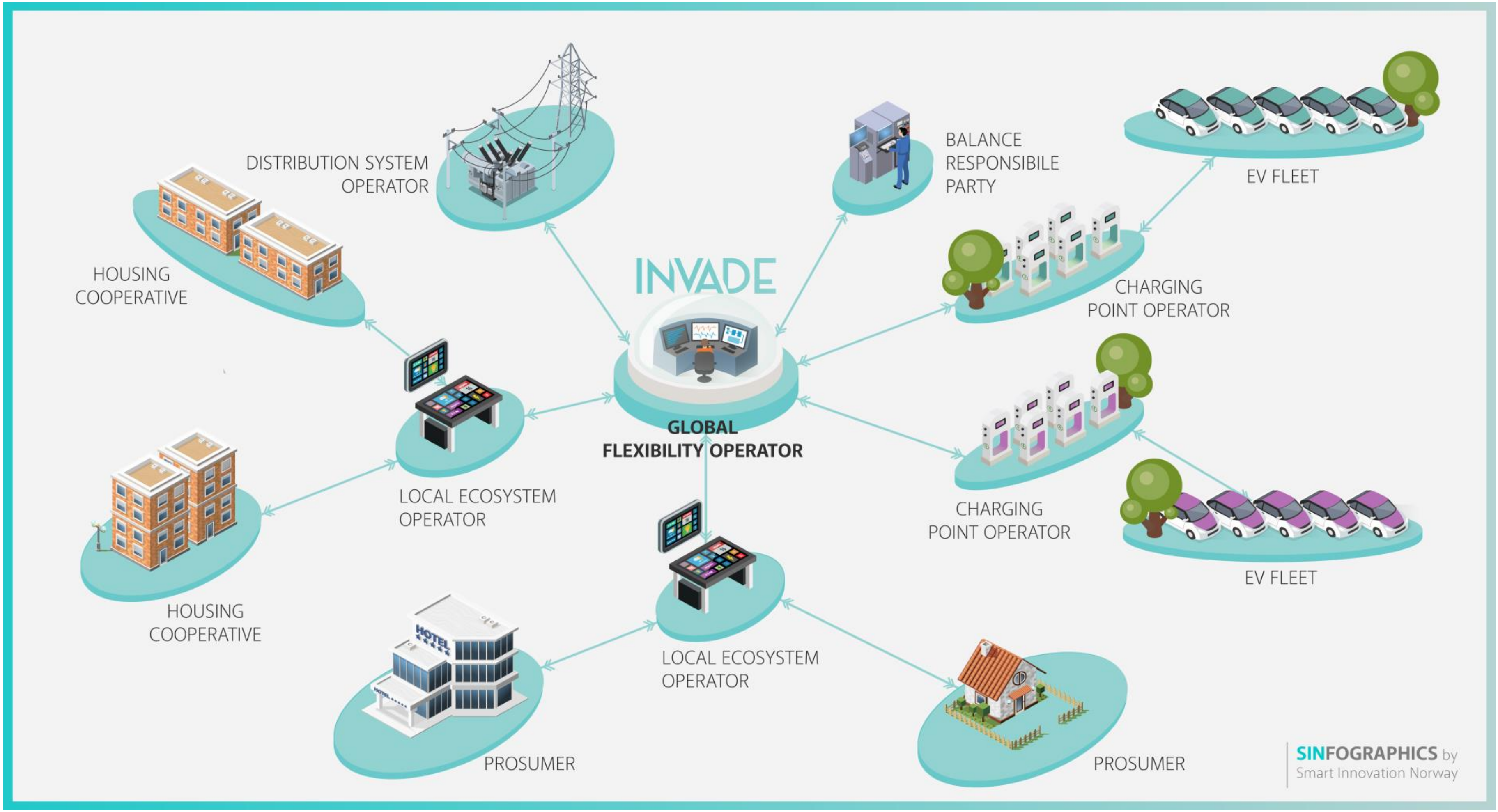
Integrated INVADE platform processes

The system will be managed by a Flexibility Operator (FO) that will control different kind of flexible devices:

- Batteries
- Electric vehicles
- Photovoltaic panels
- Water heaters
- Heat pumps



