Independent Aggregation in the Nordic Day-Ahead Market:
Potential Impact of Different Supplier Compensation Mechanisms

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Independent aggregation in EU

An **Independent Aggregator** (IA) is a market participant engaged in aggregation who is **not affiliated to the customer's supplier**.

The **Electricity Directive** (EU 2019/944) mandates member states to enable the participation of **Demand Response** (DR) via IAs in **all organized electricity markets**.

However, it also allows Member States to require electricity undertakings or participating customers to **pay financial compensation to other market parties** directly affected by DR activation.

Most Member States with a framework for IA in place implemented a compensation mechanism (Schittekatte et al., 2021).

However, such compensation mechanism **should not create a barrier** for flexibility, and it may take into account the **benefits brought by IAs to other market participants**.

(Welfare) benefits of more DR?

Chao (2011), Chao and DePillis (2013): welfare improvements possible compared to a situation where consumers are subject to a flat retail rate

Baker (2016, 2017): increasing competition in wholesale markets, leading to a wholesale price reduction & shift of producer surplus to consumer surplus

Su and Kirschen (2009): increased DR participation leads to substantial savings in system operating costs which are transferred to the demand-side.

But….without asking a compensation for energy sourcing costs

Chao (2011): not asking a compensation for sourcing costs will lead to a welfare reduction due to excessive DR

Chao and DePillis (2013): DR can only lead to a welfare reduction if only active when the wholesale price is two times the flat retail rate (under certain assumptions)

Hogan (2010a, 2010b): the net effect of potentially reducing average wholesale market prices, by the increased participating of DR compared to a counterfactual to a situation with a compensation in place, would be to increase payments through the capacity mechanisms. In principle, these would be dollar for dollar, at least in the long run

Data and methodology

Data and methodology

Dataset of supply & demand curves of the Nordic electricity market in 2018

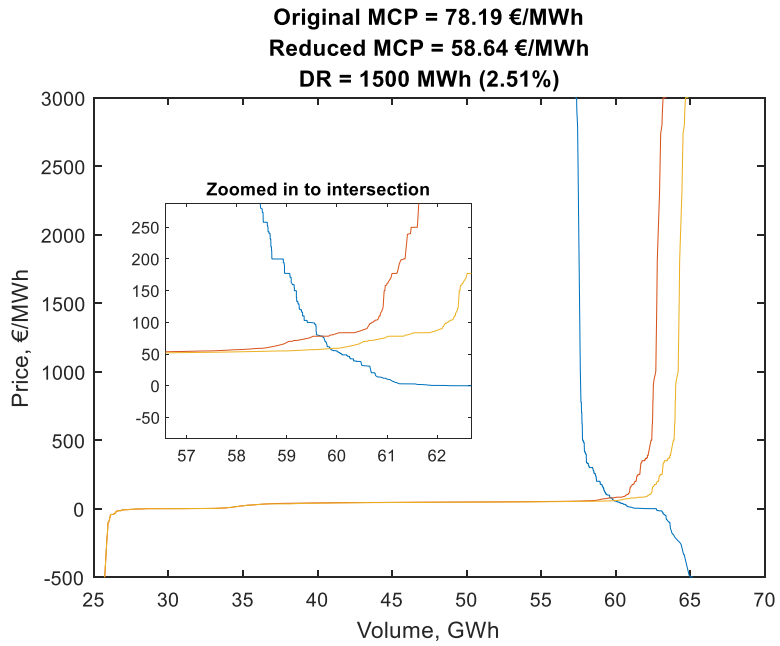
In 2018, the ratio of electricity bought in DA vs total consumption in Nordics was 93.30% (the least in FI – 71.79%); the most in NO – 101.25%)

We can calculate the impact of DR via IA on the DA prices and volumes:

IA demand response bids are **added to the supply curve** as competitors to generators.

IAs sell the DR as energy (*"nonconsumption"*) and receive remuneration at the resulting day-ahead price (*if their offer is in-the-money*) minus compensation (*if applicable*).

The IA offered volume is added to each **original supply curve** point, where the price is greater or equal to IA offer price.



Example of IA DR effect on the price based on curves from 2018-12-12 17–18 CET
Assumptions on IA DR – volume 1.5 GWh, price 35 €/MWh

The bidding curve-based analysis is in principle similar to studies on PV and load shifting impact on the Iberian day-ahead market by **Roldán-Fernández et. al. (2017)**, **Roldán-Fernández et. al. (2021)** and **Arcos-Vargas et. al. (2020)**

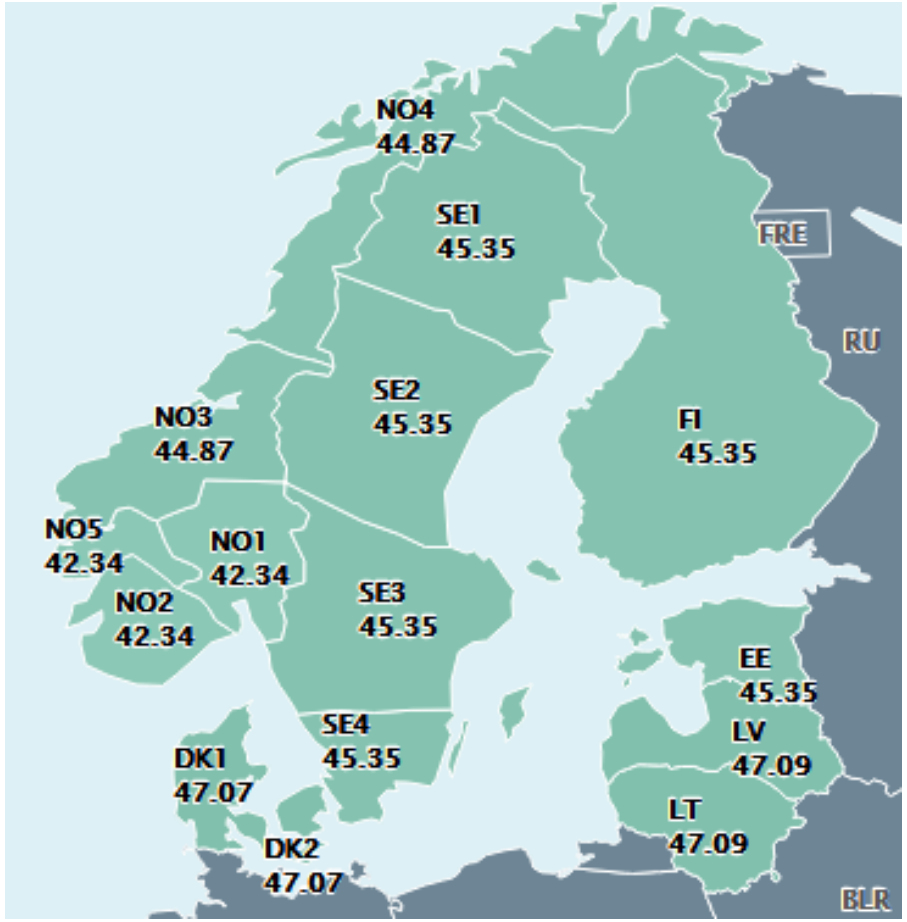
Background about the Nordic day-ahead market

Nord Pool is the leading nominated electricity market operator (NEMO) in Nordic and Baltic bidding areas*

The Nordic System price serves as the reference price for most standard financial contracts traded in the region

In the year considered, Swedish and Norwegian area prices are very well correlated with the System price (>=0.95); Finnish and Danish – less so (0.75-0.80).

