FIRM SUPPLY OF DEMAND RESOURCES AND CRM COST ALLOCATION

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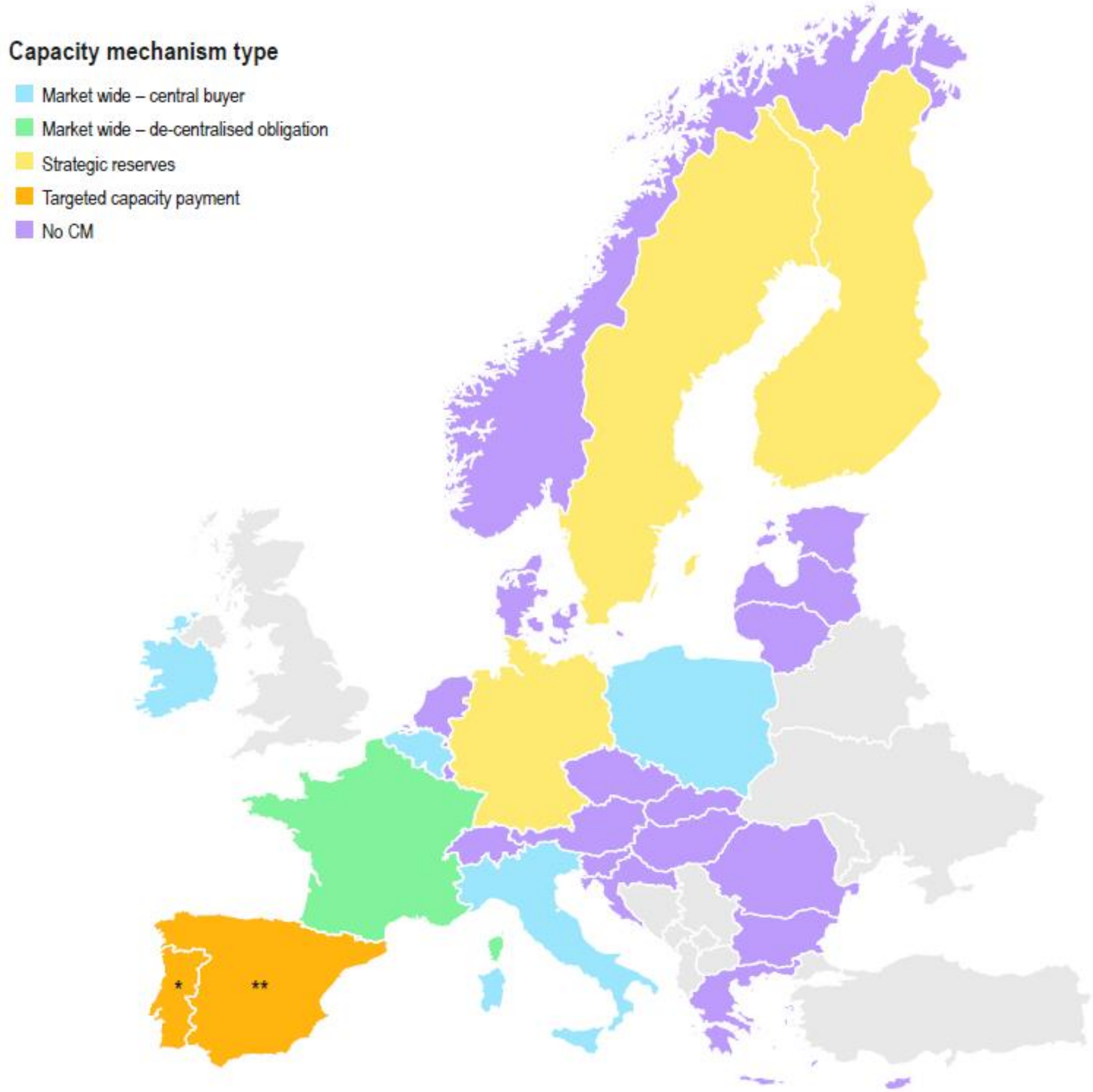
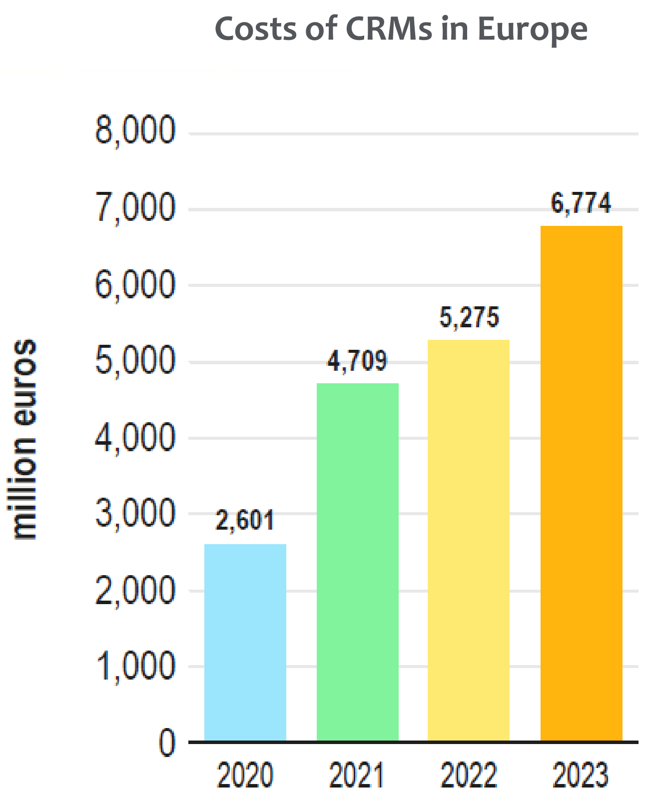
Context and theoretical framework

