Which Specific Value of Demand-Response Mechanisms in Active Distribution Grids?

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Outline

- **Introduction**
- Theoretical background and motivations
- The model
- Preliminary results
- Conclusions and further developments
- Appendices

Introduction

- Smart grids technologies will deeply modify distribution and final consumers' environment.
- Consumers' adaptation to signals:
  - *Information.*
  - *Prices.*
- Potentially, a new "era" in electricity markets as demand is usually seen as inelastic.
- In this context, Demand Response (DR) programs to be developed, but:
  - *Which level of available DR?*
  - *Which pricing schemes to value DR?*
  - *Which allocation between "actors" of the power "value chain"?*

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Dynamic pricing and elasticity

- Lijensen (2007):
  - *Consumers of electricity are captive in the short run.*
- Haney & al. (2009), Faruqui & Sergici (2010):
  - *Demand could be elastic with SG and DR.*
- Herter (2007):
  - *Consumers could be worse off with DR mechanisms (dynamic pricing, critical peak pricing (CPP)).*
  - *Consumers' anticipate greater electricity bills increase with the use of DR tools (also Park et al., 2014).*
- Léautier (2014):
  - *Marginal value of Real Time Price (RTP) decreases with the number of consumers "covered".*

Examples of signals and load reductions

- Indirect feedback (education, information campaigns):
  - *Rather limited impact.*
  - *0 to 7% load reduction.*
- Direct feedback (in home display, monitoring data from smart meters):
  - *More significant.*
  - *2 to 15% load reduction.*
- Dynamic pricing (with or without direct load control):
  - *Highest leverage.*
  - *Up to 50% load reduction for some periods.*

The pricing of DR

- Crampes and Léautier (2010):
  - *Consumers must pay for the baseline of their consumption.*
  - *DR must be paid at market price.*
- Chao (2011):
  - *Market price.*
  - *Second best pricing : difference between market price and retail rate.*
  - *Buying the baseline at market price.*
- Chao's (2011) main results:
  - *Buying the baseline is the most efficient to improve the welfare.*
  - *Second best pricing then follows.*

Motivations and main results

- Objectives:
  - *Study DR programs under different pricing schemes in the French context.*
- Approach:
  - *Computing model with EPEX market data to simulate actors' revenues.*
  - *Relationships between actors are those of Chao (2011).*
- Preliminary results:
  - *Demand response reductions are greater when DR is paid at market price.*
  - *To reduce peak demand, buying the baseline or second best pricing have the same impact; only allocations of revenues differ.*
  - *DR is profitable for welfare if total average costs are below 50€/MWh.*

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Mains assumptions

- Four categories of actors :
  - *Generators, suppliers, DR providers, consumers.*
  - *Revenue function combines purchases and sales of electricity.*
- Transfers of revenues from DR valorization between suppliers, DR providers and consumers.
- Consumers buy electricity at the retail rate (RR) whereas suppliers buy it at spot prices (P_s).
- DR providers:
  - *Sell the DR quantities at the market price*
  - *Allocate part of this revenue to suppliers (a) and consumers (b).*
- 10 levels of DR (DR1→DR10):
  - *From 0% to 40% of total demand.*

Three schemes of DR pricing (1/2)

- Case 1:
  - *« Market price »*
  - *DR at spot price (p_s)*
  - *$p_{DR} = p_s$ (with $p_s > 0$)*
- Case 2:
  - *« Buying the baseline »*
  - *Consumers buy their consumption baseline at RR*
  - *$p_{DR} = p_s$ (with $p_s > RR$)*
- Case 3 :
  - *« Second best price »*
  - *DR remuneration is the difference between spot price and retail rate*
  - *$p_{DR} = p_s - RR$ (with $p_s > RR$)*

Three schemes of DR pricing (2/2)

- In case 1, any load reduction is profitable for consumers.
- In case 2 and 3, consumers reduce their consumption if $P_s > RR$
- In case 2:
  - *They value their unit consumption at the RR because they buy the baseline.*
  - *If $P_s < RR$, they prefer to consume*
- In case 3:
  - *$P_s < RR$ leads to negative DR remuneration.*

Operators' revenues

- With positive market prices :
  - Generators

$$R_{Gen} = p_s \,.\, (Q - DR) - CT(Q)$$

  - Suppliers

$$R_{LSP} = (RR - p_s) \,.\, (Q - DR) + a \,.\, p_{DR} \,.\, DR + Baseline \text{ (in "case 2")}$$

  - DR Providers

$$R_{DRP} = p_s \,.\, DR - (a + b) \,.\, p_{DR} \,.\, DR$$

  - Consumers

$$CS = TS + b \,.\, p_{DR} \,.\, DR - Baseline \text{ (in "case 2")}$$

- (*NB: With negative market prices, no DR is observed*)

Data

- We use data EPEX for 2014.
  - *Hourly prices and hourly quantities.*
- Peak period is defined as hours 5PM to 8PM (“rush hours” from EPEX)
- We use these data :
  - to compute actor’s revenues in each pricing schemes;
  - to determine the “implicit” break even point (revenues divided by sales or consumed quantities).

Comparing “peak” vs “global” periods

- Peak demand represents ± 20% of the global demand (EPEX 2014)
- DR rate is higher in peak periods as profitable conditions are more satisfied.
- In each scheme, variations of revenues are less important if global periods are considered.
  - For example, losses for LSP are lower because they do not buy energy at $P_s > RR$.
- Differences of revenues between scenarios are lower with global demand.
  - Smoothing effect of a larger demand.