	NO	SE	FI	DK	EE	LV	LT	Total
DA buy/cons:	101.25%	97.85%	71.79%	97.39%	89.86%	101.85%	114.11%	**93.98%**



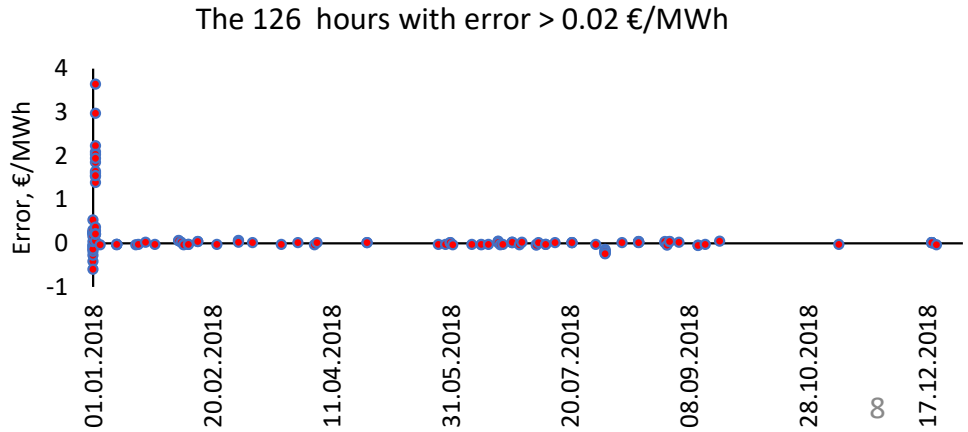
Snapshot of the Nordic/Baltic bidding areas on 2018-05-28 21–22 CET

*The only day-ahead market operator before Multi-Nemo Arrangements

Data quality assessment

The **quality of the data** and the performance of the price identification approach is evaluated by simulating the 8760 hourly prices from 2018*:

- For **88.36%** of the hours the simulated price is **exactly equal** to the actual;
- For **94.99**% the error is **equal or less than 0.01** €/MWh;
- For **98.56%** the error is **equal or less than 0.02** €/MWh;
- The **max. error is 3.65** €/MWh.
- For hours with error > 0.02 €/MWh, the original price is 24.15–66.90 €/MWh with an average of 41.23 €/MWh (i.e., **not outliers**). A significant share of those are on January 1 and 2.
- Despite the erroneous hours, the overall average, median and st. dev. are **equal to the original**.



*Baltputnis & Broka (2021)

Setup

Key assumptions:

- For now, only **load-reducing DR** is considered (*future work includes the option to also include **load-increasing DR***);
- DA price changes due to DR via IA are not corrected by free entry;

Main sensitivity: We test several shapes/parameters of the IA DR curves

Benchmark: The IA DR curves are subject to the average annual DA price (ex-ante of DR activations), i.e., the IA is not participating in the market and the DR consumers pay a "flat volumetric rate"".

Alternatives: The IA DR curves are subject to the hourly DA prices with compensation payment (*set equal to the average DA price, i.e., the "flat volumetric rate"*) socialized to a level from **0% (no socialization)** to **100% (full socialization)**.

The overall benefits are estimated by comparing the alternatives against the benchmark (*i.e., subtracting*)

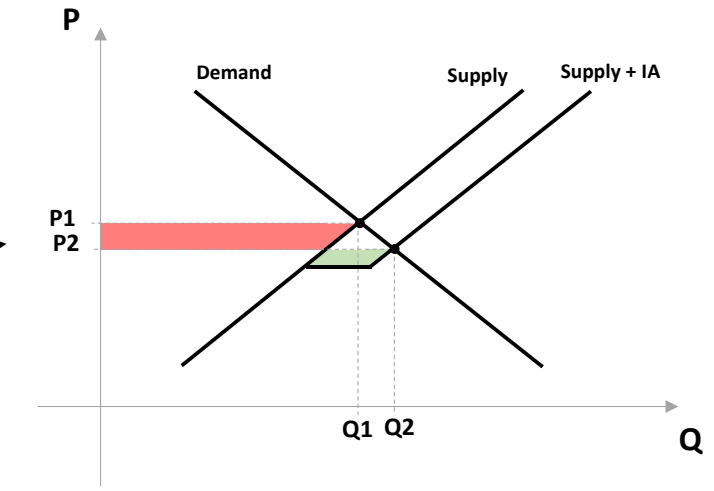
Main metrics of interest

1/ Changes in **producer surplus**

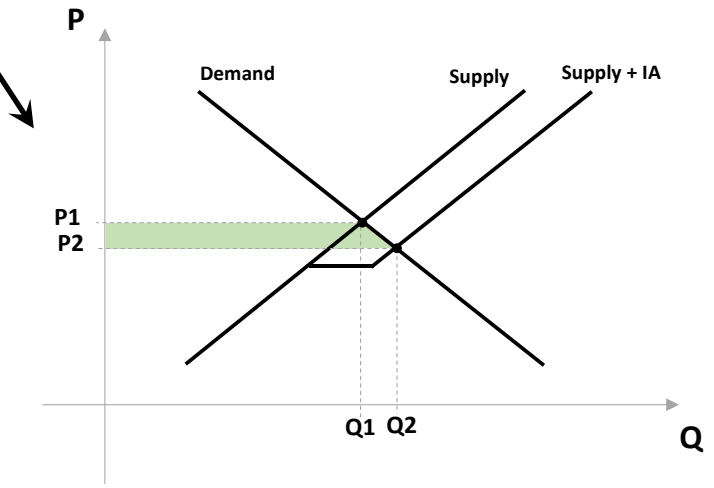
2/ Changes in **consumer surplus**

(both derived from the market curves)

Producer surplus change



Consumer surplus change



Consumer and producer surplus calculated from the day-ahead market aggregated bidding curves as in **Arcos-Vargas et. al. (2020)**

Main metrics of interest

1/ Changes in **producer surplus**

2/ Changes in **consumer surplus**

3/ Socialized **compensation payment** → *Sold DR volume multiplied by socialized compensation price*