A connected platform of multiple ecosystems



Sandbakken Microgrid, Hvaler

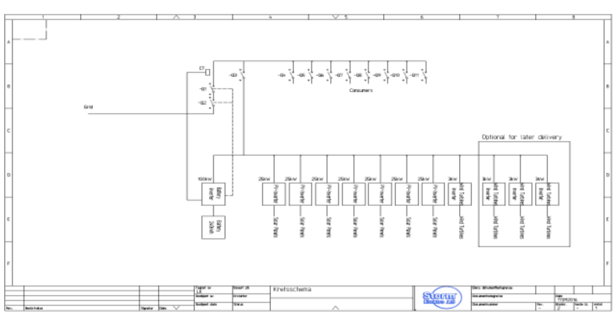
Objective 1: Maximum self-consumption
Objective 2: Flexibility resource for DSO

Transformer capacity:	800 kVA
Supply Voltage:	400V TN
Battery Storage:	240 kWh
EV Charging:	6 Terminals

Generation:

- PV (1200m2, 184kWp)
- Wind (1 mill, 3kWp)

Annual production:	169 MWh
Consumption:	200 MWh
Peak Load:	300 kW
Power ceiling (regulation)	100 kW



The Sandbakken Concept

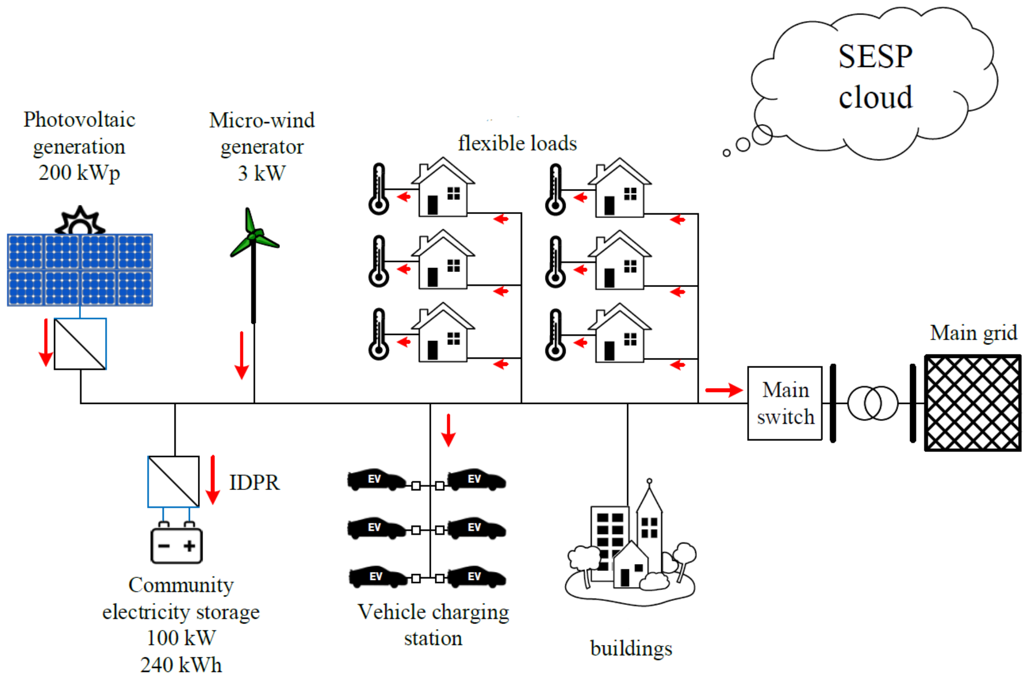
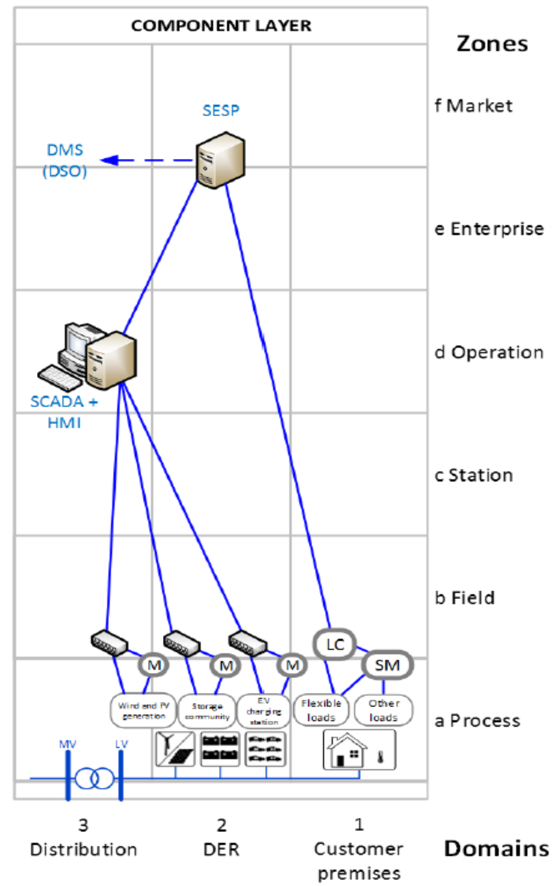