Capacity mechanisms in EU



ACER, 2022. ACER Security of EU electricity supply in 2021: Report on Member States approaches to assess and ensure adequacy

Increase of CRM costs



1

Table 4: Cost recovery method per MS with capacity payments

Cost recovery	Countries
Special levy to consumers	BE
Network tariffs	BG (availability), DE, FI, PL, PT
Pass-through to suppliers	ES, FR, GR, IE
Pass-through to BRPs	BG (energy), IT, SE

2

1. ACER, 2022. ACER Security of EU electricity supply in 2021: Report on Member States approaches to assess and ensure adequacy
2. ACER, 2022. ACER Market Monitoring Report 2020 – Electricity Wholesale Market Volume

Increase of DR participation

Contracted DR resources in CRM in France

Tender for year	Contracted volume (MW)	Remuneration (euros/ MW)
2018	733	24,000
2019	590	26,800
2020	770	24,400
2021	1,366	55,700
2022	1,982	59,600

ACER, 2022. ACER Security of EU electricity supply in 2021: Report on Member States approaches to assess and ensure adequacy

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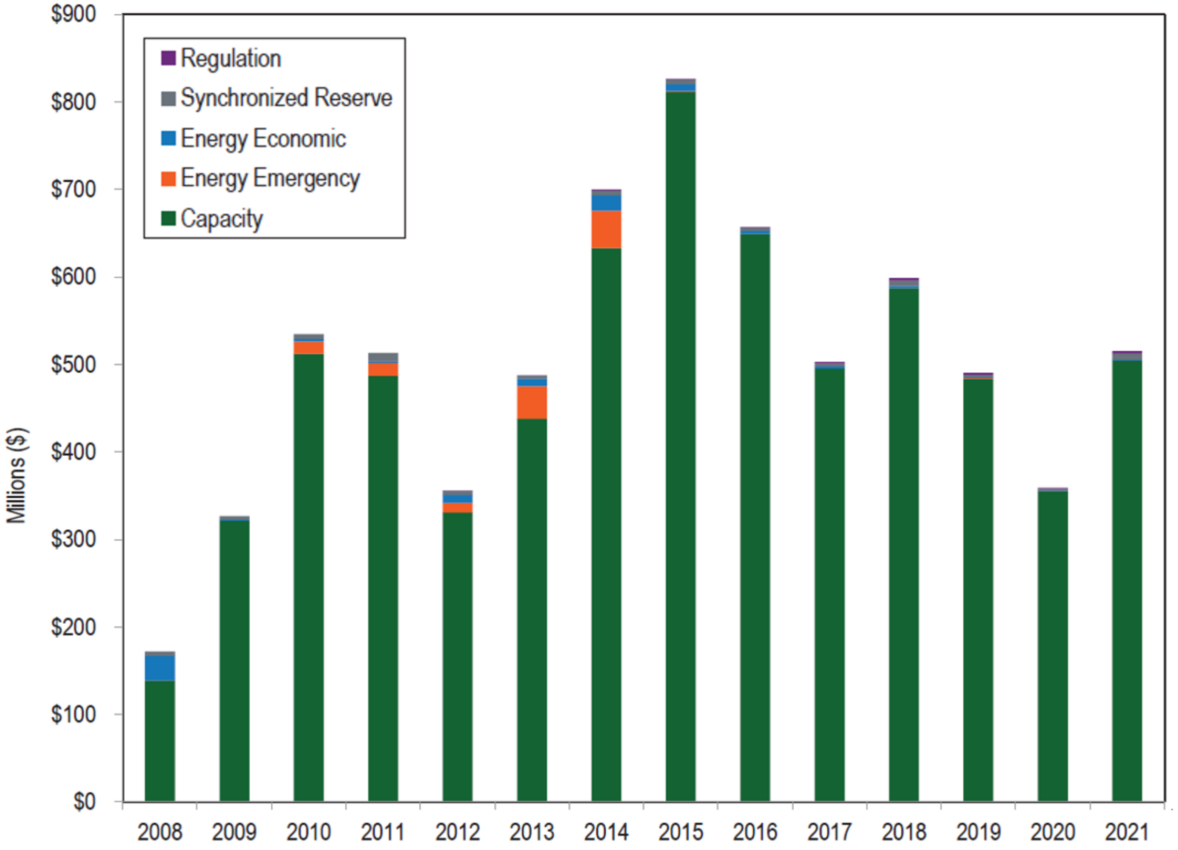
Increase of DR participation