Main metrics of interest

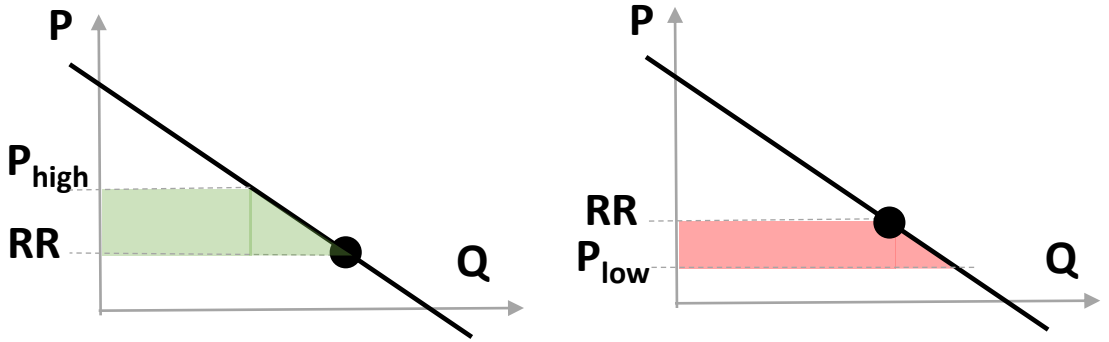
1/ Changes in **producer surplus**

2/ Changes in **consumer surplus**

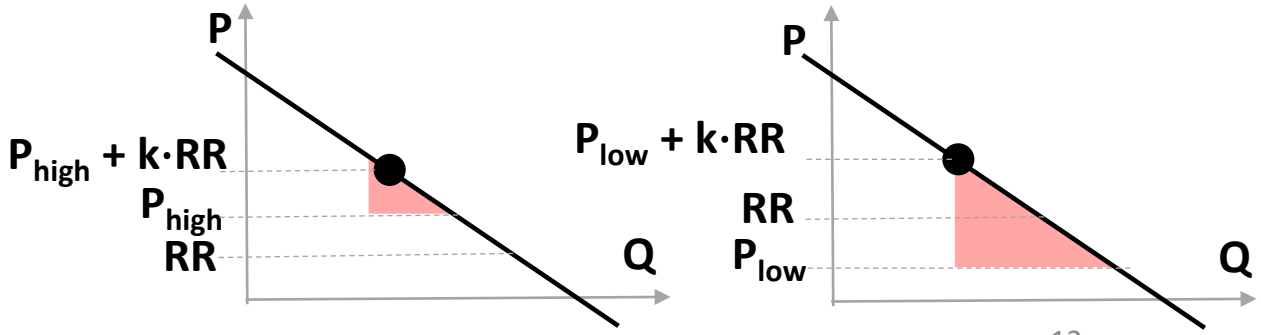
3/ Socialized **compensation payment**

4/ **Impact on** the **IA DR consumer's welfare**

Benchmark: positive effect on the flat-rate (RR) customer, when the market price is above it (*overconsumption*), negative – when it is lower (*underconsumption*)



Alternatives: either no impact on DR consumer welfare (w full compensation), or negative effect due to some level of underconsumption; can be generalized as (*k denotes level of socialization*):



Main metrics of interest

1/ Changes in **producer surplus**

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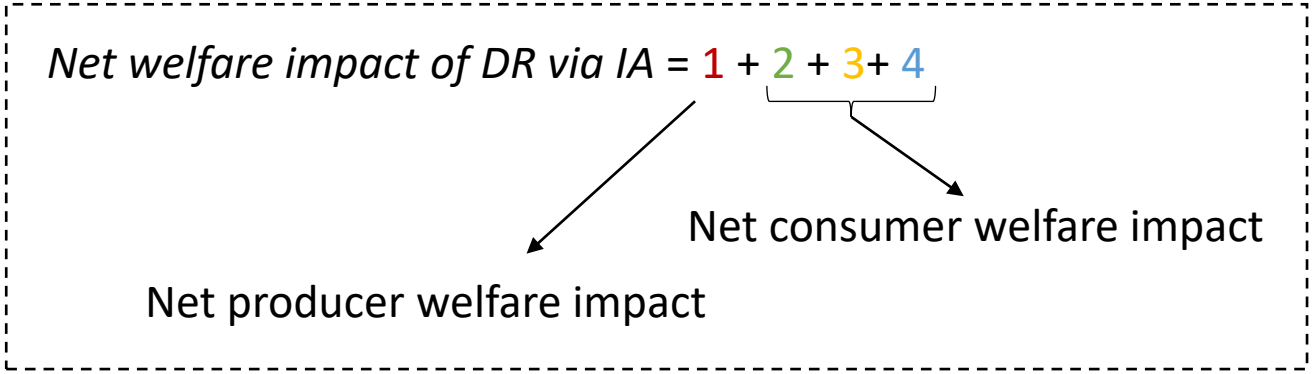


$$\left(\sum_{t}^{T}\left(PS_{t,b,s} - PS_{t}^{\mathrm{bm}} + CS_{t,b,s} - CS_{t}^{\mathrm{bm}} - RR \cdot k_{s}^{\mathrm{comp}} \cdot DRV_{t,b,s}^{\mathrm{sold}} + DRS_{t,b,s} - DRS_{t,b}^{\mathrm{bm}}\right)\right) \Big/ \sum_{t=1}^{T} MCV_{t,b,s}$$

t, T – hour number

b, B – bid curve scenario

s, S – compensation socialization scenario

Other assumptions

The full **compensation price is set constant** in all the calculated scenarios; it equals the 2018 actual average DA price – **43.99 €/MWh**.

IAs know in advance the compensation rules (*including the price*) and, consequently, can price it in their bids.

All calculations are **based on the system price**, disregarding that, in reality, it could vary between the Nordic bidding areas.

The IAs are assumed to be operating in the DA market situation as it was in **2018**, as opposed to future projections.

The Nordic countries are treated as one region with **equal IA rules**.

Results and Discussion

Assumed DR cost curves

It is assumed that the IA DR portfolio can be represented by **multi-step DR activation cost curves**.

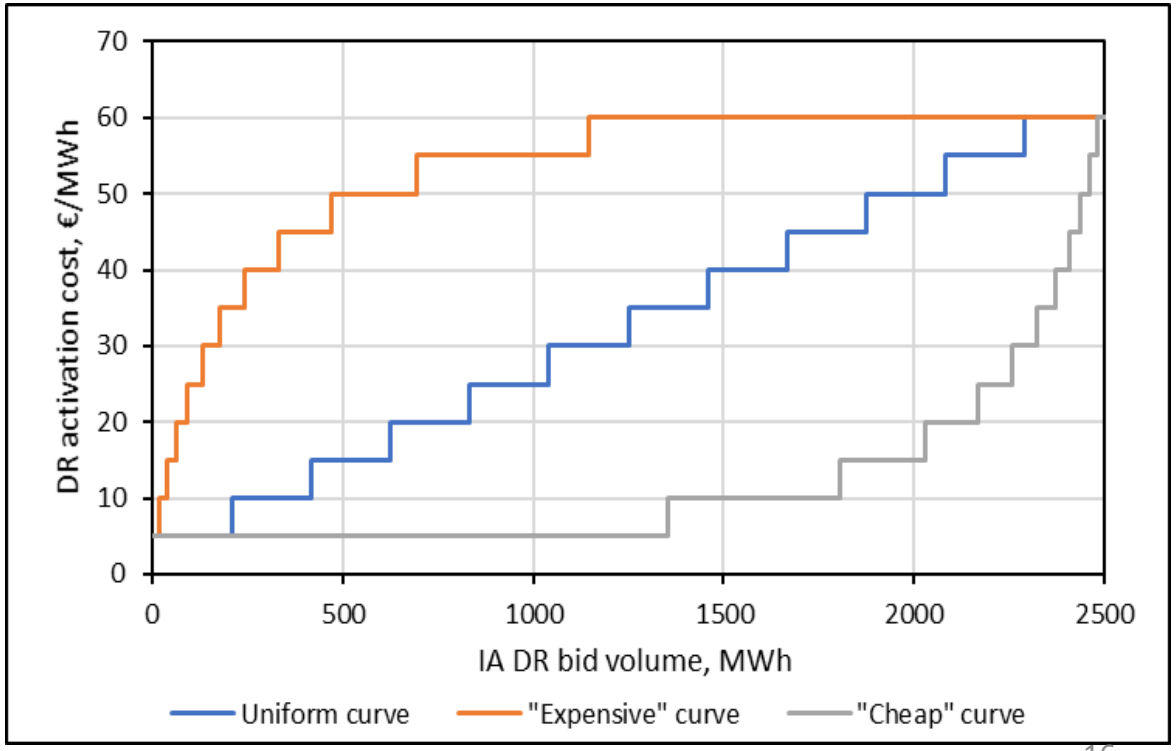
The price steps in the curves have an increment of 5 €/MWh (with a range from 5 to 60 €/MWh).