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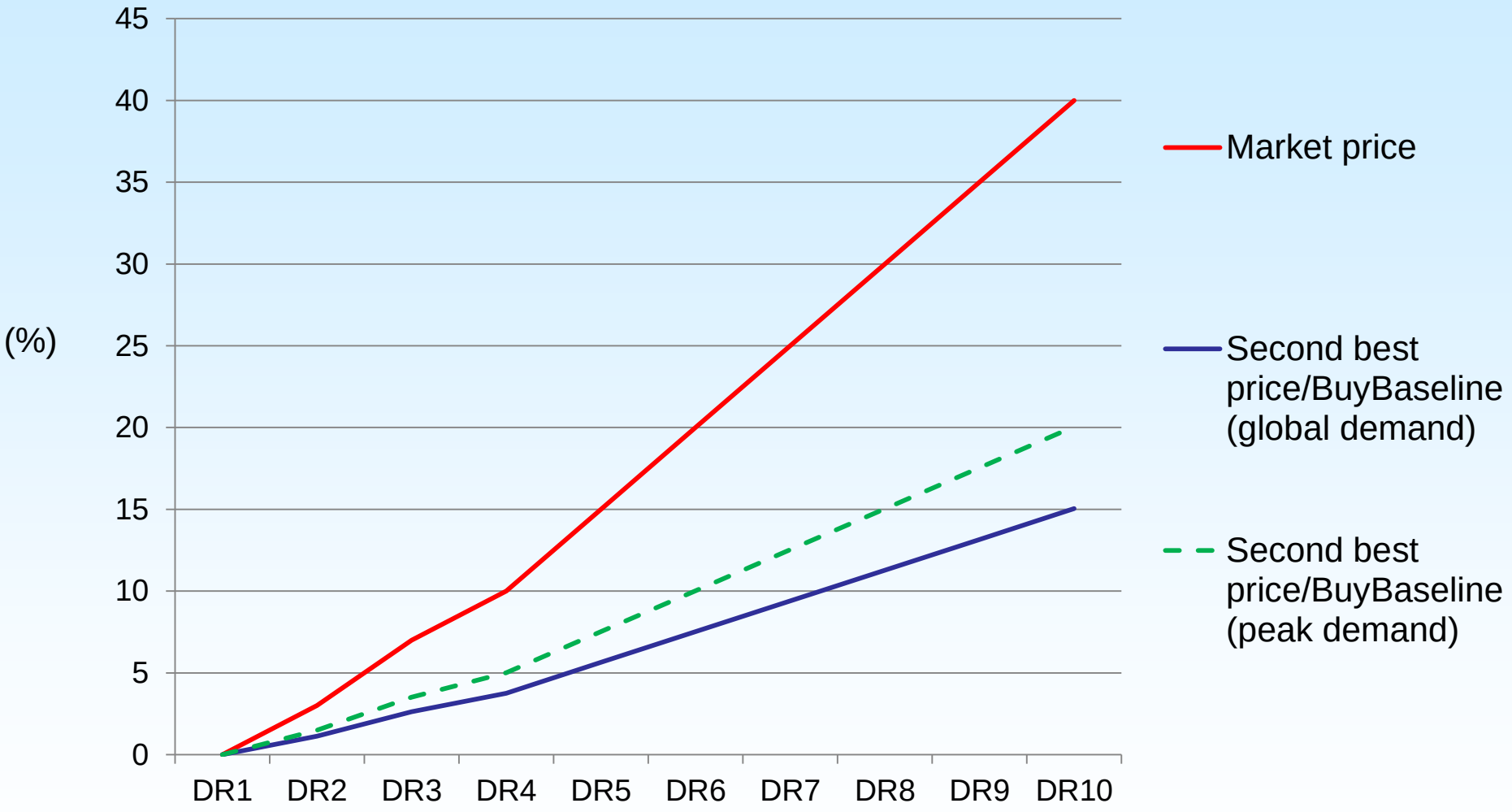
Intuitions

- Generators
  - ⏩ Direct revenues
  - ⏩ Potential transfers
- Suppliers
  - ⏩ Direct revenues
  - ⏩ Decrease of costs and losses, transfers, “buying baseline”
- DR Providers
  - ⏩ Transfers
  - ⏩ Revenues
- Consumers
  - ⏩ “buying baseline”
  - ⏩ Decrease of costs, transfers
- Welfare
  - ↗ Value induced by DR > negative effect

Results 1 : DR level

- DR quantities are higher under market price (case 1):
  - *Up to 40% of demand (both for "global" and "peak")*
- « Buy the baseline » (case 2) and « second best price » (case 3) lead to the same DR levels:
  - *Up to 15% of global demand*
  - *Up to 20% of peak demand*
- But these 2 cases differ by the redistribution of revenue between actors.

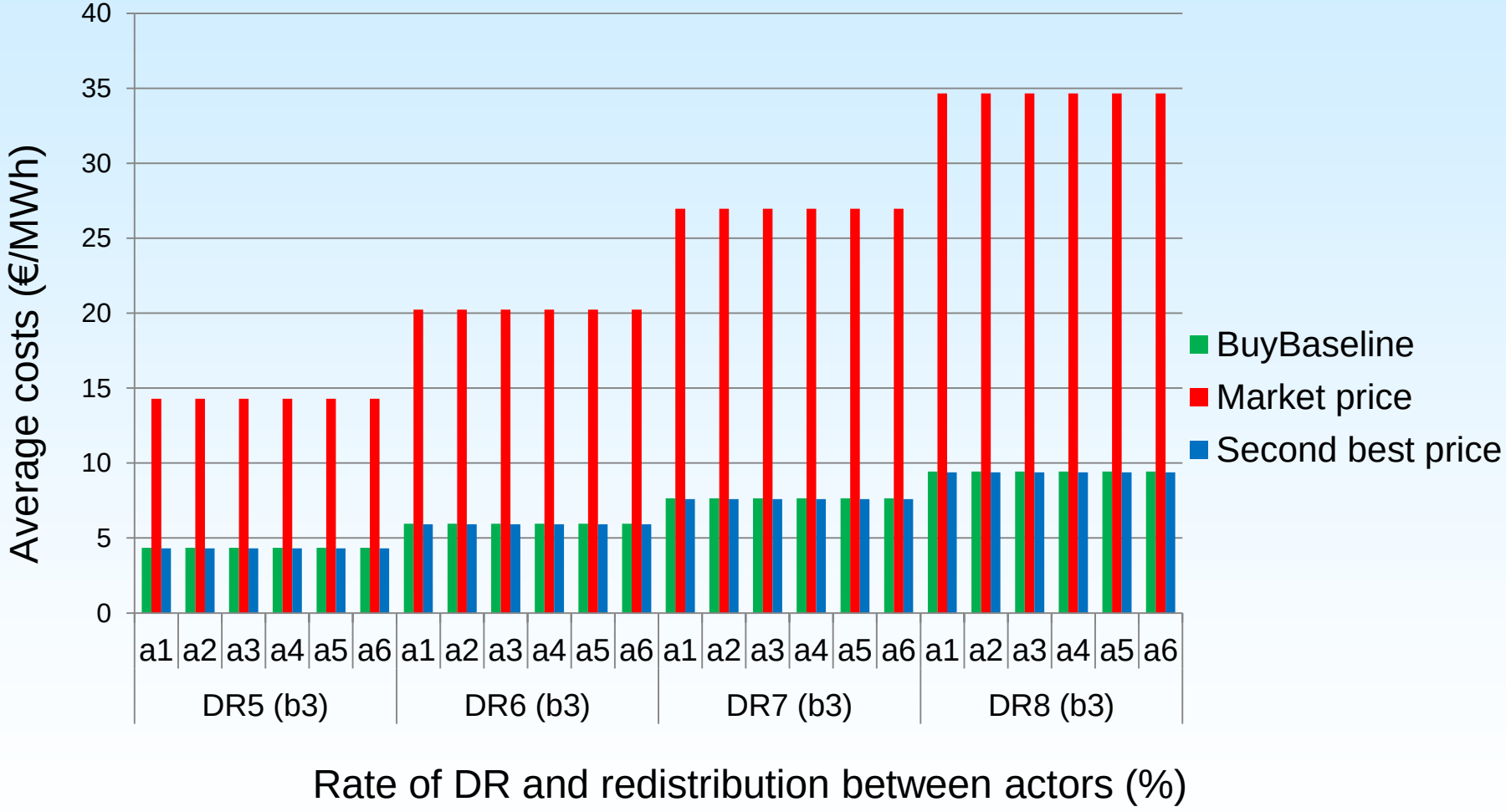
DR rate for each pricing scheme



Result 2 : impact on welfare

- When load-shedding is available, case 1 is the best scheme for welfare.
  - *Intuition : DR often occurs and is paid at market price.*
  - *Break even point up to 50 €/MWh to make DR strategies profitable in case .*
  - *Break even point up to 8 €/MWh for others schemes.*
- For peak hours, range is similar :
  - *Up to 53€/MWh in case 1,*
  - *Up to 13 €/MWh in others cases.*
- Consistent, in terms of best pricing scheme, with Crampes and Léautier (2010).