Evolution of demand resources' income in PJM



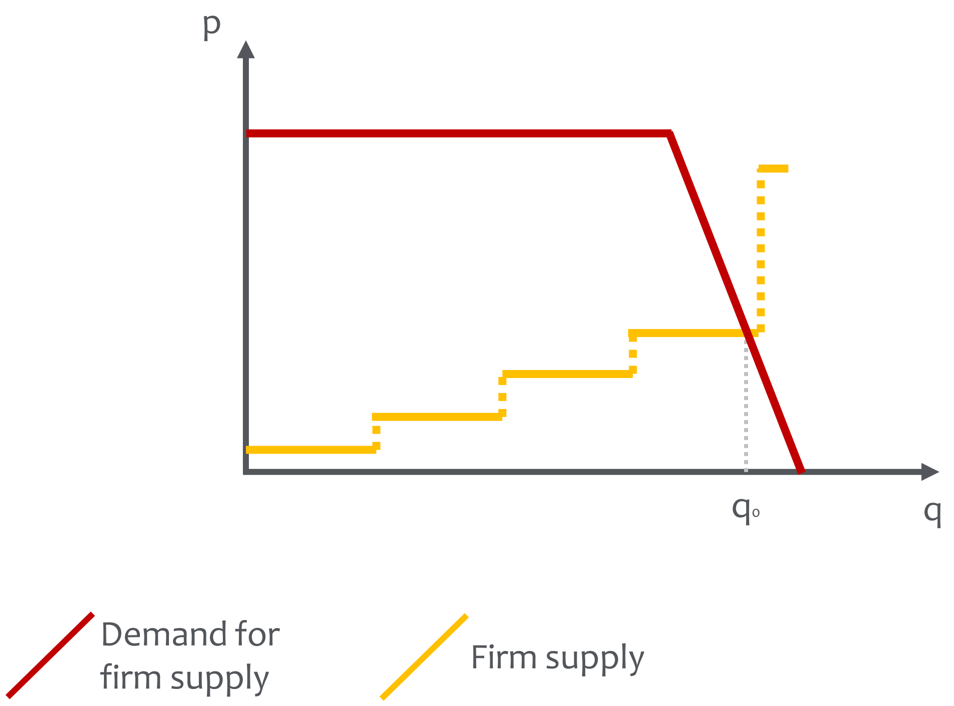
PJM, 2021. PJM State of the market – 2021. Technical report.

Duality of demand resources

- Electricity consumers must bear the costs of the CRM
  - How do we assign the CRM costs?
- Consumers can also act as demand response, providing adequacy
  - How do we define demand response's firm supply?
- If not defined correctly, these two elements could lead to arbitrage opportunities

