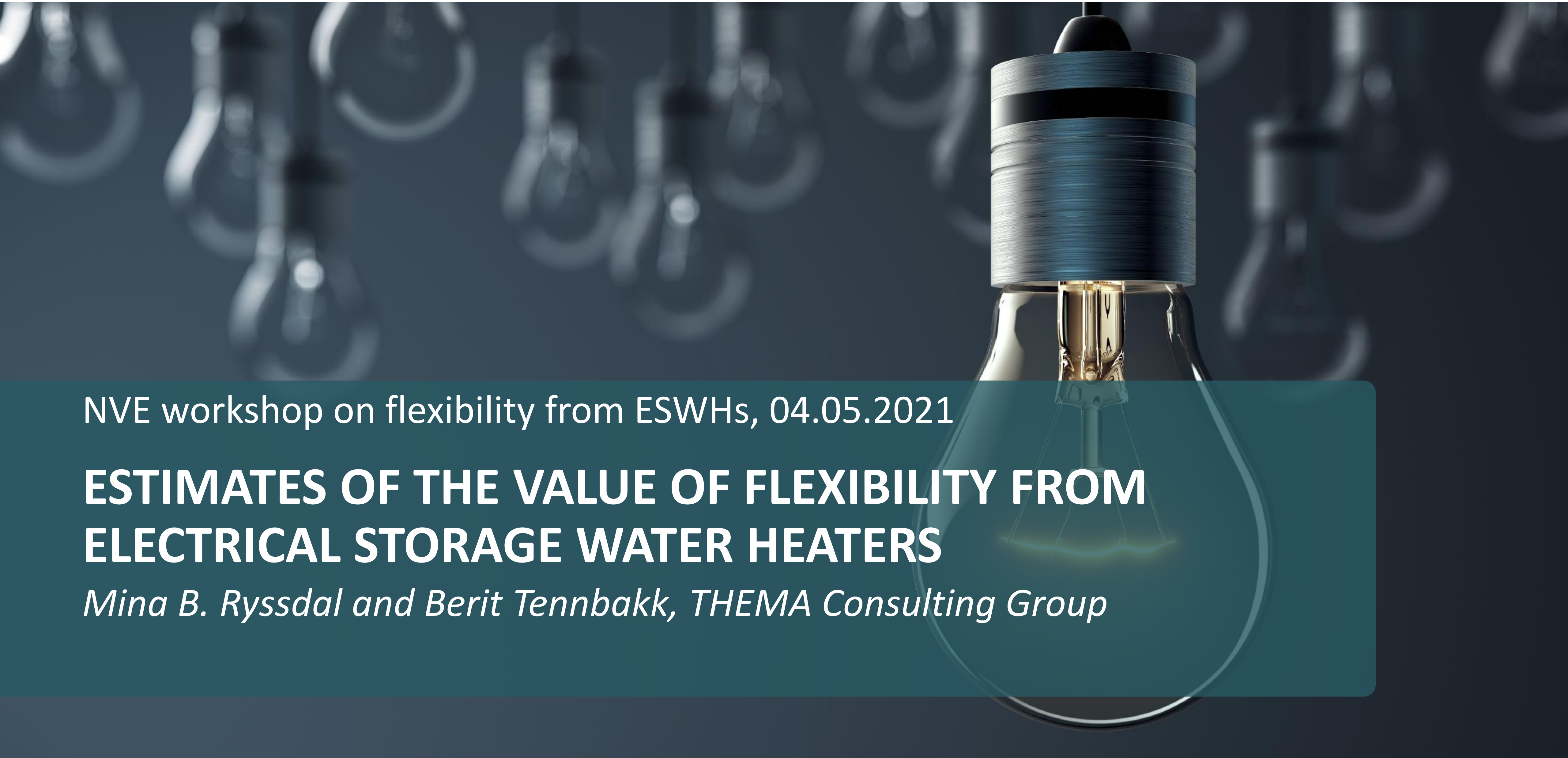


NVE workshop on flexibility from ESWHs, 04.05.2021

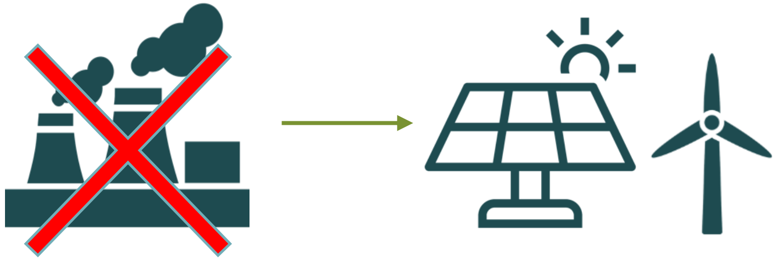
ESTIMATES OF THE VALUE OF FLEXIBILITY FROM ELECTRICAL STORAGE WATER HEATERS

Mina B. Ryssdal and Berit Tennbakk, THEMA Consulting Group

The value of flexibility in the energy system is set to increase, and ESWHs is a potential flexibility provider

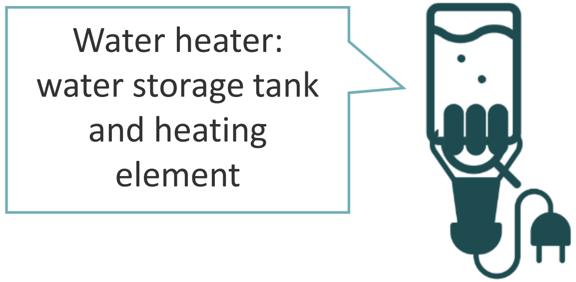
The need for flexibility increases

- Increasing shares of inflexible, intermittent renewable generation
- Reduction in flexible thermal capacity
- More peaky electricity consumption
- Harder to forecast consumption growth
- Grid expansion becomes less economical



ESWHs can provide flexibility, …

- ESWHs are flexible energy storage devices with:
  - Fast reaction