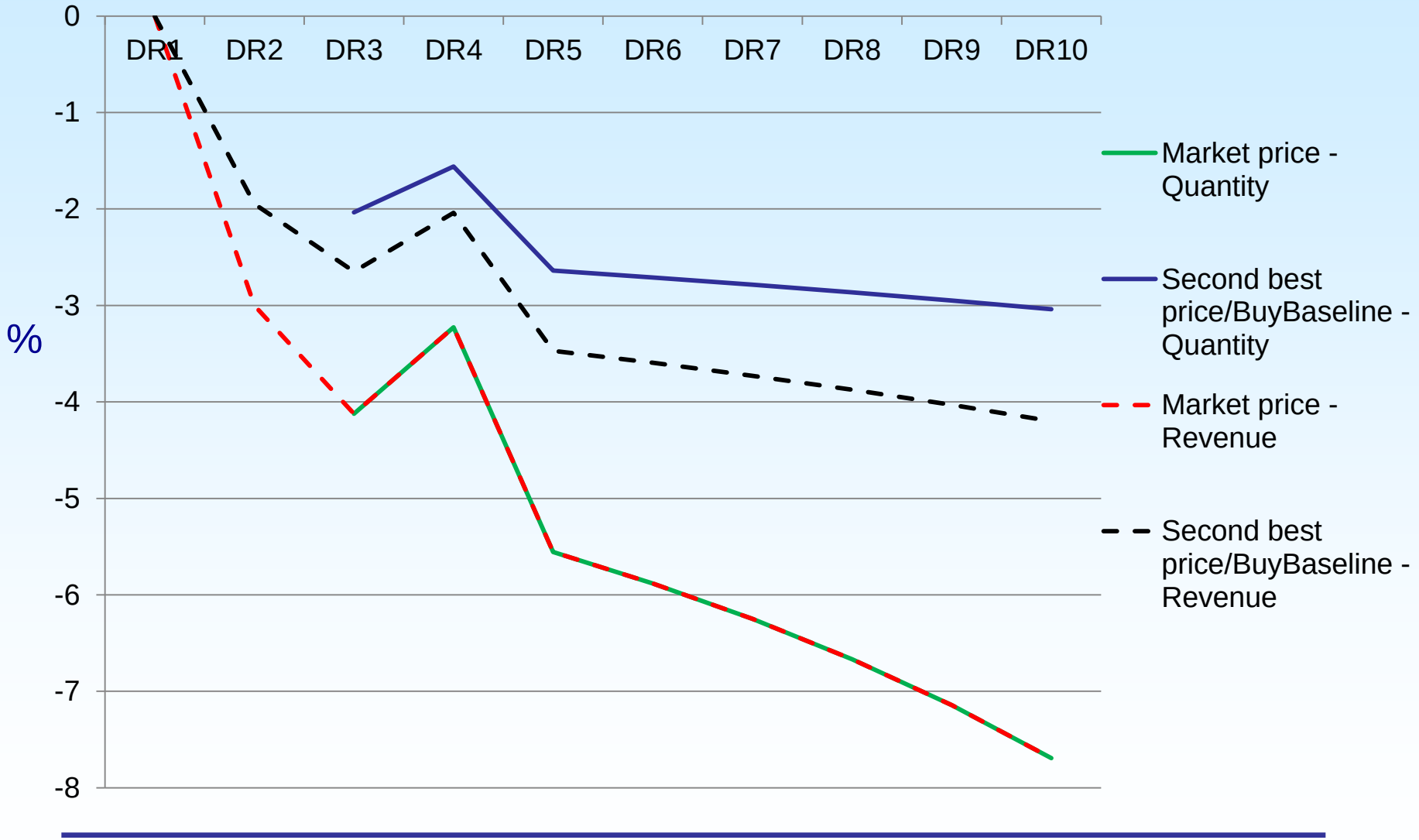
Break even for DR in peak hours: Welfare analysis



Results 3 : focus on generators

- DR imply transfers towards generators to compensate direct revenue losses (quantity effect).
- The break even is a decreasing function of the DR rate for case 2 and 3 :
  - *32 to 35€/MWh for global demand.*
  - *37 to 40 €/MWh for peak demand.*
- For case 1, break even is constant :
  - *35€/MWh for global demand.*
  - *40€/MWh for peak demand.*