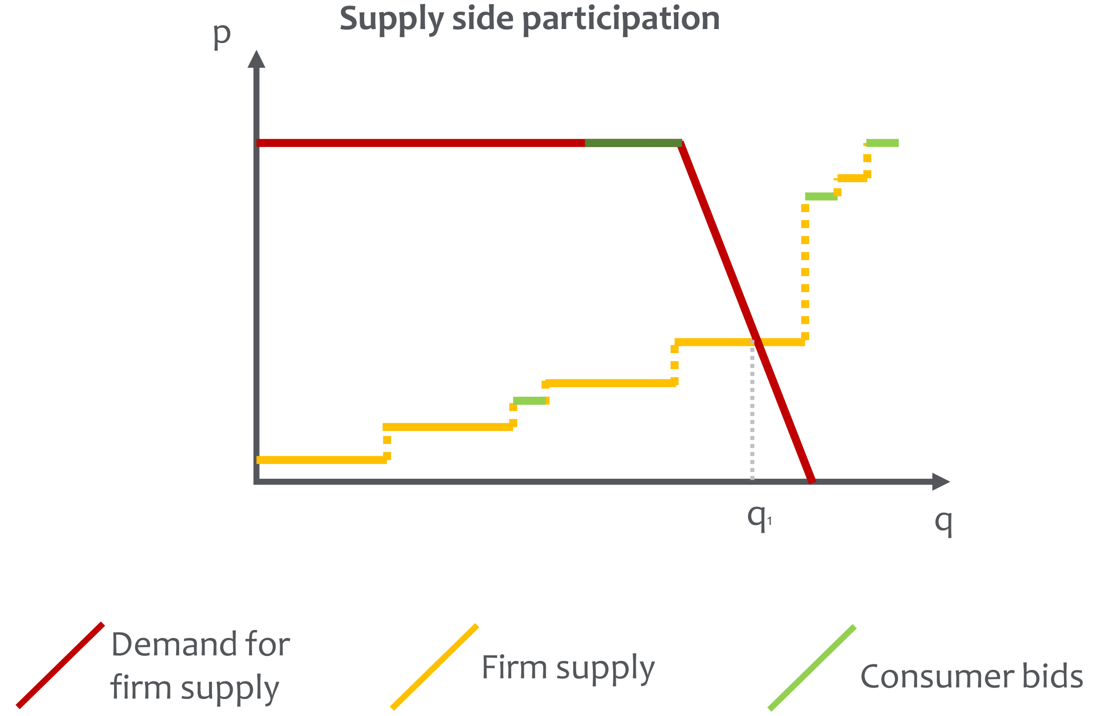
Two sides of the same coin

Example with a CRM auction



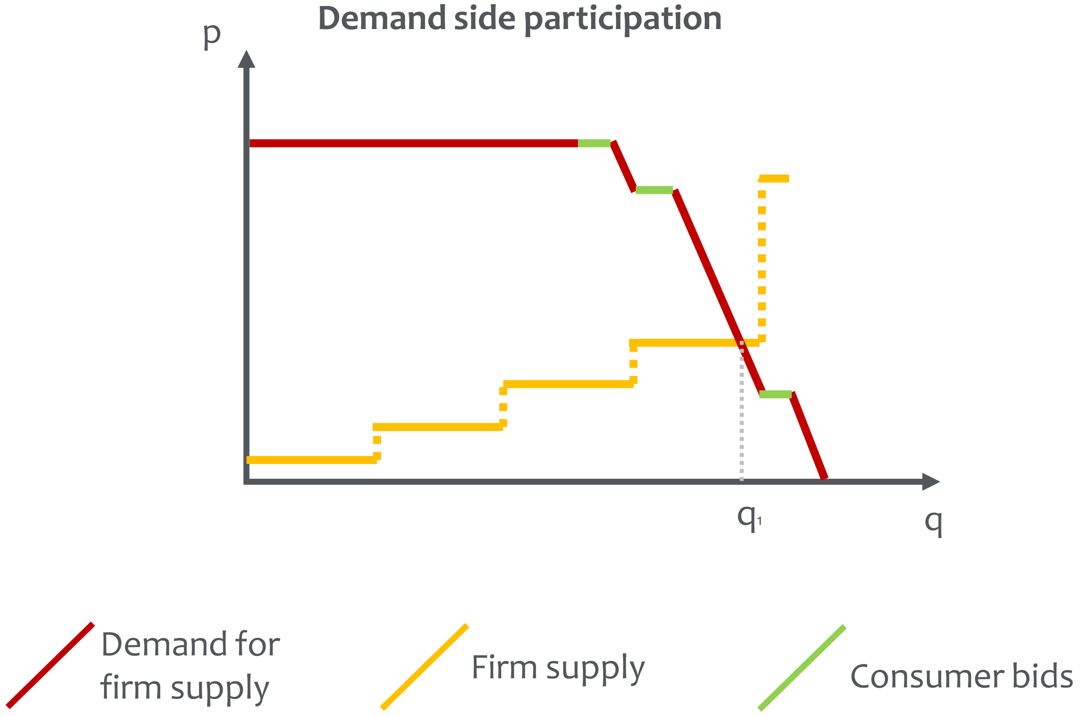
Two sides of the same coin

Example with a CRM auction

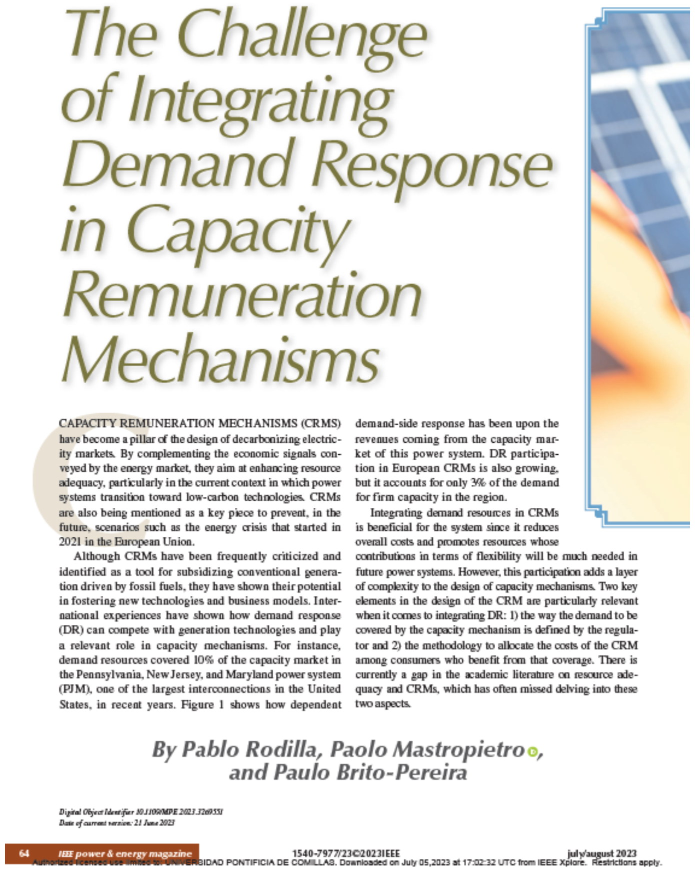


Two sides of the same coin

Example with a CRM auction



Two sides of the same coin



The Challenge of Integrating Demand Response in Capacity Remuneration Mechanisms

CAPACITY REMUNERATION MECHANISMS (CRMS) have become a pillar of the design of decarbonizing electricity markets. By complementing the economic signals conveyed by the energy market, they aim at enhancing resource adequacy, particularly in the current context in which power systems transition toward low-carbon technologies. CRMs are also being mentioned as a key piece to prevent, in the future, scenarios such as the energy crisis that started in 2021 in the European Union.

Although CRMs have been frequently criticized and identified as a tool for subsidizing conventional generation driven by fossil fuels, they have shown their potential in fostering new technologies and business models. International experiences have shown how demand response (DR) can compete with generation technologies and play a relevant role in capacity mechanisms. For instance, demand resources covered 10% of the capacity market in the Pennsylvania, New Jersey, and Maryland power system (PJM), one of the largest interconnections in the United States, in recent years. Figure 1 shows how dependent demand-side response has been upon the revenues coming from the capacity market of this power system. DR participation in European CRMs is also growing, but it accounts for only 3% of the demand for firm capacity in the region.

Integrating demand resources in CRMs is beneficial for the system since it reduces overall costs and promotes resources whose contributions in terms of flexibility will be much needed in future power systems. However, this participation adds a layer of complexity to the design of capacity mechanisms. Two key elements in the design of the CRM are particularly relevant when it comes to integrating DR: 1) the way the demand to be covered by the capacity mechanism is defined by the regulator and 2) the methodology to allocate the costs of the CRM among consumers who benefit from that coverage. There is currently a gap in the academic literature on resource adequacy and CRMs, which has often missed delving into these two aspects.