Figure 5: Sandbakken pilot diagram.



Source: EMPOWER H2020

Flexibility Trade

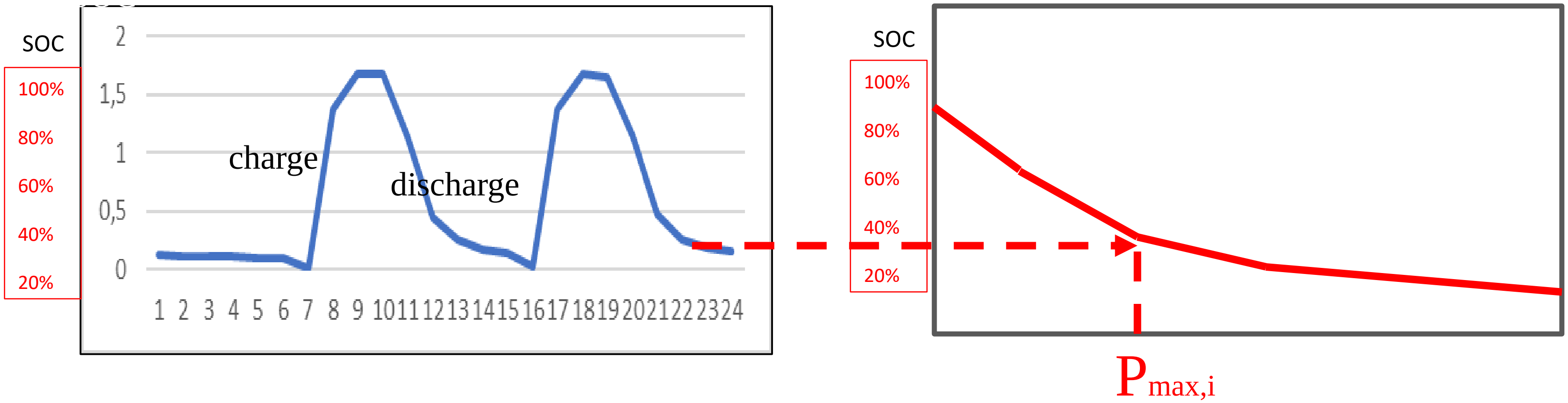
1. Test of first generation IDPR (Intelligent Distribution Power Router)
2. Simple multi-agent trading system
3. MAS oriented machine learning
4. Trade in flexibility (after Densmore and Prasad*)
   - Entities bid for priority
5. Surge pricing
6. SOC of battery pack determines price
7. Remuneration in credits
8. Status as "non-priority load" with local DSO

*Densmore, A. and Prasad, G., "An energy market for rural, islanded micro-grids," in *International Conference on the Domestic Use of Energy (DUE), 31 March–1 April* 2015