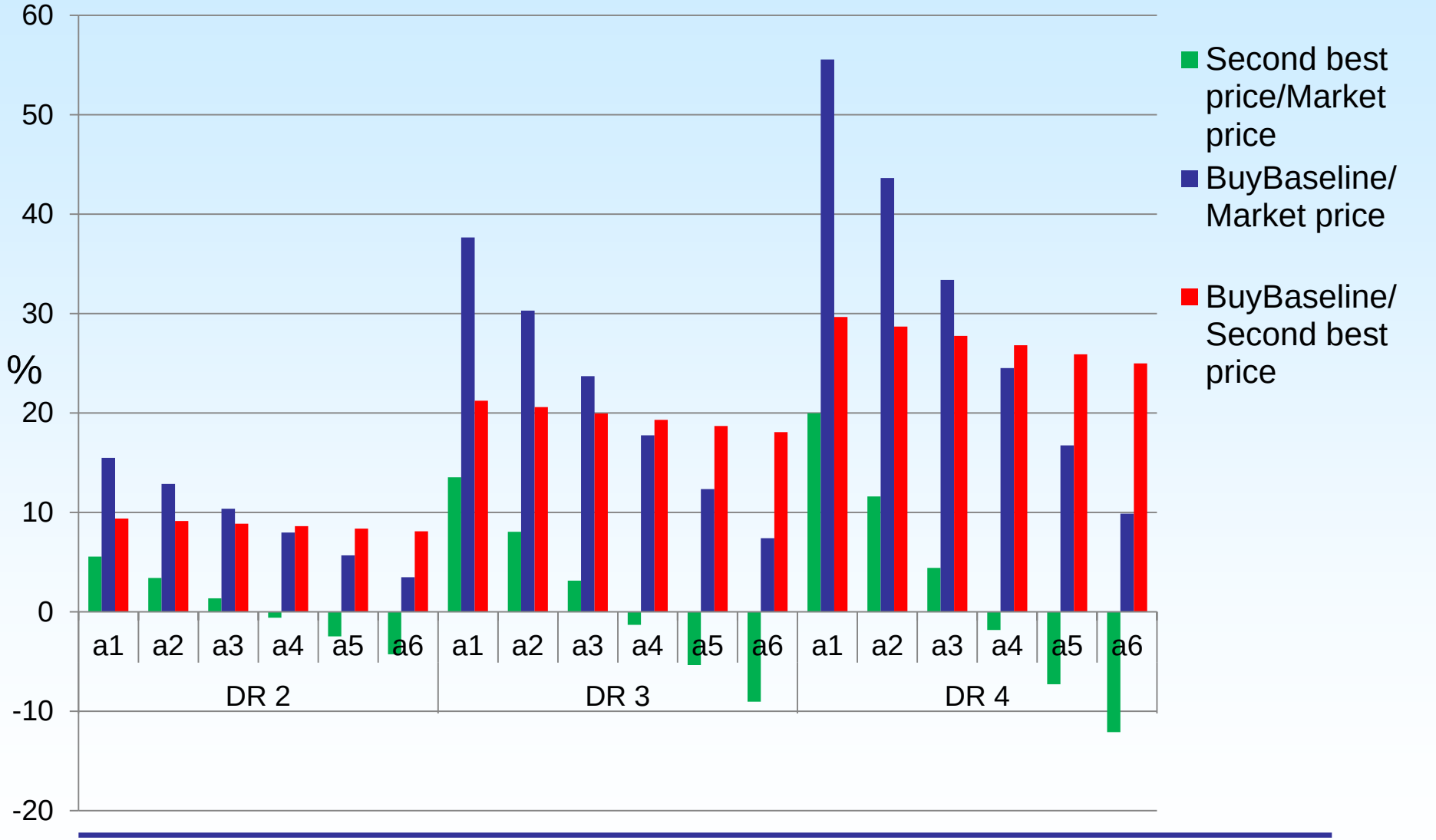
Impact on generators' revenues for each scheme (no transfer)



Results 4 : case 2 vs case 3 (suppliers)

- For suppliers :
  - *Case 2 leads to greater revenues:*
    - Up to 30% for global hours
    - Higher than 100% for only peak hours
  - *Break even:*
    - Up to 5€/MWh (case 3) or up to 8€/MWh (case 2) for global hours,
    - Up to 4€/MWh (case 3) or up to 12€/MWh (case 2) for peak hours,
  - *Intuition :*
    - Buying the baseline means additional revenues for suppliers.
    - Moreover, DR is paid at market price in case 2, whereas it is paid at second best price in case 3.
    - Thus redistribution of DR revenues is higher in case 2.

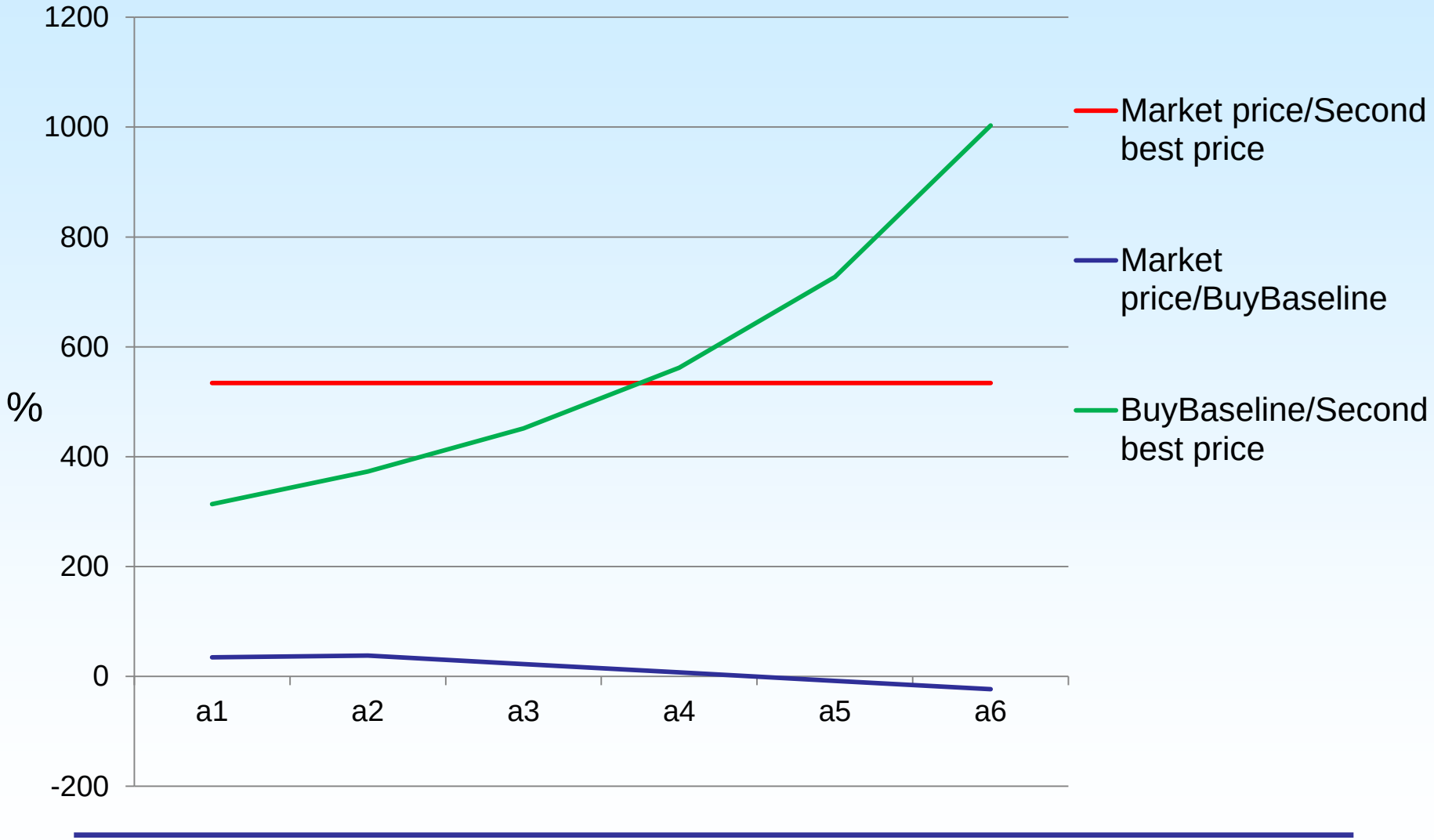
Variations of suppliers' revenues between pricing schemes (global demand): DR2 to DR4



Results 5 : case 2 vs case 3 (DRP)

- For DRP :
  - *Case 2 leads to higher revenues*
    - Higher than 400% for global hours.
    - Higher that 100 % for only peak hours.
  - *Break even:*
    - Up to 10€/MWh (case 3) or up to 50€/MWh (case 2) for global hours.
    - Up to 12€/MWh (case 3) or up to 52€/MWh (case 2) for peak hours.
  - *Intuition :*
    - DRP do not have to distribute DR revenue to suppliers because of the purchase of the baseline by consumers.
    - Thus, its revenues increase.