  - High cyclicity
  - Short resting period
- ESWH flexibility has already been used for several decades in e.g., Finland and France



… but is not the only alternative

Alternatives include

- General demand response to price signals or incentive schemes
- EV charging, heat pumps, storage
- Batteries
- Distributed generation

ESWHs can provide valuable flexibility at all levels in the power system

Behind the fuse

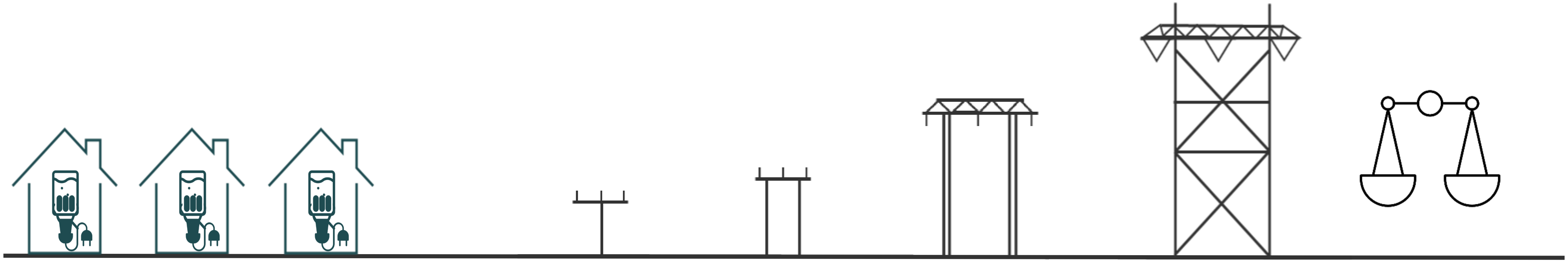
Balancing e.g., EV charging and solar PV generation

In the distribution grid

Provision of voltage control, grid capacity management (planning), and congestion management

For system operation

System services as an aggregate resource



Value estimation methodology: Avoided cost – what costs are incurred if ESWH flexibility is not available?