By Pablo Rodilla, Paolo Mastropietro, and Paulo Brito-Pereira

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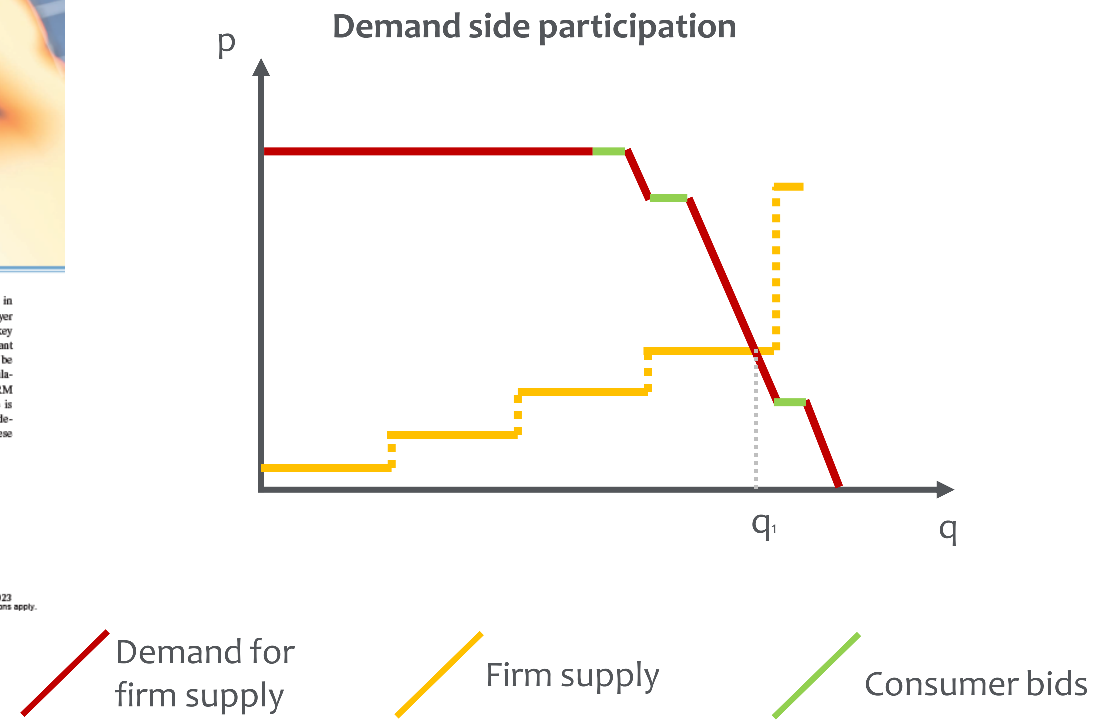
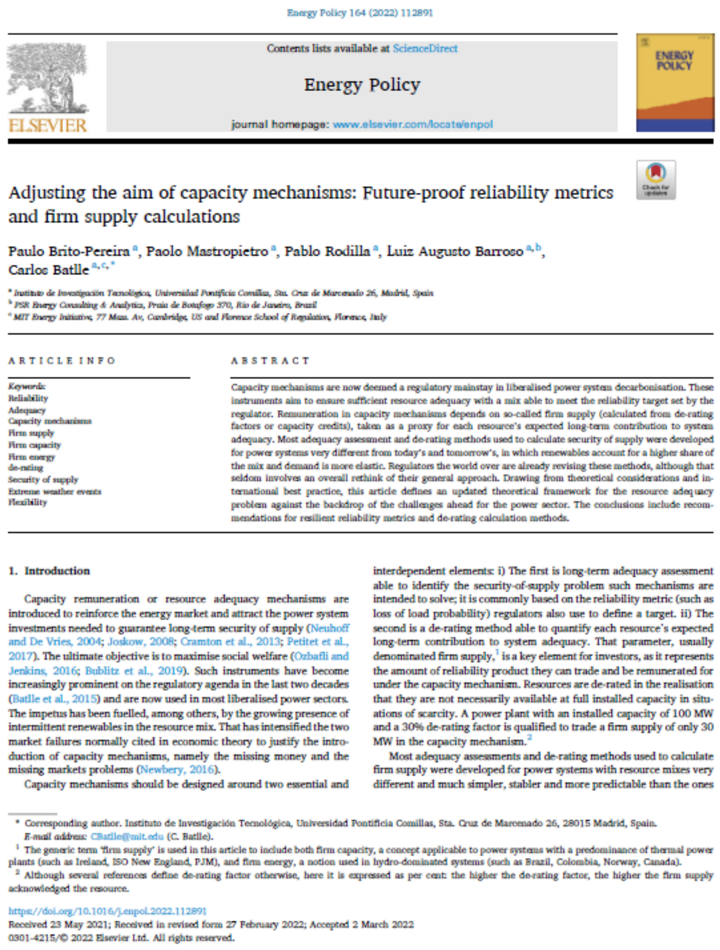
Example with a CRM auction



Firm supply in CRMs



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Adjusting the aim of capacity mechanisms: Future-proof reliability metrics and firm supply calculations

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ARTICLE INFO

Keywords:
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Capacity mechanisms
Firm supply
Firm capacity
Firm energy
de-rating
Security of supply
Extreme weather events
Flexibility