The internal market

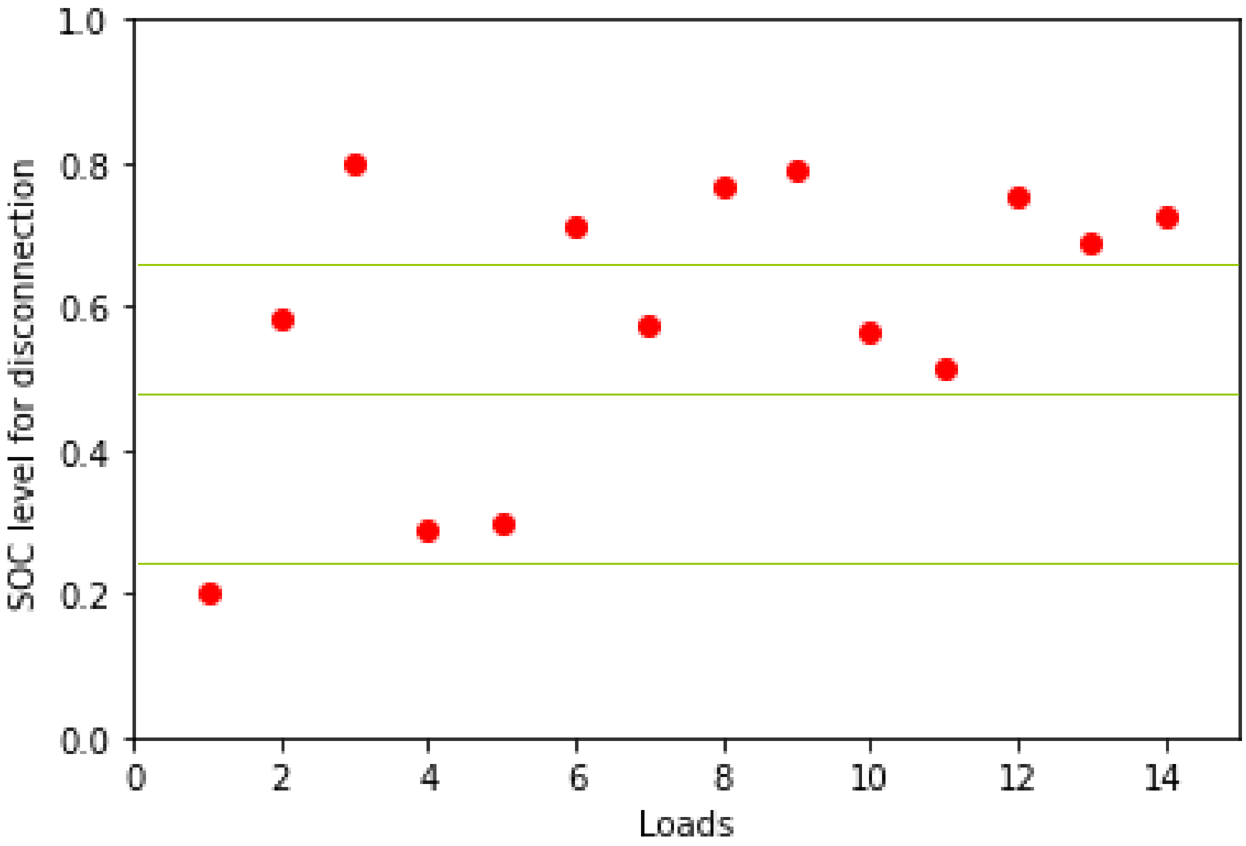
The Sandbakken Battery Stack

Price curve constructed based on bids

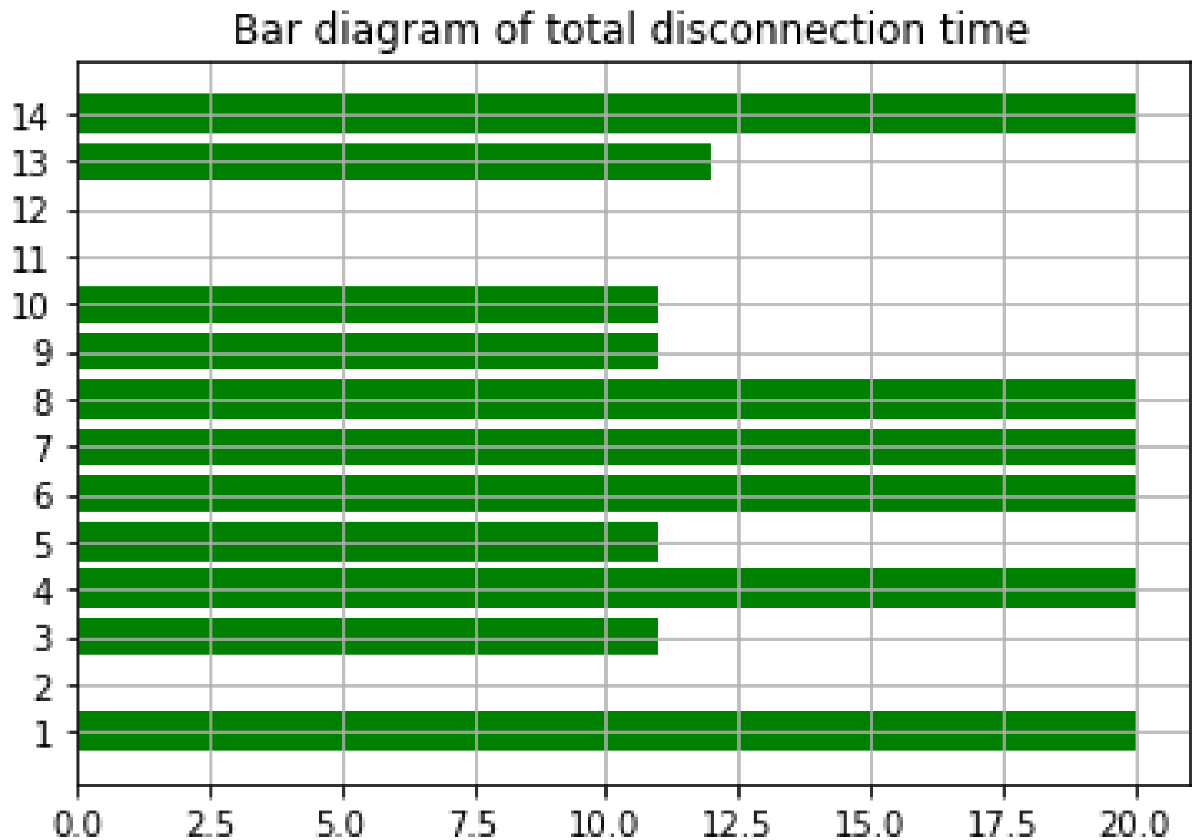


- Agents representing loads (*i*) nominate the maximum price ($p_{max,i}$) they are willing to pay for connection for the next 15 minutes
- Prices change as SOC change , $p_{market} = f(SOC)$
- When $p_{market} > p_{max,i}$, then load *i* is suspended
- When $p_{market} \leq p_{max,i}$, then load *i* is reconnected

Loads disconnected at different SOC levels



Test results



Accumulated hours of disconnection per load

Accumulated duration of disconnection(hrs)

(March – April)