- Alternative values: Cost of alternative solutions
- Market prices

ESWHs represent a substantial flexibility source in the European power system

ESWHs are highly distributed, flexible energy storage devices

Flexibility potential depends on:

- Available power and energy
  - Design: Heating power, storage capacity and temperature
  - Usage patterns
- Time dimensions
  - Fast reaction, high cyclicity, short resting period
  - Shiftable within a day
- Prevalence and location
  - Highly distributed
- Control

ESWHs are suited for flexibility provision by:

A. Fast response with up/down regulation

B. Load shifting within a day with energy storage

The existing EWSHs in Europe have a large flexibility potential

Estimated flexibility potential from the 57 million primary ESWHs in the EU:

- **Daily flexible power capacity of 20 GW**
  - Corresponding to 1/3 of nuclear capacity in France or the entire installed generation capacity in Czechia
- **Daily controllable storage capacity of >120 GWh**
  - Corresponding to 3 million Nissan LEAF batteries

Based on the available flexibility from ESWHs in France[1]:

- In France a daily flexibility of 8-9 GW and >50 GWh with 15 million units, where
  - 80% available for DSM
  - 50% can be shifted each day
- Smaller tanks on average in EU than in France, assuming 40% lower flexibility potential

[1]Source: EDF's position paper on review studies for ecodesign and ecolabelling regulations for water heaters and storage tanks (2020)

Behind the fuse: Interaction between ESWHs and other loads or self-production can reduce the need for investments and give a better utilization of resources

More power demanding loads and distributed generation imply a need for flexibility to avoid the need for fuse increase and grid capacity expansion.

Considered two use cases:

Load shifting for EV charging	Heating water using PV generation
• Reduce peak load • Provide additional flexibility during peak hours	• Flatten the prosumers load curve • Increase self-consumption by up to 60%

Overall, flexibility from ESWHs and other loads can flatten the consumption profile within the fuse, providing value by:

- **Better utilization of local generation**
- **Avoid costs related to expansion of fuse size and connection capacity**

Flexibility needs and alternative sources in the distribution grid

The value of flexibility for DSOs increases

Estimated substantial massive need for grid capacity expansion, …

.. but grid investments less economical and more uncertain

More peaky loads in distribution grids

- Distributed generation, such as solar PV
- Electrification, such as EVs

Smart metering etc. caters for increased price flexibility / demand response, …

- Market price exposure, grid tariff structures

… but also more uncertain demand projections

Alternative flexibility solutions

Access to flexibility can

- Defer or postpone grid investments
- Provide system services such as voltage control

Alternative flexibility sources have *different characteristics*

- *Time* (when, how fast, how often, how long), *Volume* (capacity, energy), *Location* (where)
- Demand-side response
  - Behavior: Less reliable, more uncertain characteristics
  - New sources: EV charging, heat pumps
  - Cost: ESWHs can provide flexibility without comfort loss
- System battery solutions
  - Dedicated to provision of system services
  - ESWHs already installed as hot water supply

Alternative costs in distribution grids – lack of market pricing and current prices poor indicators of future values

System level cost saving estimates

Grid investment savings in Germany:

Flexibility used in a grid-friendly manner can save grid investments in Germany by **€20 bn**

- Annual savings to 2035 exceed 40 %
- Flexibility sources include RES, EVs, heat pumps, small-scale storage, and other household loads

Based on current market price structure and end-user pricing schemes

Reduction in DSO operational costs:

- Cost of peak to off-peak load shifting **34–39 €/MWh** lower than alternatives
- Alternative include biomass, CHP, wind and PV generation

Market prices

Ideally, the marginal value of flexibility across all sources should be reflected in market prices

- But flexibility markets are in their infancy,
- Marginal values differ according to system characteristics, and
- Current flexibility values do not reflect future values.

GB: DSO flexibility markets

- Estimated value of flexibility from an average ESWH **125–190 €/year**

Western Power's pricing of flexibility products

	Arming	Availability	Utilisation
Secure	£ 125 / MWh		£ 175 / MWh
Dynamic	-	£ 5 / MWh	£ 300 / MWh
Restore	-	-	£ 600 / MWh

Early days: Prices are not yet market-based, aim to use auctions in future

Cost of batteries

Batteries may be the most relevant marginal source in future.