The volume steps are from 0 to 2.5 GWh, divided in 12 steps, with either uniform, increasing or decreasing volume each.

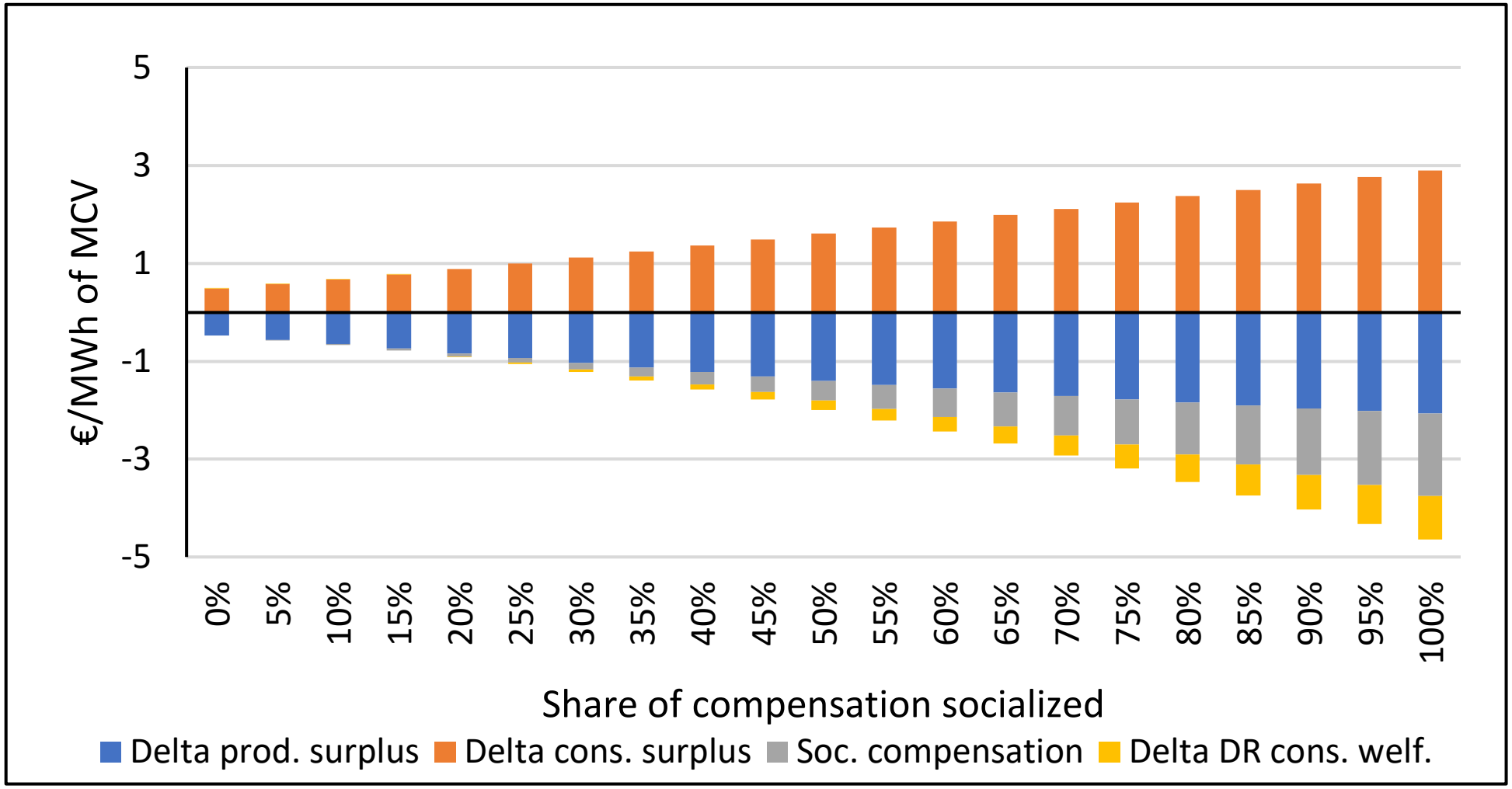
Consequently, **3 scenarios** are created:

- with a Uniform curve (equal volume and price);
- with an Expensive curve (whereby most of the volume is at the higher activation cost range);
- with a Cheap curve (whereby most of the volume is at the cheaper activation cost range.