The Inspiria Charging Court

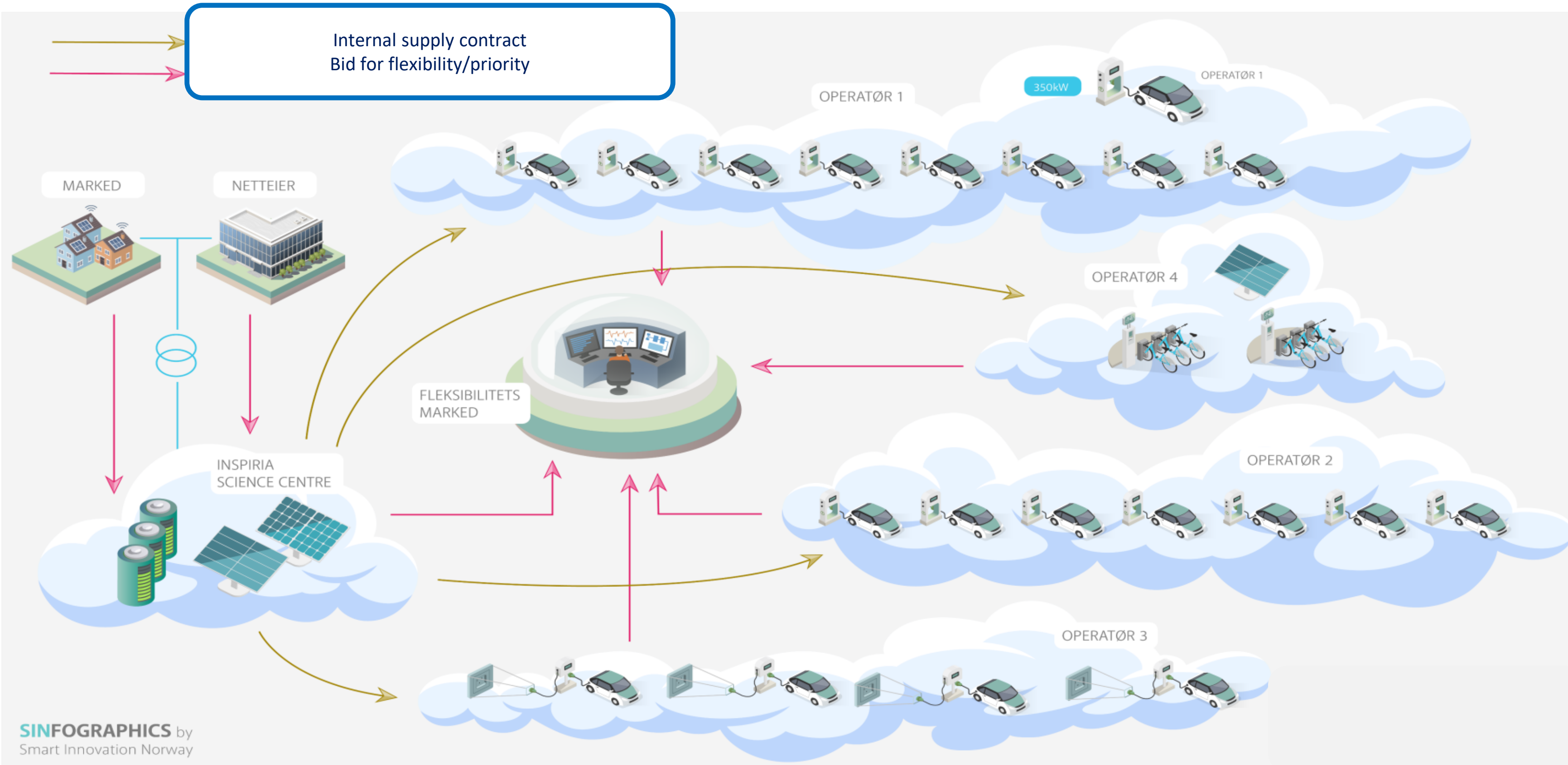
- COPs in a charging court share common infrastructure and power
  - Reduced cost (shared economy)
  - Increased resilience
  - Higher attraction value
- They target different parking and charging needs
  - Ultrafast charging for by-passers on the E6 (300 kW)
  - Parking places with charging facilities (22kW and 50kW)
  - Etc.
- The different needs are exploited to create a flexibility regime that includes local generation, storage and smart charging.
- Local DSO charges up to $1350 per kW per month
  - Curtailment makes sense
  - So does local production and self-consumption
- 915 Amps is the constraint of the PoCC
- Standard infrastructure upgrade is very costly
- Virtual microgrid solution with FO management

Consolidated flexibility resources

- A Flexibility Operator(FO) manages the technical system
- Trade in priorities assures that enough power can go around within the 915 amps limit at PoCC.
- Supported by/enables:
  - Local batteries
  - Local PV generation (to curtail peaks only)
  - Smart charging
  - V2G
  - Local market (exchange of priorities between COPs)
  - Dynamic price regime dependent on system state and demand
- Forms a unified community that can respond to requests from DSOs and BRPs too (“non-prioritized load”) – improved economy for all involved