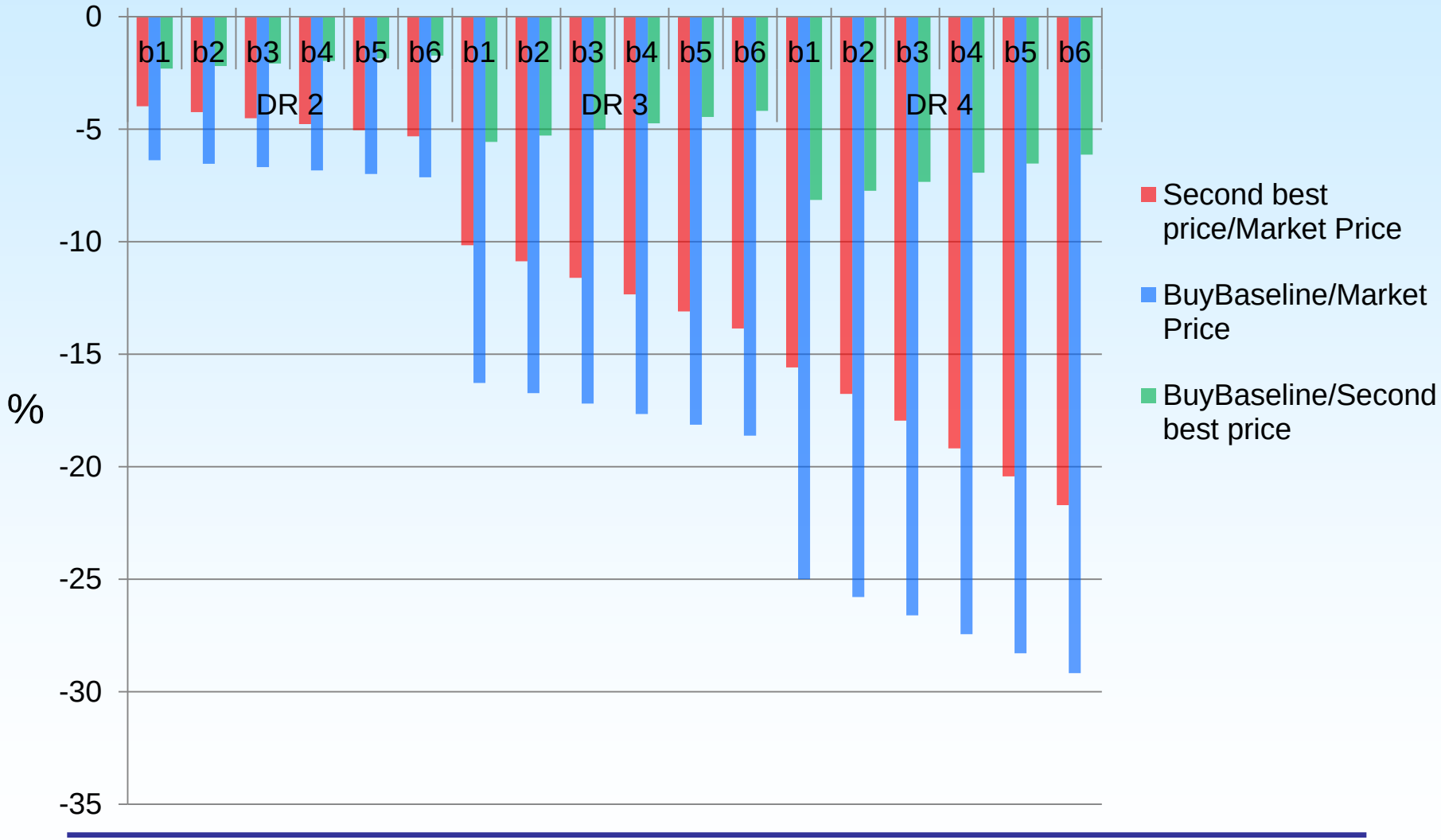
DRP's revenues between pricing schemes: Peak hours



Results 6 : case 2 vs case 3 (consumers)

- For consumers:
  - *The contrary to the two others actors.*
  - *Case 3 leads to higher revenues*
    - Up to 8% for global hours
    - Up to 66% for only peak hours
  - *Intuition : consumers do not buy the baseline (lower costs).*
  - To make DR strategies profitable, surplus by unit consumed quantity must be higher than :
    - Up to 39€/MWh (case 3) or up to 40€/MWh (case 2) for global hours,
    - Up to 39€/MWh (case 3) or up to 50€/MWh (case 2) for peak hours,

Consumer's revenue between pricing schemes: global demand



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Conclusion

- Very preliminary results to be “refined”
- DR pricing schemes impact the level of available DR.
- Promoting DR programs with appropriate pricing schemes could improve the welfare.
- Allocation of DR revenues:
  - *important to combine opposed interests*
  - *and consumers’ fears of increasing bills.*
- The break even point is “high” in some cases…

Further developments

- Introduction of generation costs and consumers' surplus with supply and demand curves from EPEX.
- Simulation with an impact of DR on the fixing procedure (with the use of supply and demand curves).
- Demand segmentation (all consumers do not have the same level of available DR quantities).
- Splitting hours of the days in different periods to implement load-shifting and the rebound effects.
- Introduction of the valorization of DR on balancing market.
- The TSO/DSO are not included (potential impact on CAPEX and OPEX and, then, on DR benefits)