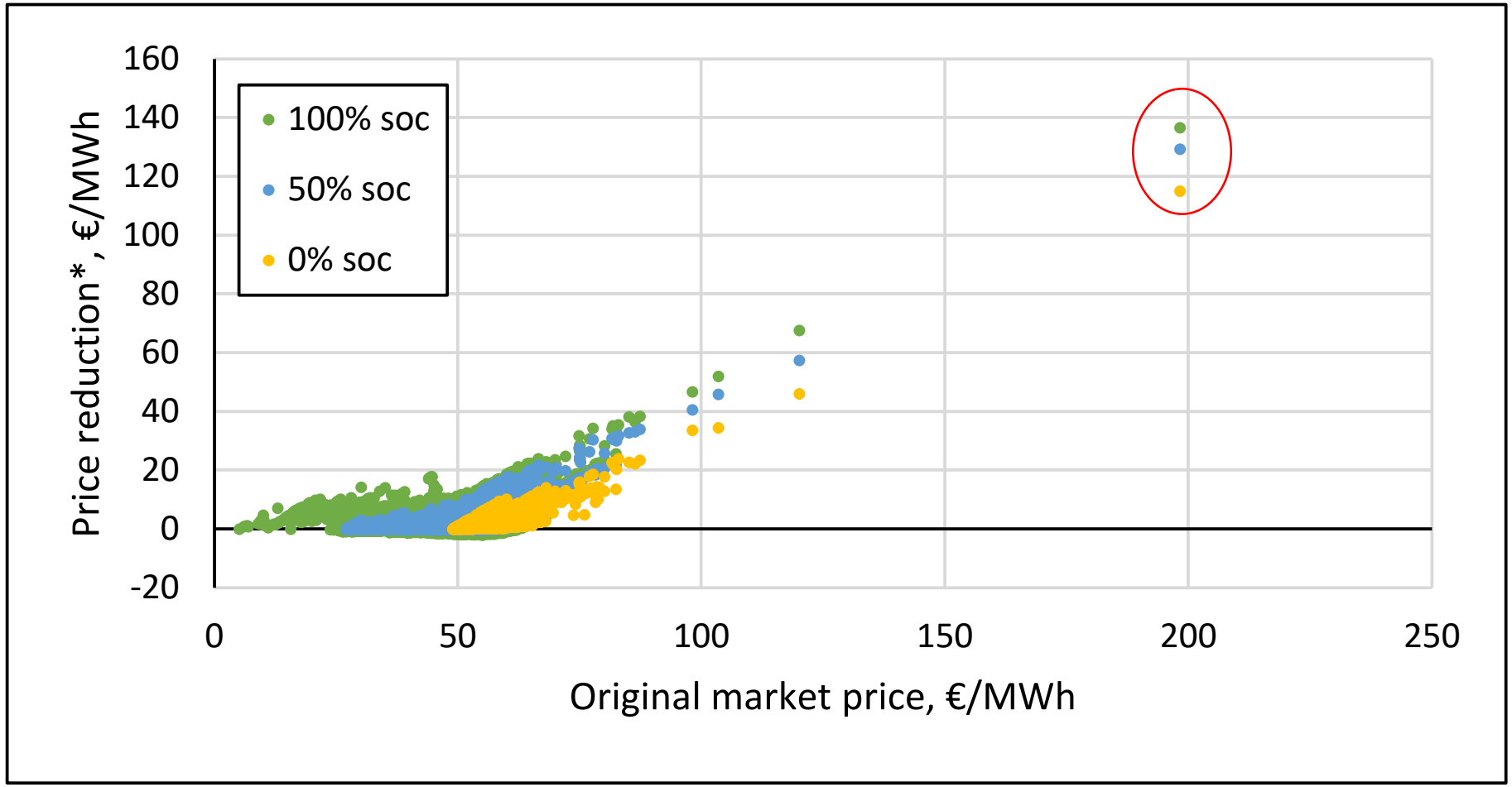
Only the **share of compensation socialization** is a scenario parameter now, it is varied from 0% to 100% with a step of 5%.



Net benefit per its components (w uniform curve DR)

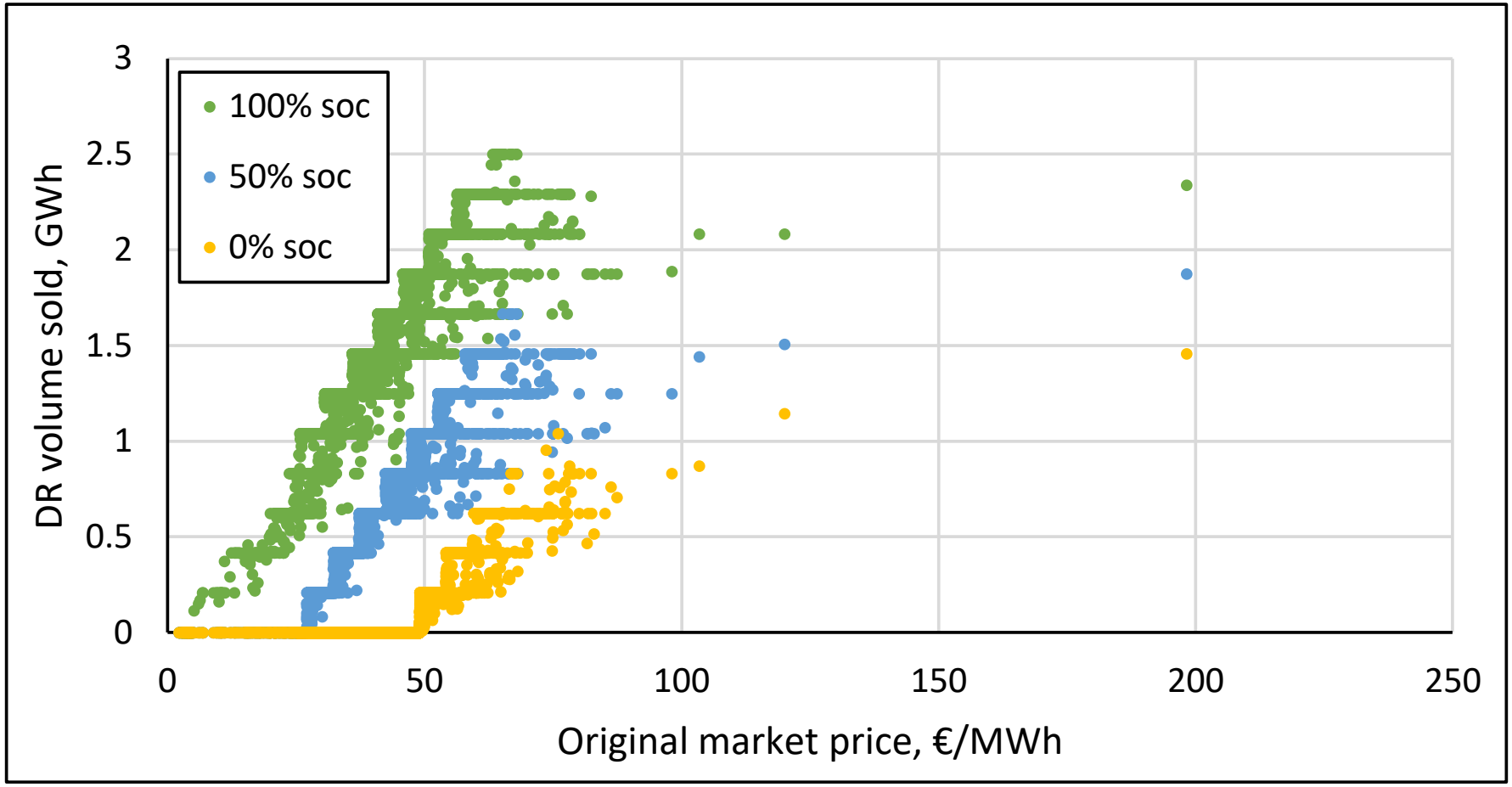


Price impacts of DR (w uniform curve DR)



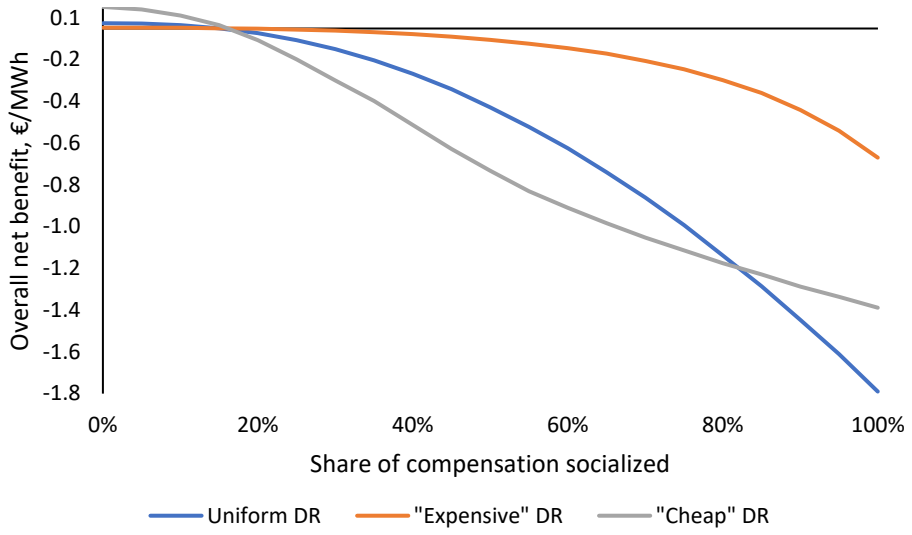
*also considering the supplier compensation