Local trade in energy flexibility

INVADE



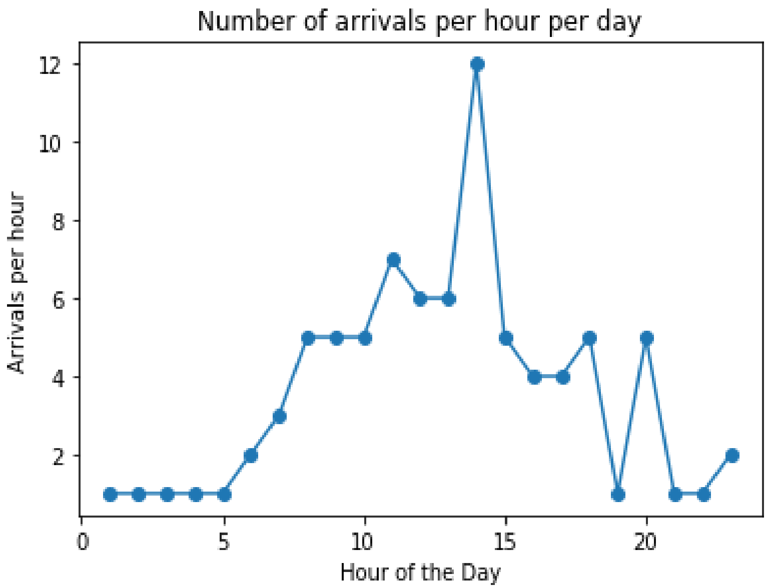

Smart Charging

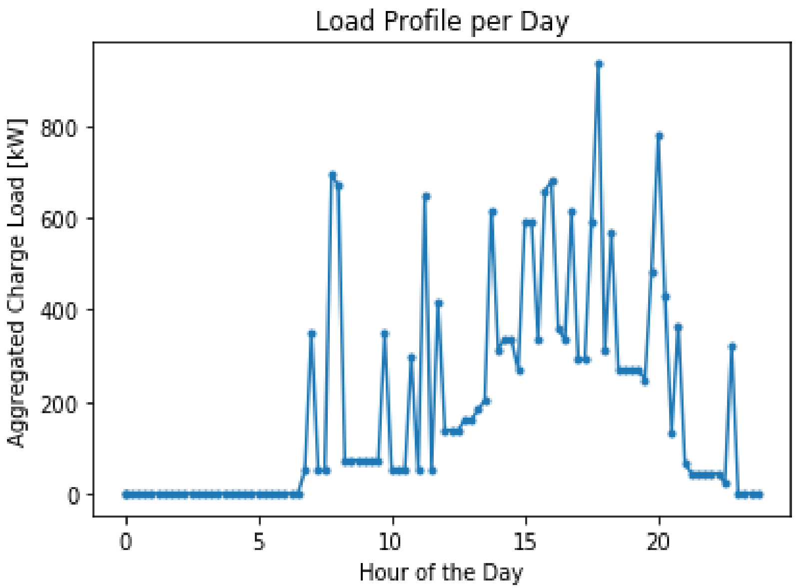

Local Production

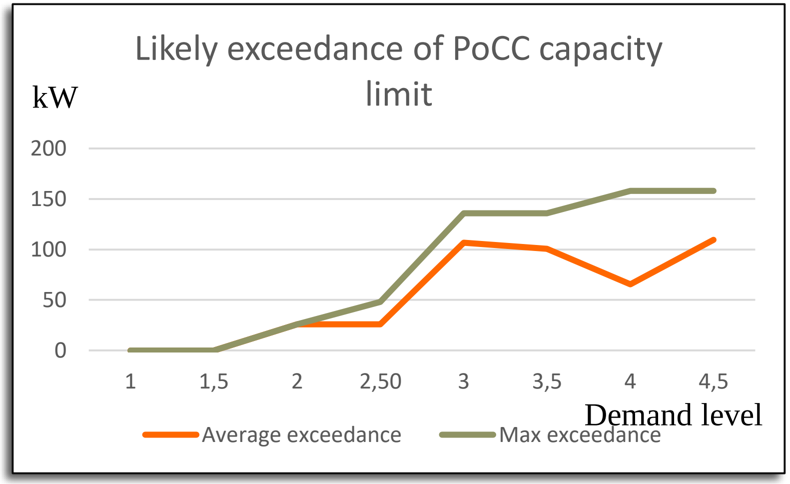

Battery Pack


V2G and dynamic pricing

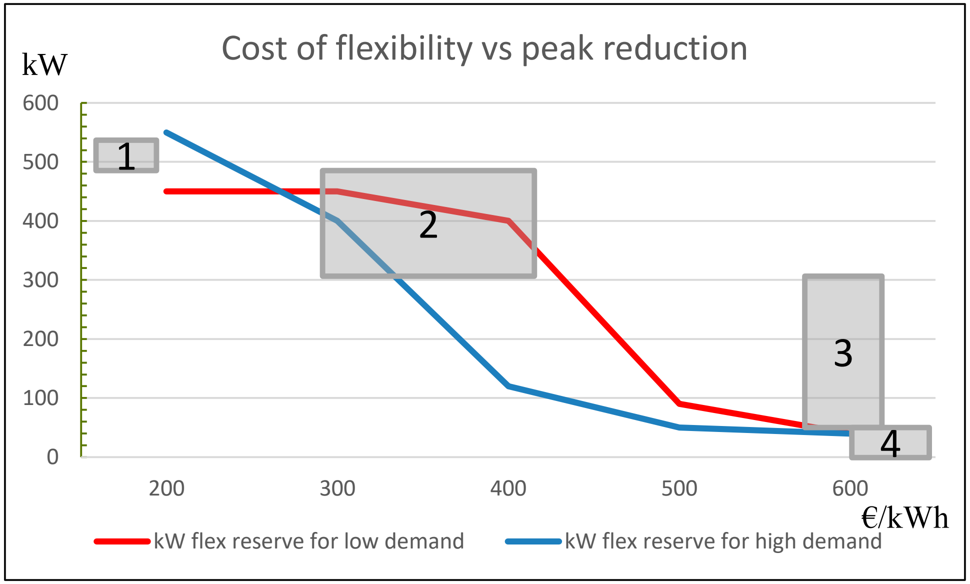
Demand side effects



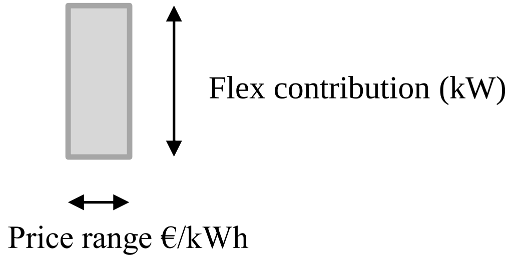




Composing a local flex regime



1. Demand-response (in-house flexibility)
2. Smart charging
3. Battery
4. V2G/B



Some take-aways

- The cloud based INVADE system has proven to support platform based business models for energy flexibility
- INVADE has triggered external investment in both virtual and physical microgrids (exploitation of R&D) (Inspiria)
- Creation of ecosystems set in a microgrid to benefit self-consumption and collective peak load management can be economically attractive (also in regions with low energy prices).
- Prosumer directed use-cases under Time-of-Use (ToU) regimes or capacity oriented tariffs (e.g. KWmax control) have proven a stepping stone for further business development.
- Microgrids organize communities with a common interest. But diversity within a community increases benefits for all (Inspiria)
- Local flexibility trade can create attractive price incentives for increased self-consumption and local balance between supply and demand. As a game conventions and trust can develop through mutual learning (Sandbakken & Inspiria)
- Batteries are important, but not unproblematic or without alternatives (Sandbakken & Inspiria)
- An INVADE controlled, self-sustaining energy cell organized as an ecosystem produces increased negotiating power with the local DSO. It increases the possibility of achieving status as a dispatchable load ("non-priority load") with lower monthly grid tariffs. (Sandbakken & Inspiria)
- BRPs and TSOs have been apprehensive in co-developing the INVADE and EMPOWER concept, but appear to be attracted to the use of consolidated, self-sustaining energy-cells already in place (Sandbakken & Inspiria)
- Other players like hydroelectric producers are looking to INVADE to organize dams within an ecosystem for energy flexibility too to increase yield

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