ABSTRACT

Capacity mechanisms are now deemed a regulatory mainstay in liberalised power system decarbonisation. These instruments aim to ensure sufficient resource adequacy with a mix able to meet the reliability target set by the regulator. Remuneration in capacity mechanisms depends on so-called firm supply (calculated from de-rating factors or capacity credits), taken as a proxy for each resource's expected long-term contribution to system adequacy. Most adequacy assessment and de-rating methods used to calculate security of supply were developed for power systems very different from today's and tomorrow's, in which renewables account for a higher share of the mix and demand is more elastic. Regulators the world over are already revising these methods, although that seldom involves an overall rethink of their general approach. Drawing from theoretical considerations and international best practice, this article defines an updated theoretical framework for the resource adequacy problem against the backdrop of the challenges ahead for the power sector. The conclusions include recommendations for resilient reliability metrics and de-rating calculation methods.

1. Introduction

Capacity remuneration or resource adequacy mechanisms are introduced to reinforce the energy market and attract the power system investments needed to guarantee long-term security of supply (Neuhoff and De Vries, 2004; Joskow, 2008; Cramton et al., 2013; Petitet et al., 2017). The ultimate objective is to maximise social welfare (Ozbafli and Jenkins, 2016; Bublitz et al., 2019). Such instruments have become increasingly prominent on the regulatory agenda in the last two decades (Batlle et al., 2015) and are now used in most liberalised power sectors. The impetus has been fuelled, among others, by the growing presence of intermittent renewables in the resource mix. That has intensified the two market failures normally cited in economic theory to justify the introduction of capacity mechanisms, namely the missing money and the missing markets problems (Newbery, 2016).

Capacity mechanisms should be designed around two essential and interdependent elements: i) The first is long-term adequacy assessment able to identify the security-of-supply problem such mechanisms are intended to solve; it is commonly based on the reliability metric (such as loss of load probability) regulators also use to define a target. ii) The second is a de-rating method able to quantify each resource's expected long-term contribution to system adequacy. That parameter, usually denominated firm supply,[1] is a key element for investors, as it represents the amount of reliability product they can trade and be remunerated for under the capacity mechanism. Resources are de-rated in the realisation that they are not necessarily available at full installed capacity in situations of scarcity. A power plant with an installed capacity of 100 MW and a 30% de-rating factor is qualified to trade a firm supply of only 30 MW in the capacity mechanism.[2]

Most adequacy assessments and de-rating methods used to calculate firm supply were developed for power systems with resource mixes very different and much simpler, stabler and more predictable than the ones

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[1] The generic term 'firm supply' is used in this article to include both firm capacity, a concept applicable to power systems with a predominance of thermal power plants (such as Ireland, ISO New England, PJM), and firm energy, a notion used in hydro-dominated systems (such as Brazil, Colombia, Norway, Canada).

[2] Although several references define de-rating factor otherwise, here it is expressed as per cent: the higher the de-rating factor, the higher the firm supply acknowledged the resource.

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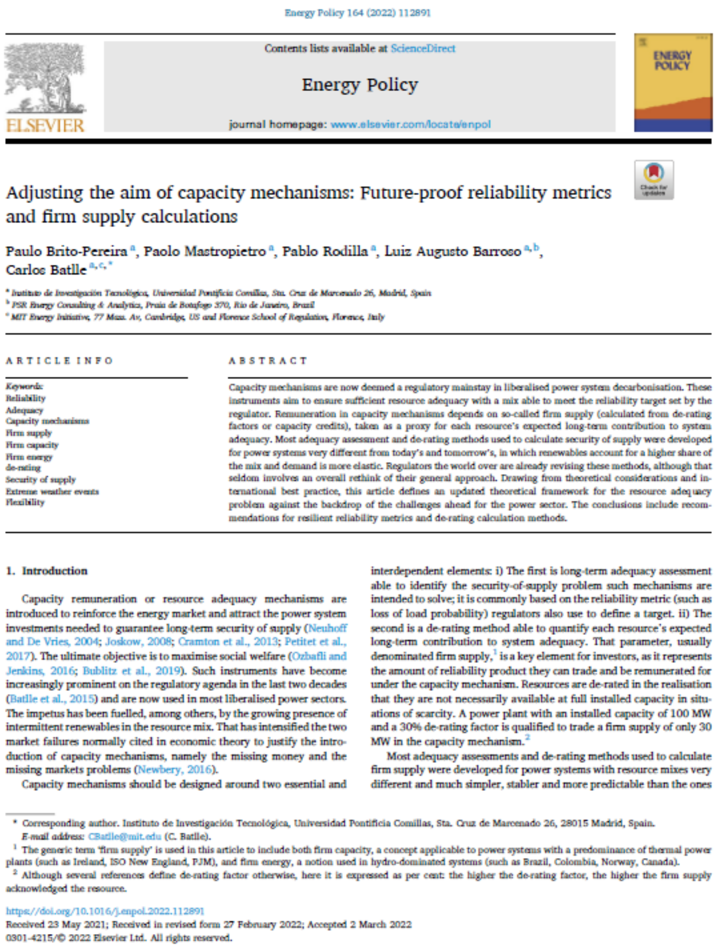
- Firm supply should be determined according to marginal contributions to the reliability target

Firm supply in CRMs



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- Firm supply should be determined according to marginal contributions to the reliability target
- The same methodology can be used also for CRM cost allocation

Objectives

- Define a methodology for CRM cost allocation
- Define a methodology to compute the firm supply of demand resources
- Demonstrate that using the same methodology for both items prevents arbitrage opportunities