DR volume sold (w uniform curve DR)

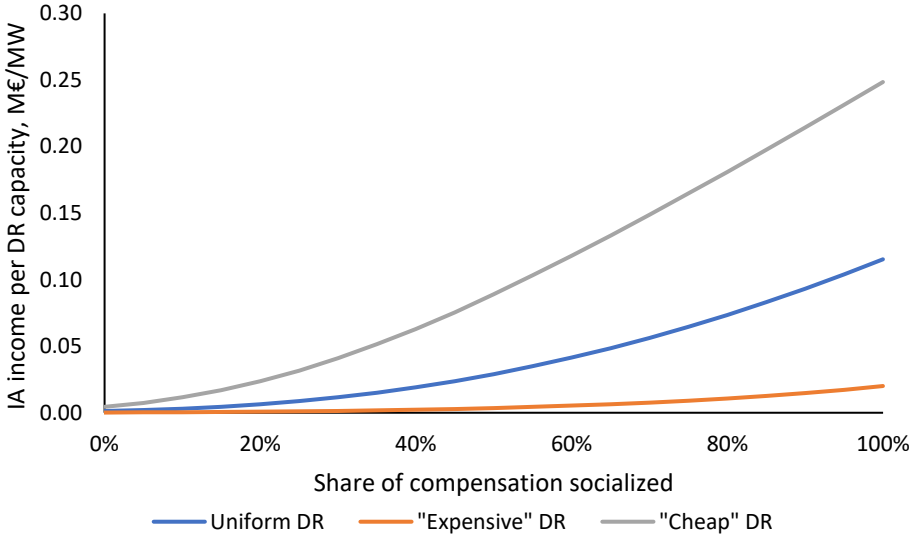


Overall net welfare benefit

- **<u>Overall net welfare benefit</u> relative to total volume of energy traded in DA (€/MWh)**



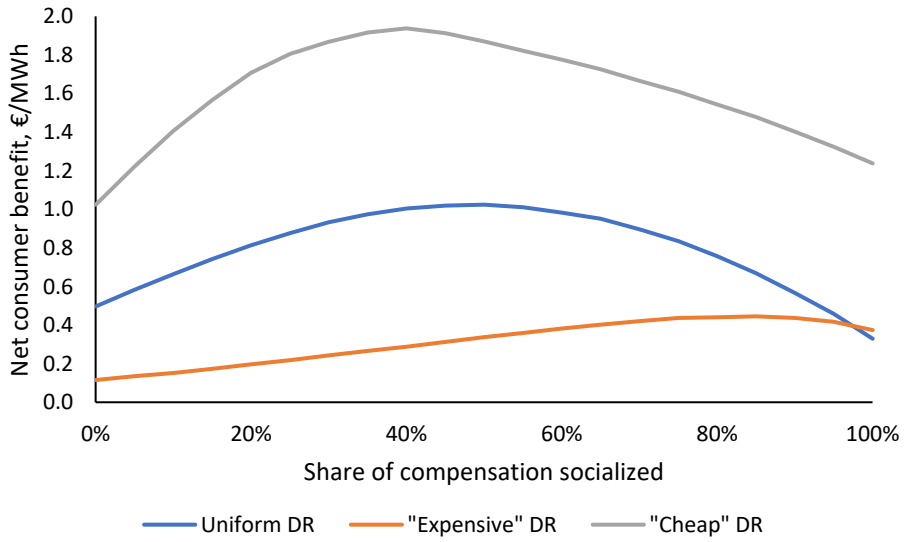
- **<u>IA income</u> per DR capacity (M€/MW)**



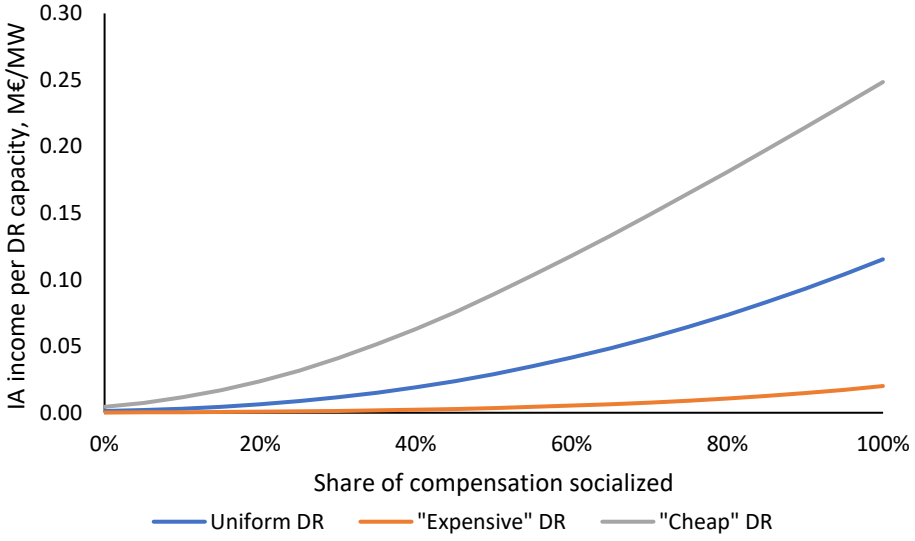
- **Sum of all the metrics of interest**
- There is **positive <u>overall net benefit</u> only at no or very low socialization** of the compensation costs
- At the same time, expectedly, **IA profitability keeps rising** with increasing socialization, despite the negative overall welfare effect

Net consumer benefit

- **Net consumer welfare benefit relative to total volume of energy traded in DA (€/MWh)**