Batteries have similar flexibility characteristics as ESWHs

- EV batteries – best availability at night
- System batteries – can be tailored to the need

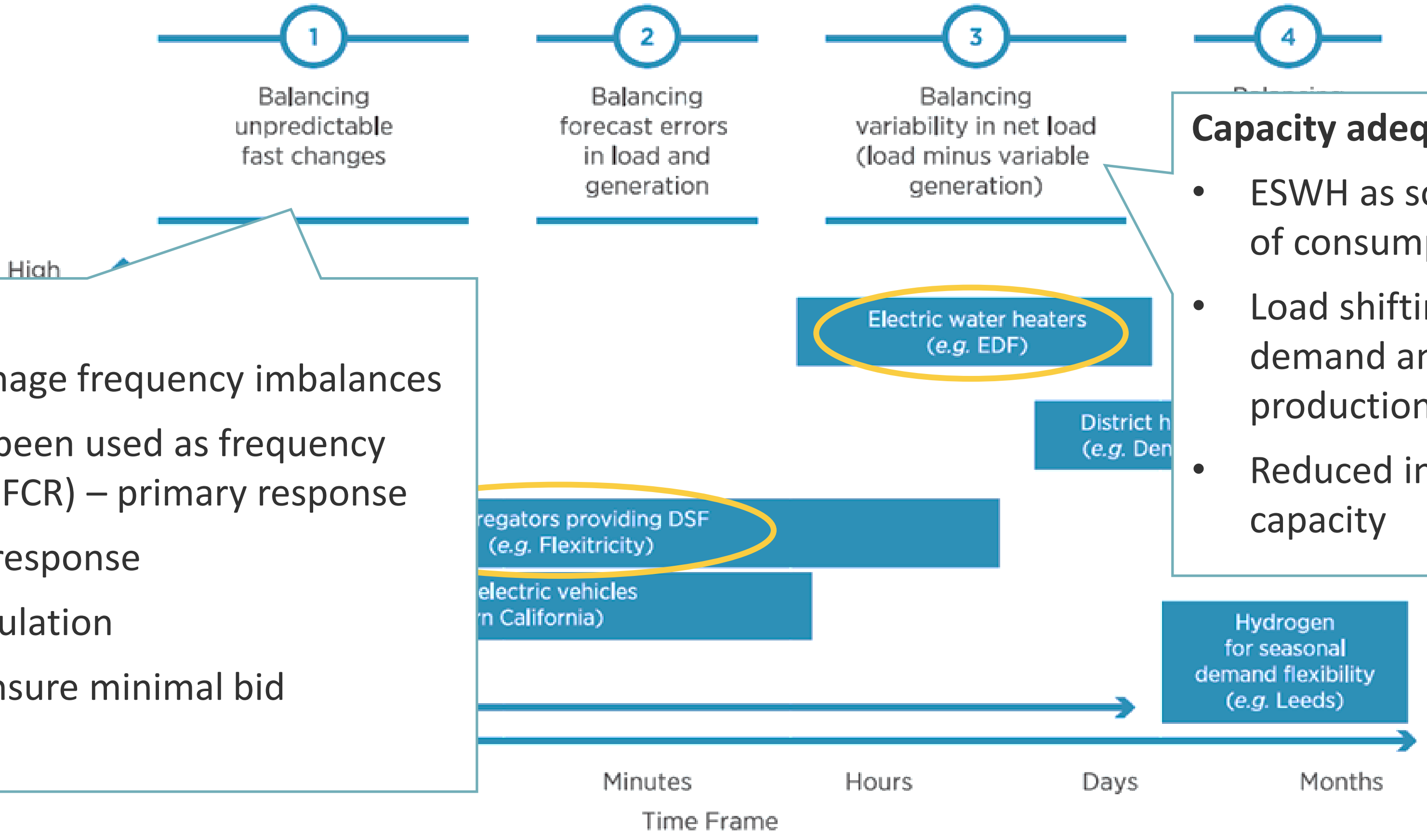
Different use cases and battery types indicate LCOE of system batteries at

- **346–474 €/kW/year**
    - Of which capital costs make up 66 %
- To replace the services of 10 MW battery capacity, 5.000 ESWHs with 2 kW capacity are needed

Sources: Özalay et.al. 2019, Frontier 2017, Western Power Distribution, Lazard 2020

ESWHs can contribute with flexibility to maintain the balance in system operation for frequency control and capacity adequacy

Demand-side flexibility real applications classified by maturity and time scale



Frequency control

- ESWHs respond to manage frequency imbalances
- ESWHs have primarily been used as frequency containment reserves (FCR) – primary response
  - Fast (automatic) response
  - Up and down regulation
  - Aggregation to ensure minimal bid