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Methodology

DR firm supply in CRMs

- To show how CRM costs should be allocated, and how to determine demand response's firm supply we have used:
  - A convolution model
  - Expected Energy Non-Served as the reliability metric

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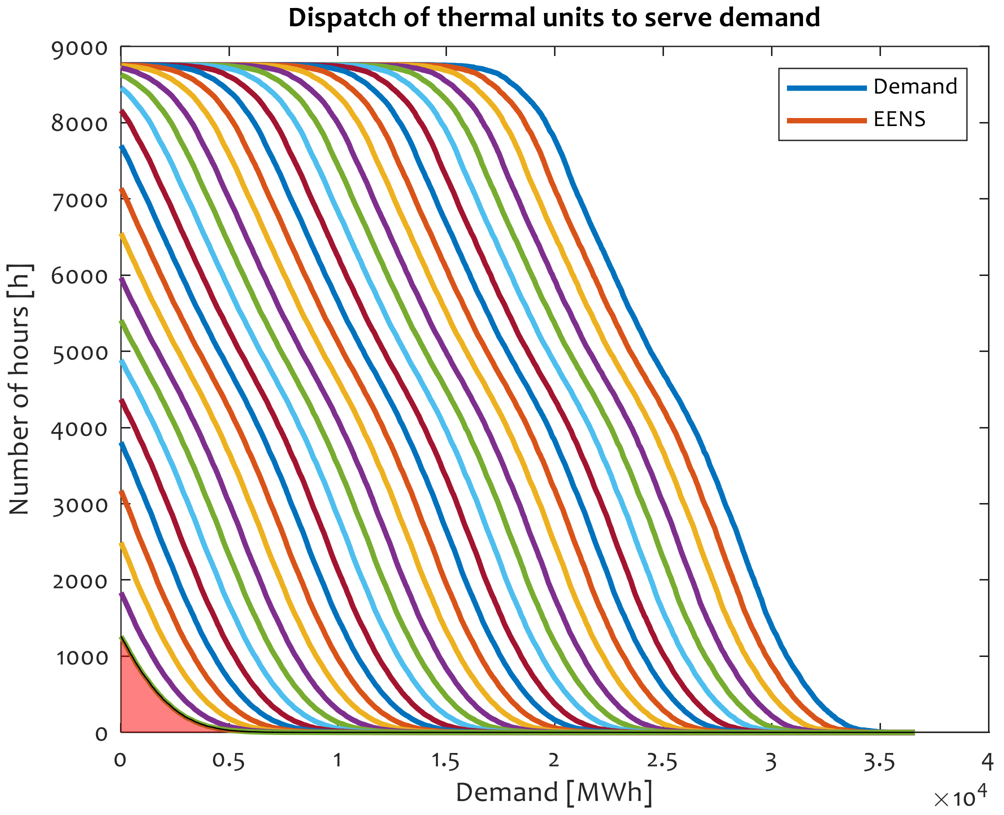
Convolution models

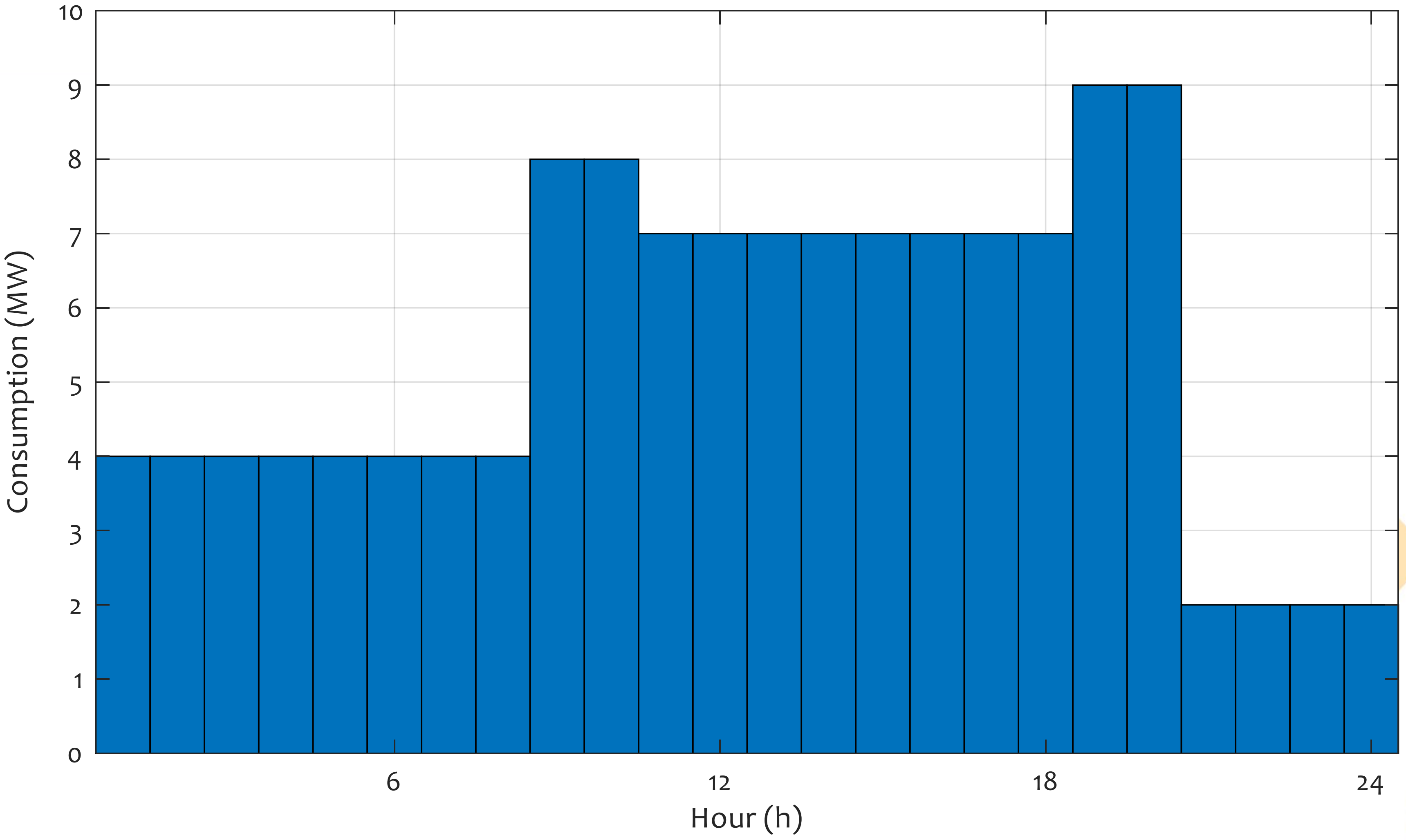
- Statistical model to estimate the expected value of non-served energy given a load-duration curve and the expected outages of generation assets