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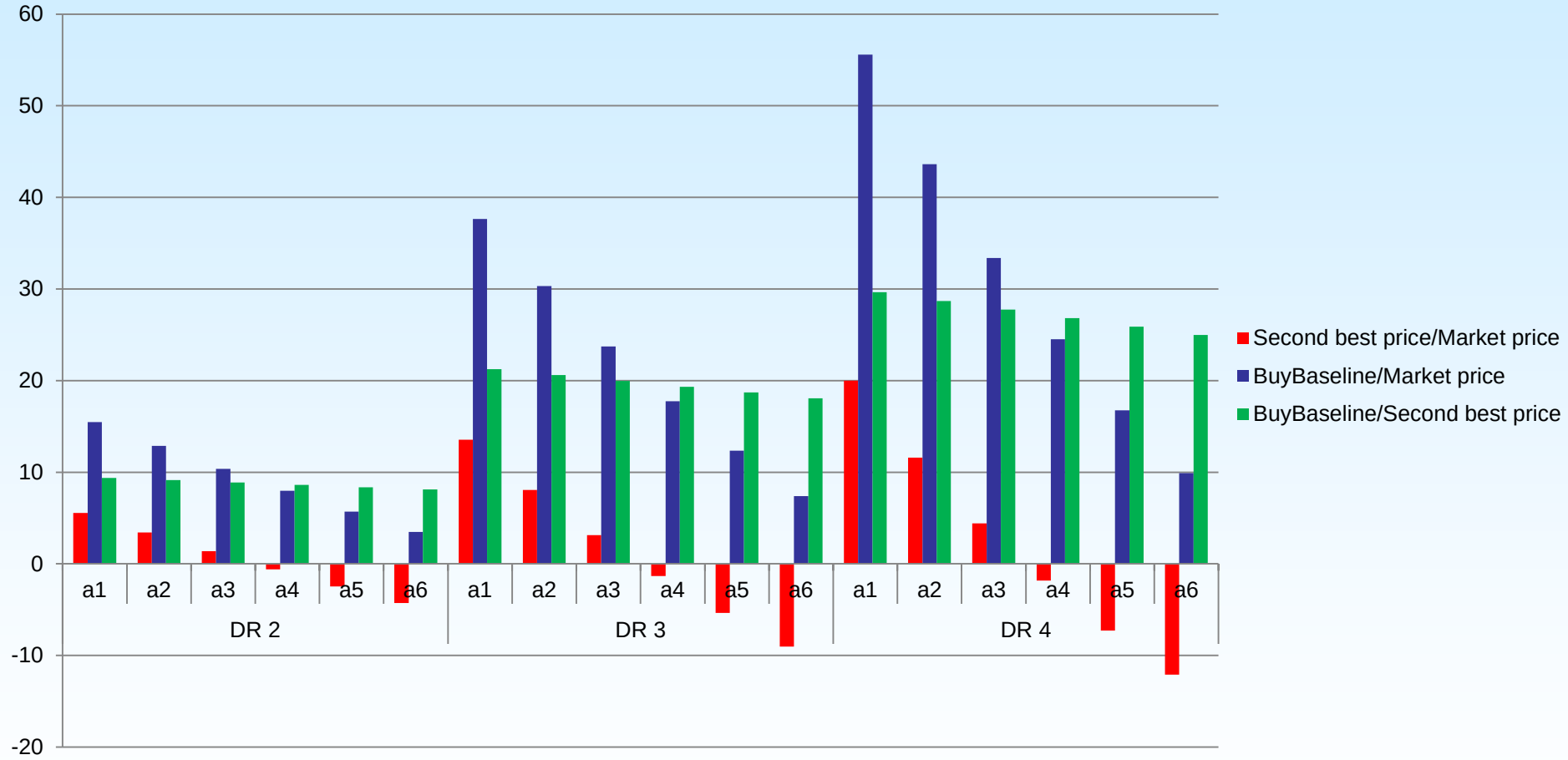
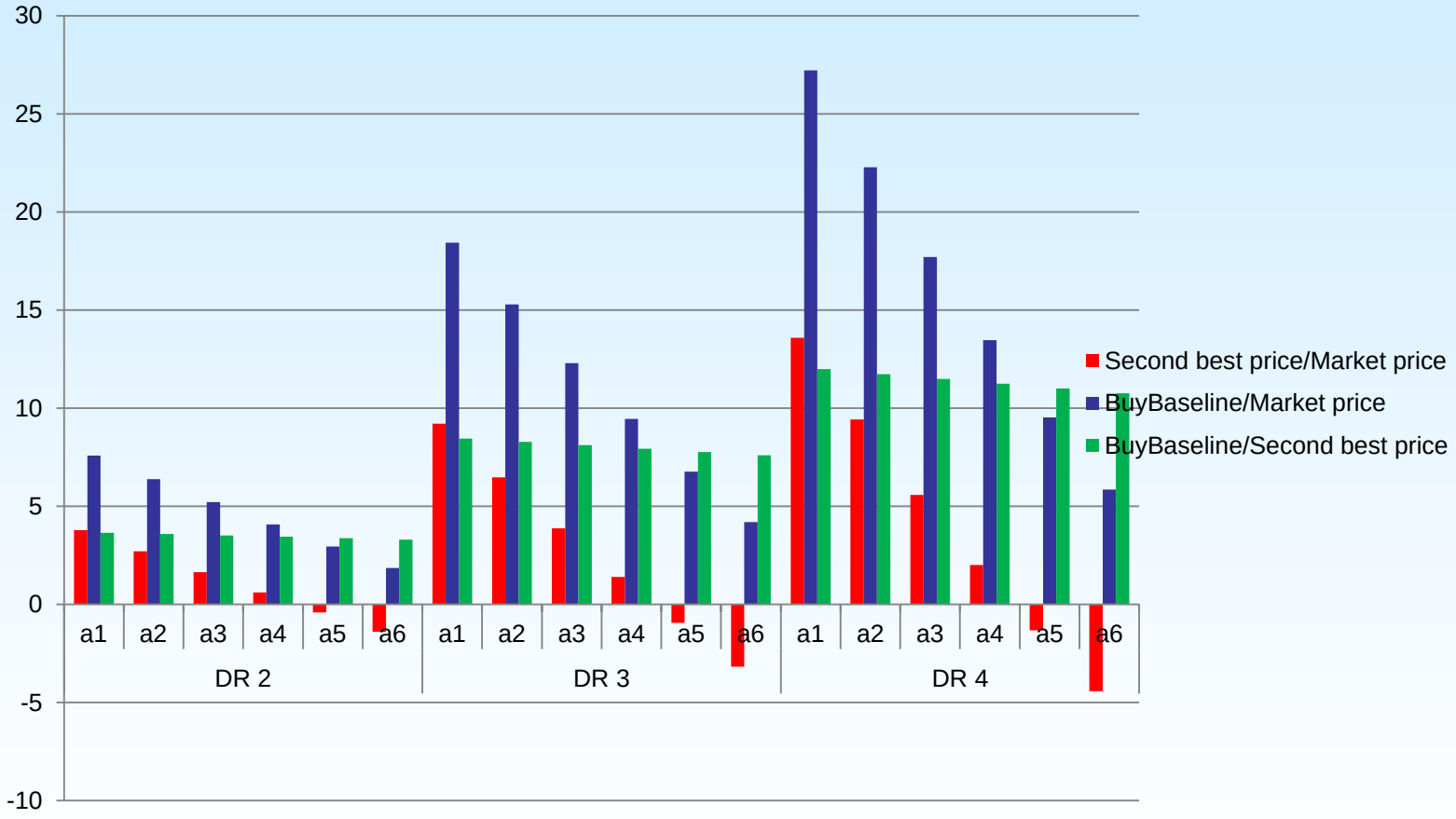
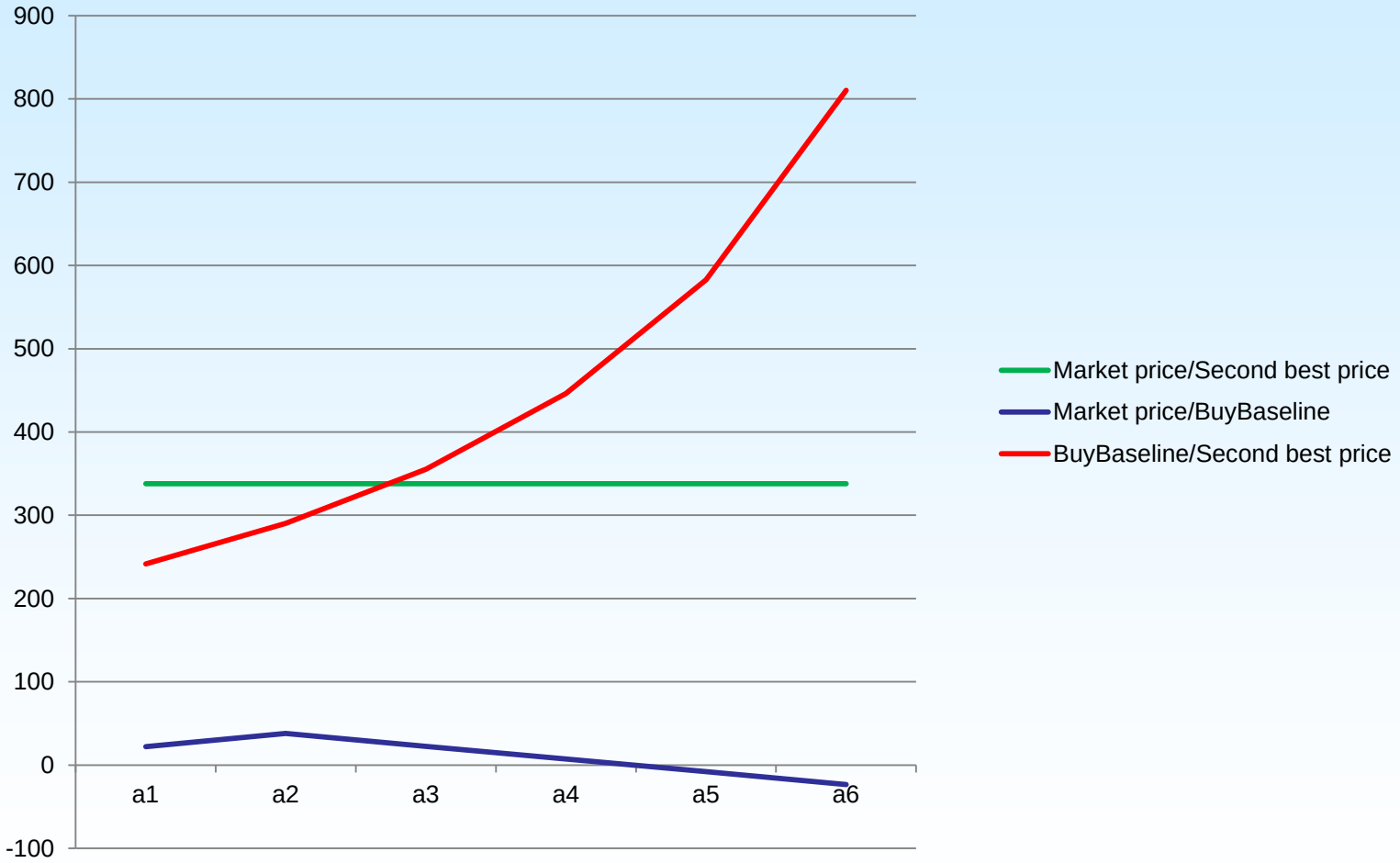
≠ of suppliers' revenues between pricing schemes (global demand) - DR2 to DR4 - RR=35€/MWh