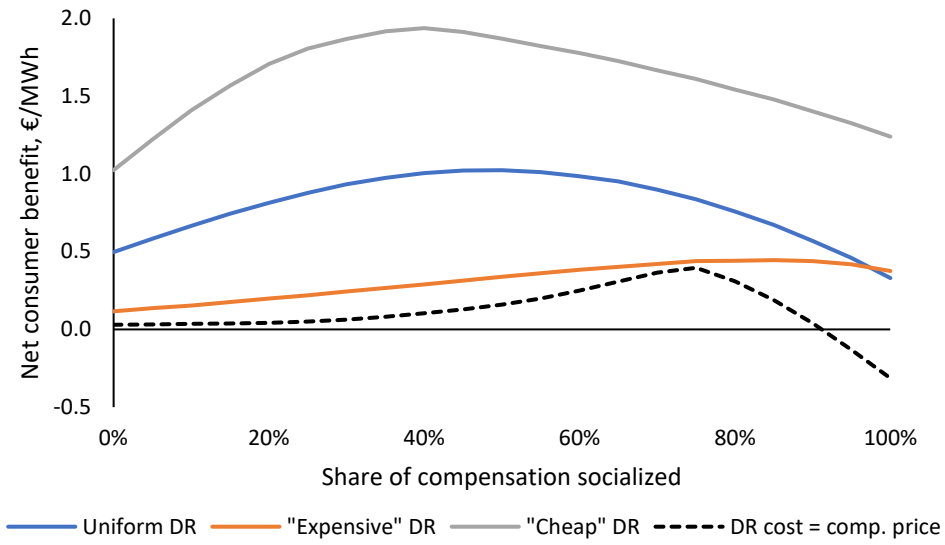
- **IA income per DR capacity (M€/MW)**



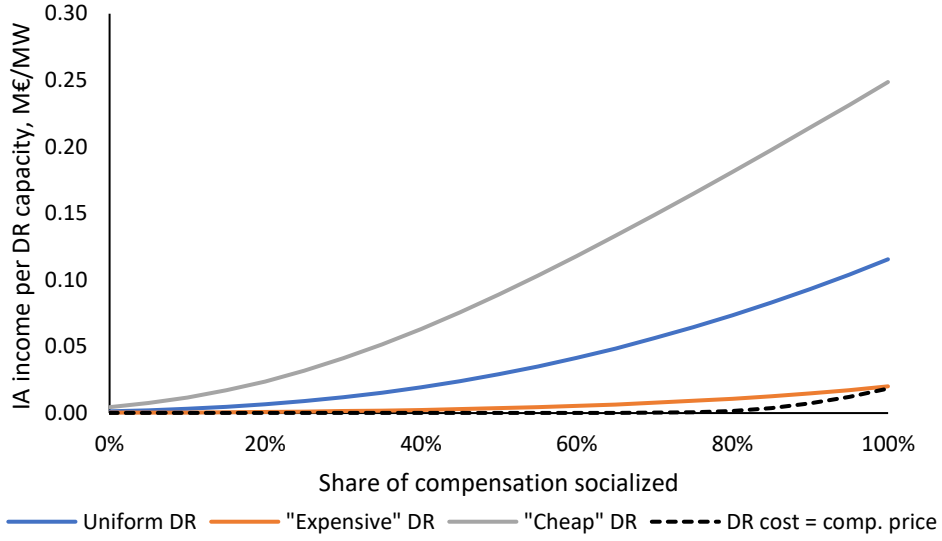
- View from **the consumer's perspective** (i.e., disregarding producer surplus loss).
- In general, it can be seen that that **socialization at about medium level** brings the largest net consumer benefit with low and medium DR activation costs, but generally larger activation costs bring the most benefit at larger level of socialization.
- Additionally, evidently, with expensive DR curve, **IAs have very limited business case** regardless of how much of the compensation is socialized, and, with low socialization, it is quite limited also for uniform and cheap DR curves.

Net consumer benefit

- **Net consumer benefit relative to total volume of energy traded in DA (€/MWh)**



- **IA income per DR capacity (M€/MW)**



- View from **the consumer's perspective** (i.e., disregarding producer surplus loss).
- The **dashed line** represents a case, when the IA DR has a **cost equal to the full compensation price** (max volume set at 2.5 GWh), i.e., it is a one-step curve.

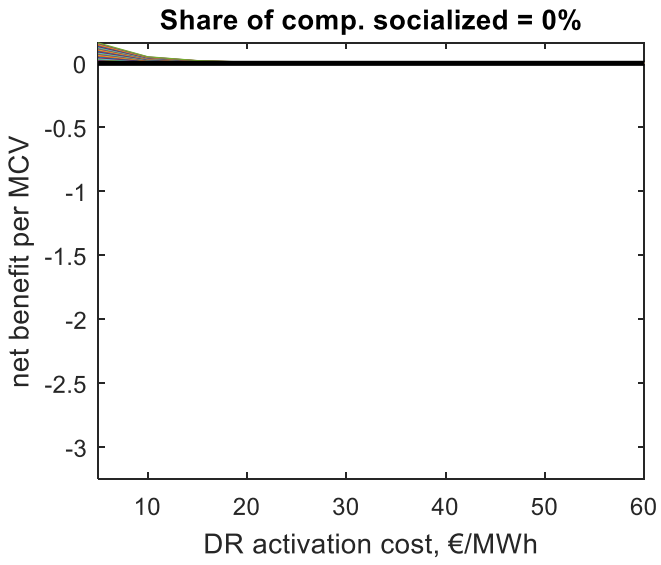
Additional scenarios

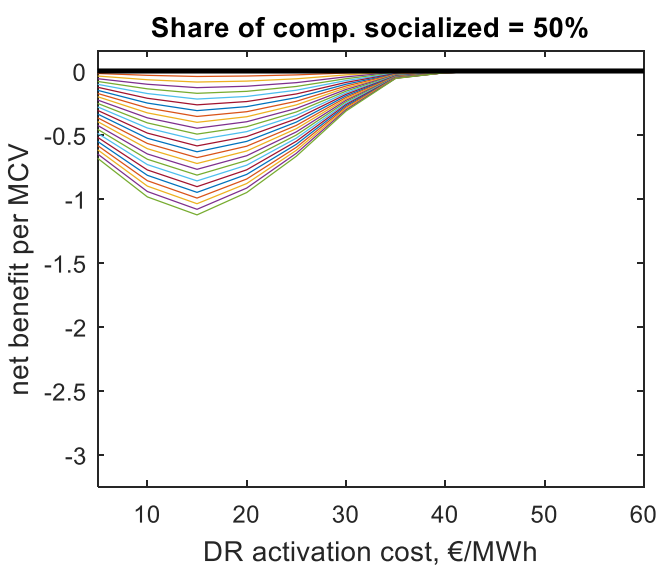
Sensitivities are performed on **simple DR curves** (with only one price-quantity pair), varying these assumptions:

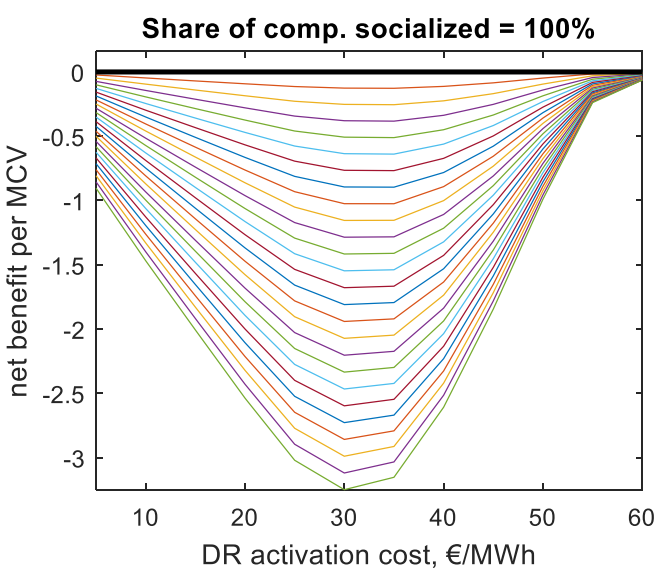
- **IA DR max. bid volume** (v, V) is varied from **0 to 2.5 GWh/h** with an increment of 0.1 GWh/h;
- **DR activation price** (p, P) is varied from **5 to 60 €/MWh** with an increment of 5 €/MWh;
- **Share of compensation socialized** (s, S) is varied from **0 to 100%** with an increment of 25%.
- Only **consumption-reducing** DR is considered, and it can be activated in any (and theoretically all) of the hours-of-the-year, if the price allows it. Hence why most results are displayed per unit of energy basis (as expected values), and not in total values.