Capacity adequacy

- ESWH as source of down-regulation of consumption in peak load hours
- Load shifting to hours with low demand and high renewable production
- Reduced investments in peak plant capacity

Value of ESWHs as frequency containment reserves and capacity adequacy measures

Value of availability for frequency containment reserves estimated to 75 €/kW/year

Estimate per ESWH's installed capacity

Available capacity based on Svenska Kraftnät pilot[1]
- 0.1 MW from 100 ESWHs[2]

Participation in FCR-N markets receiving capacity price
- 17.04 €/MW/h – average capacity price FCR-N, Sweden 2020

Value of use for capacity adequacy estimated to 50 €/kW/year

Comparison of:

Estimated cost of peak capacity reserves
- 40 000 – 60 000 €/MW/year[3] = 40-60 €/kW/year

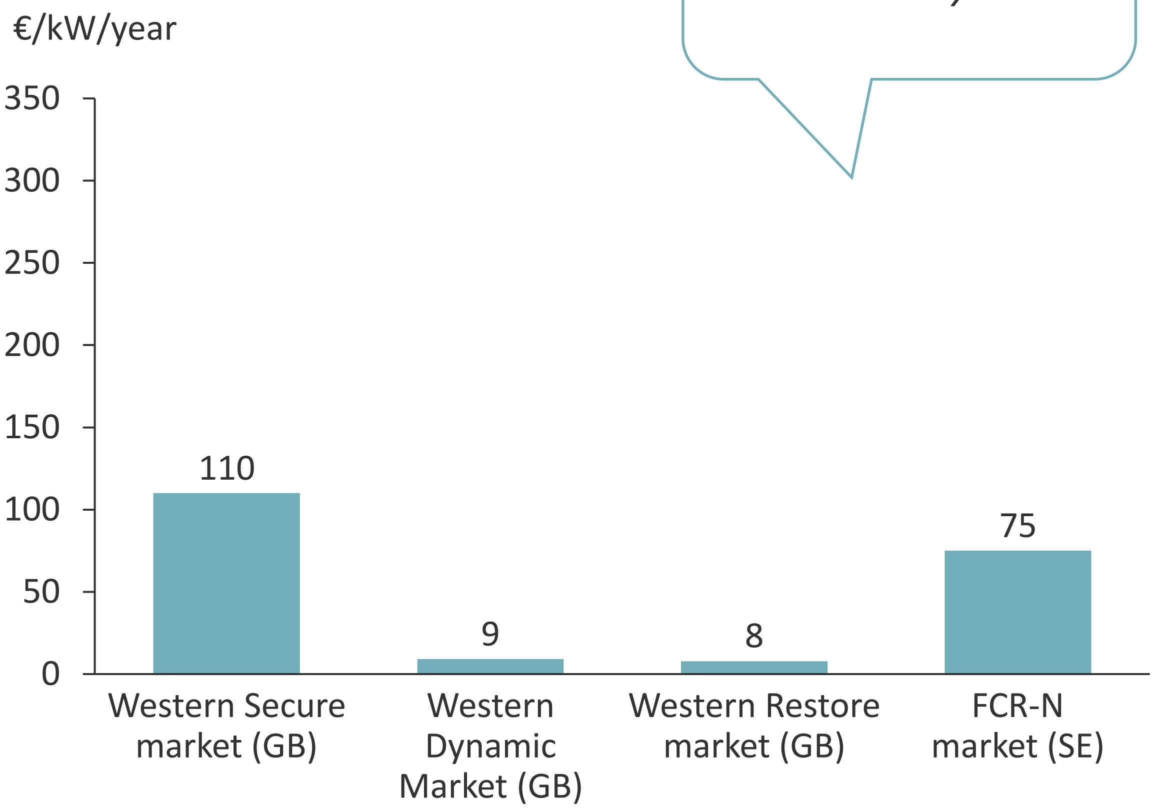
Estimate based on price differentials between peak and off-peak hours in Germany [4]
- 50 €/year, assuming that ESWHs are
  - Activated for down-regulation four hours twice a day
  - Available half of the days in the year

[1] *The pilot project "Flexibla hushåll" ("Flexible households") conducted by Svenska Kraftnät in 2017*
[2] *2kW ESWHs with 50% of capacity switched on/off to provide symmetric up- and down-regulation required in the FCR-N market*
[3] *THEMA Consulting Group: estimate of fixed gas turbine costs and costs of reserve capacity in Swedish bilateral agreements*
[4] *Frontier (2017)*