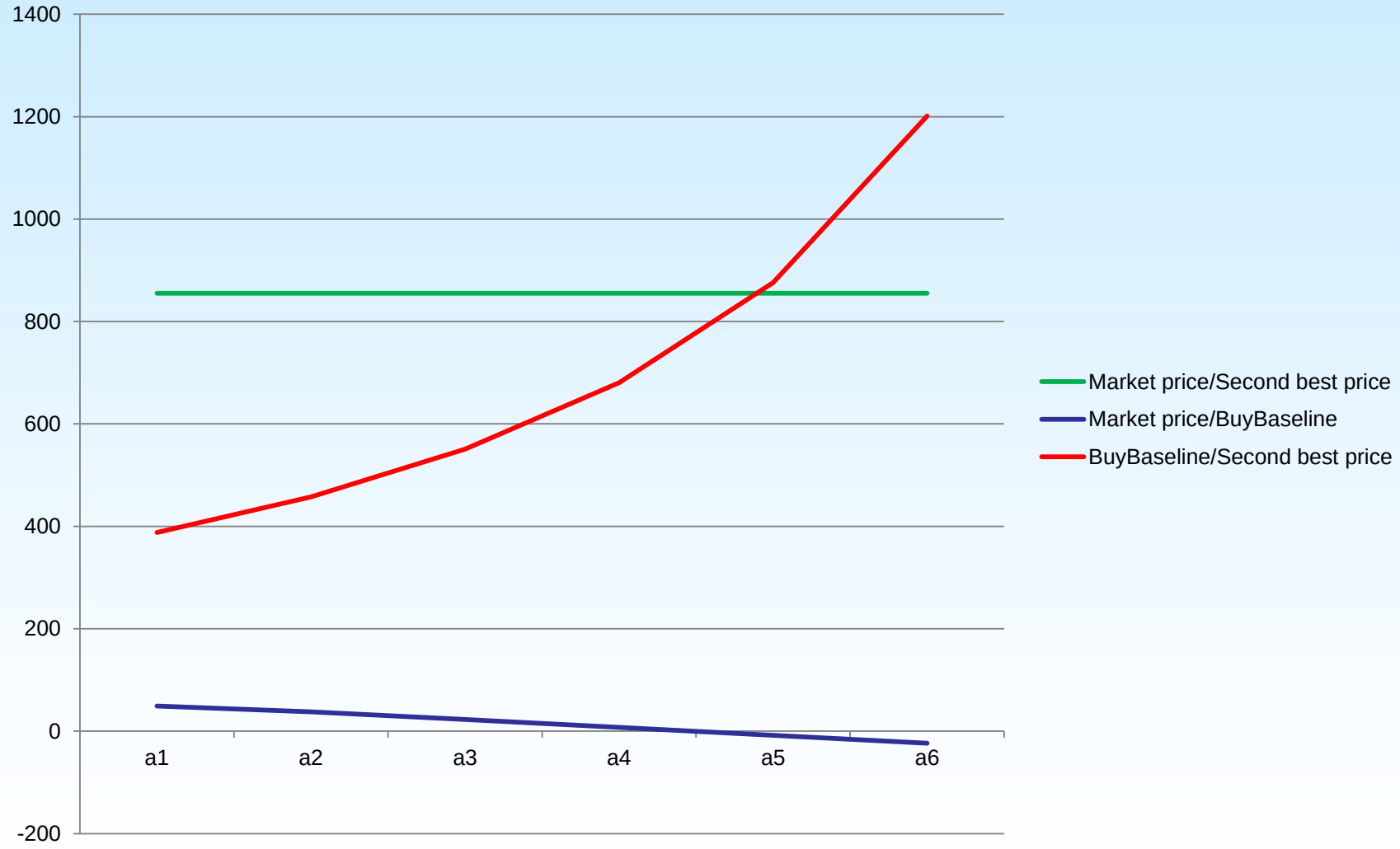
≠ of suppliers' revenues between pricing scenario (global demand) - DR2 to DR4 - RR=45€