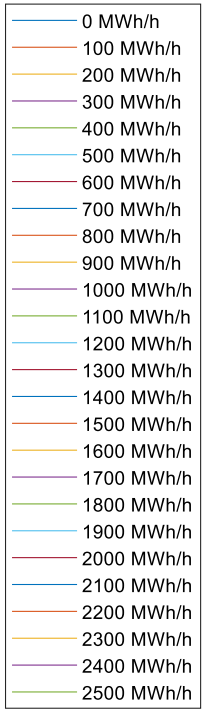
Overall net welfare benefit (varied assumptions)

Sum of change in producer & consumer surplus less compensation costs and impact on DR welfare shows miniscule overall benefit with full compensation and negative overall benefit at any level of socialization



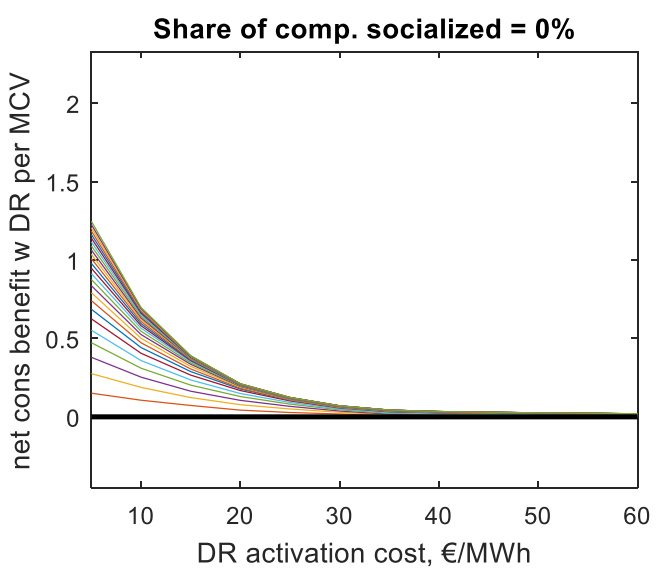


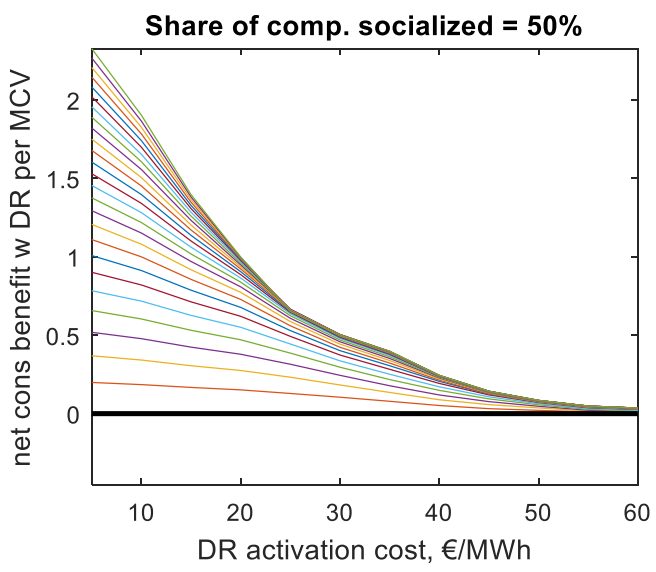


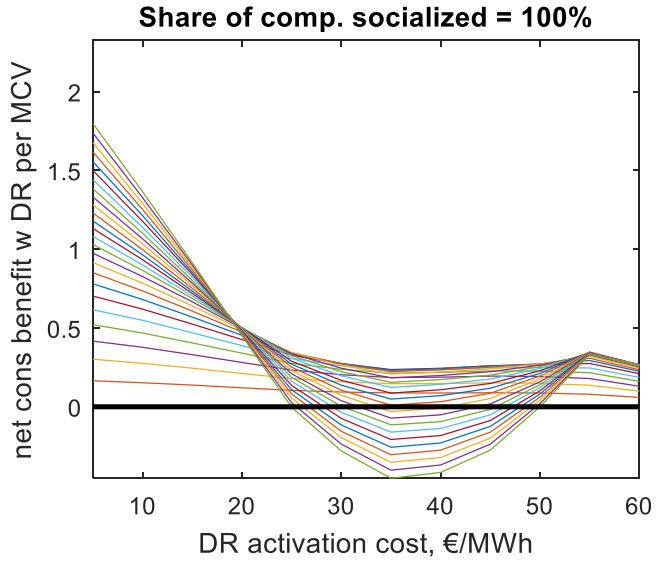


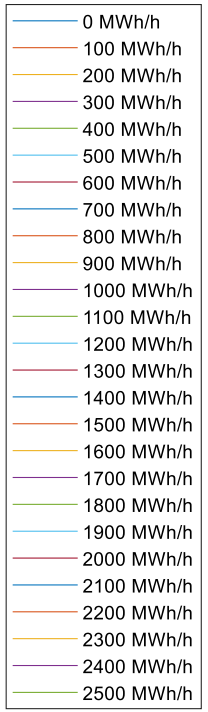
Net consumer benefit (varied assumptions)

However, looking from **the consumer perspective** (change in consumer surplus, plus net change in DR consumer welfare, minus compensation), the benefit is positive (*but with caveats*)









Limitations

Data availability **limits the model scope** to calculating the system price, likely **leading to underestimation** of IA created benefits, as, in practice, the price has more variability in most of the bidding zones.

Impact of IA activities on the **behavior of other market participants** not considered, likely **leading to overestimation** of IA activities.

The **net flows** with other areas remain unaffected, as do the block bids.

The **data-driven** approach is limited to **historical** market situations.

Baselining and other IA DR **practical implementation issues** are not addressed in the calculations.

Conclusions

- Aggregated market data on supply and demand bids can be used to **evaluate the potential impact** of IA entry in the market and estimate the **consequences of compensation socialization**. Our major assumption was that price reductions due to DR activity are not corrected by free entry.
- In our case study we have found that even under this strong assumption, socialization creates an **overall negative effect** on the total welfare compared to our benchmark of no additional entry of DR via IAs.
- However, since part of the producer surplus is transferred to the consumers (via market price reduction), from the consumer's perspective, **IA activities bring benefits** (*even when considering the induced underconsumption of IA DR consumers*). In case of market power, the welfare loss might be limited compared to the gain of consumer surplus.
- Evidently, **over-incentivizing** IAs can lead to consumer benefit reductions; in certain conditions even creating negative overall benefit to them.
- At the same time, under requirement to pay full compensation, the business case of IAs in the studied day-ahead market is **questionable**, i.e., more price volatility would likely be required.
- The current study should be **extended** to also allow for **load-increasing** DR (*i.e., by the IAs purchasing from the day-ahead market the energy for the increased load*).

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Thank you!

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