Alternative value estimates differ substantially

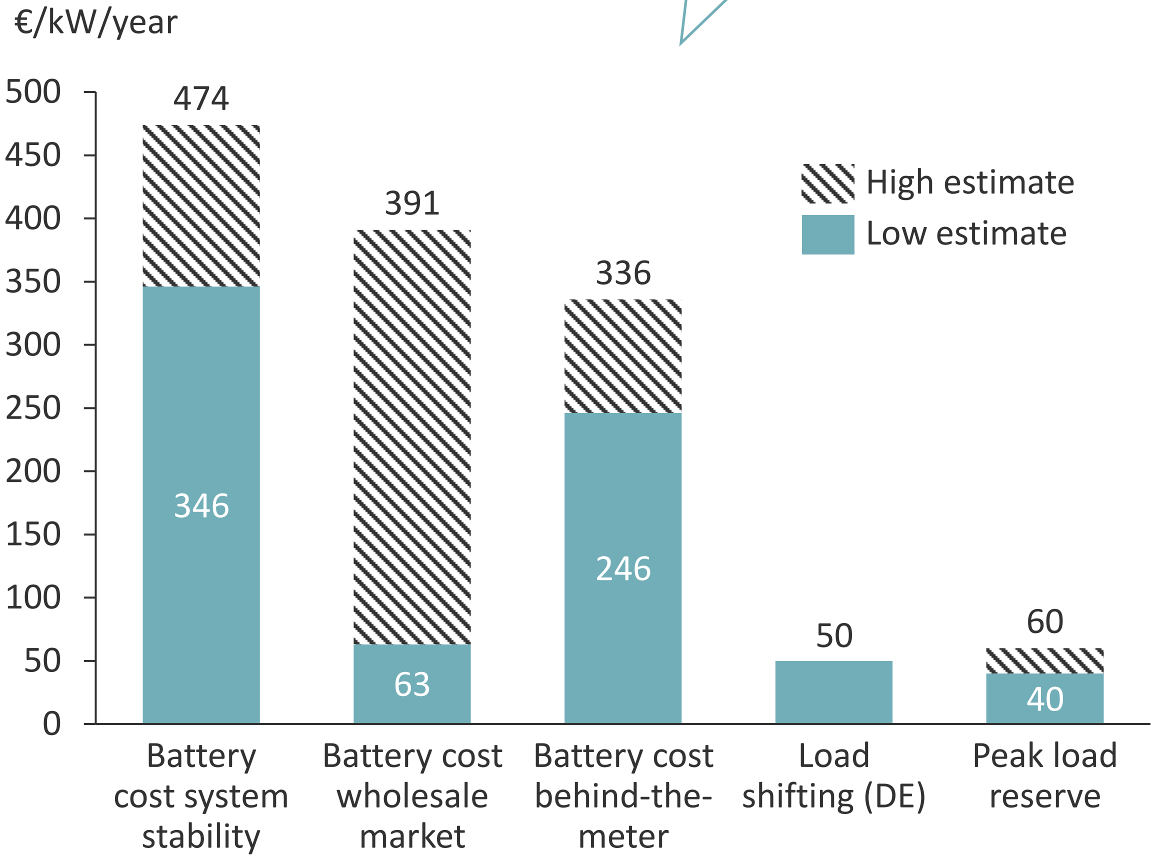
Flexibility market prices

Prices in DSO market are significantly lower than battery costs



Alternative cost estimates

ESWHs can potentially provide flexibility for several uses "at the same time"



ESWHs constitute an *existing and proven* flexibility resource that represents a positive option value for the future electricity system

Regulation of ESWHs should take into account that ESWHs can provide a range of flexibility services:

- A highly distributed flexibility resource
- Fast response
- Frequent response
- Low to no investment cost or comfort loss to the consumer
- Proven control technology in different contexts

The value of flexibility and the cost of alternatives are still uncertain, and the option value can be much higher than current estimates

  - The demand for flexibility is set to grow
  - The value of flexibility will increase
  - Flexibility from several sources will be needed, and the cost and scope of most of the alternatives is still uncertain

THEMA

CONSULTING GROUP