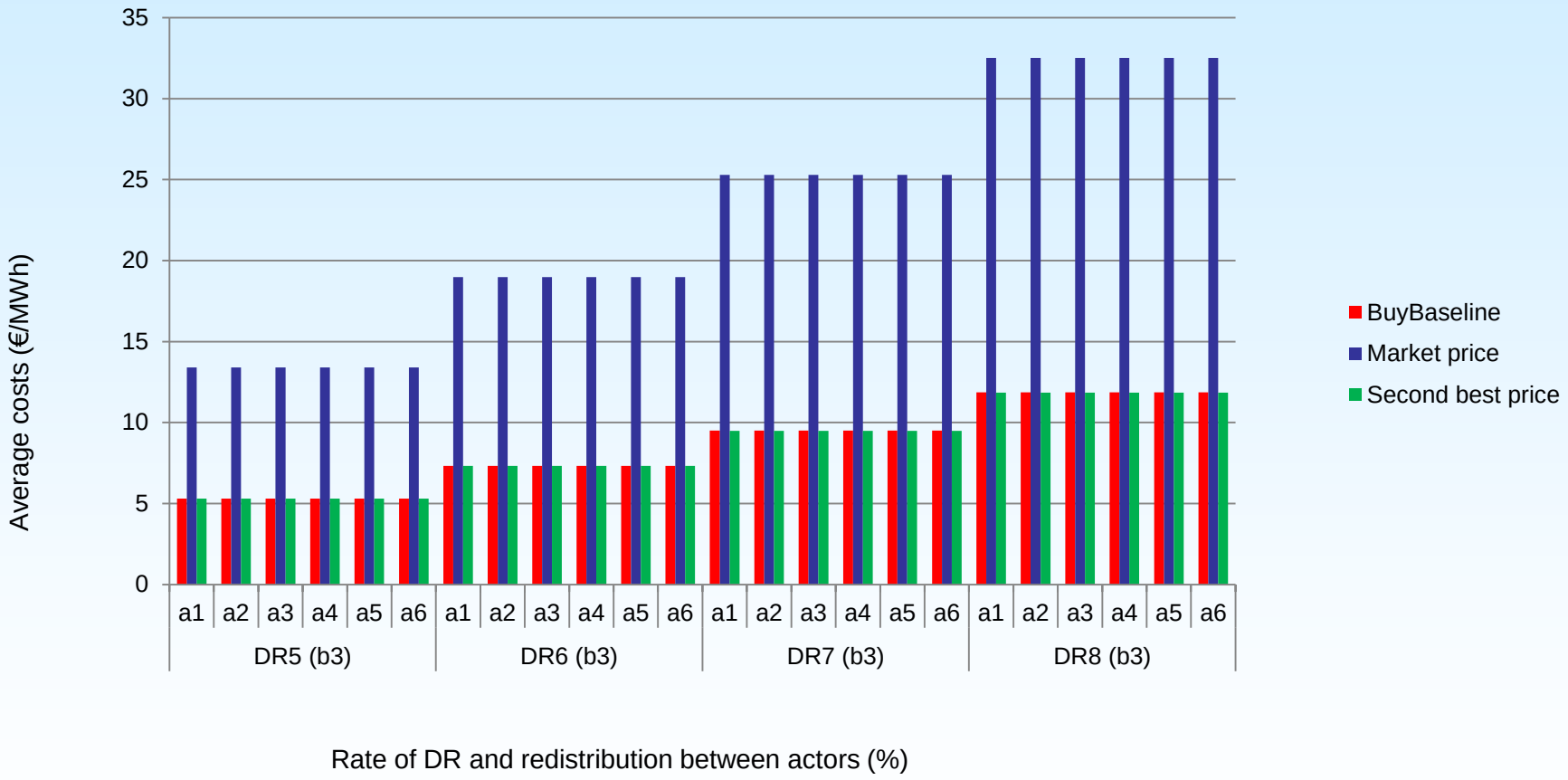
Evolution of DRP's revenues between pricing scenarios (%) - Peak hours - RR=35 €/MWh



Evolution of DRP's revenues between pricing scenarios (%) - Peak hours - RR=45 €/MWh



Average costs of profitability for DR in peak hours- Welfare analysis- RR=35 €/MWh



References

- Chao H. P., (2010). "Price responsive demand management for smart grid world". Electricity Journal, vol. 23, n° 1, pp. 7-20.
- Chao H. P., (2011). "Demand Response in wholesale electricity markets: the choice of customer baseline". Journal of Regulatory Economics, vol. 39, n° 1, p. 68- 88.
- Crampes C., Léautier T.O., (2010). Dispatching et effacement de demande. Toulouse : Institut d'Economie Industrielle.
- Faruqui, A., Sergici, S., (2010). Household response to dynamic pricing of electricity: a survey of 15 experiments. J. Regul. Econ. 38 (2)
- Herter, K. (2007).Residential implementation of critical-peak pricing of electricity, Energy Policy, 35:4, April, 2121-2130.
- Haney, A.B., Jamasb, T., Pollitt, M.G., (2009). Smart Metering and Electricity Demand: Technology, Economics and International Experience. Electricity Policy Research Group, Cambridge, Working Paper EPRG0903.
- Lijesen Mark G., (2007) The real-time price elasticity of electricity, Energy Economics, Volume 29, Issue 2..
- Park, C-K., Kim H-J., Kim Y-S. (2014), "A study factor enhancing smart grid consumer engagement", Energy Policy, 72.

Thanks for your attention