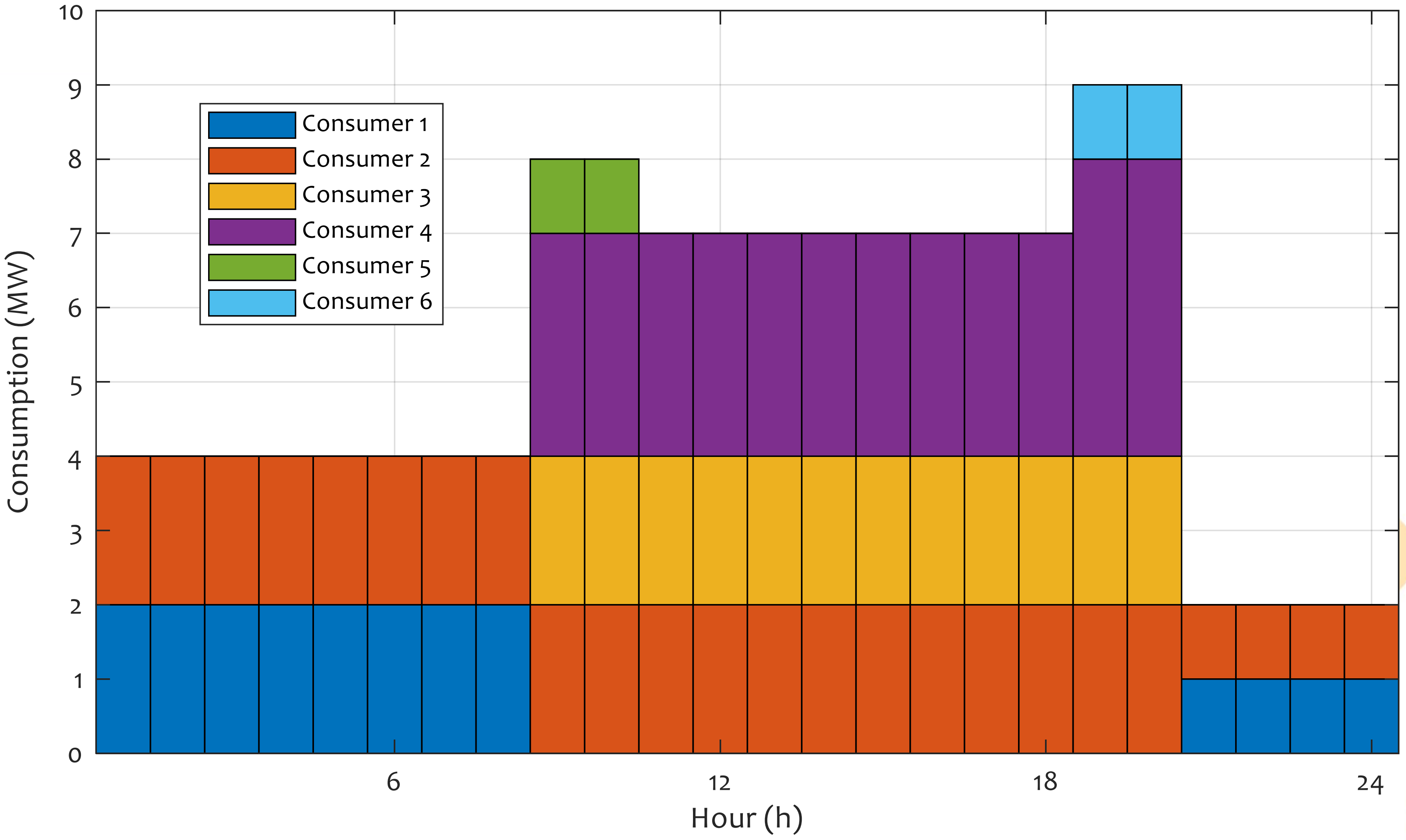
CRM cost allocation

Illustrative example

Hourly demand



Hourly demand per consumer



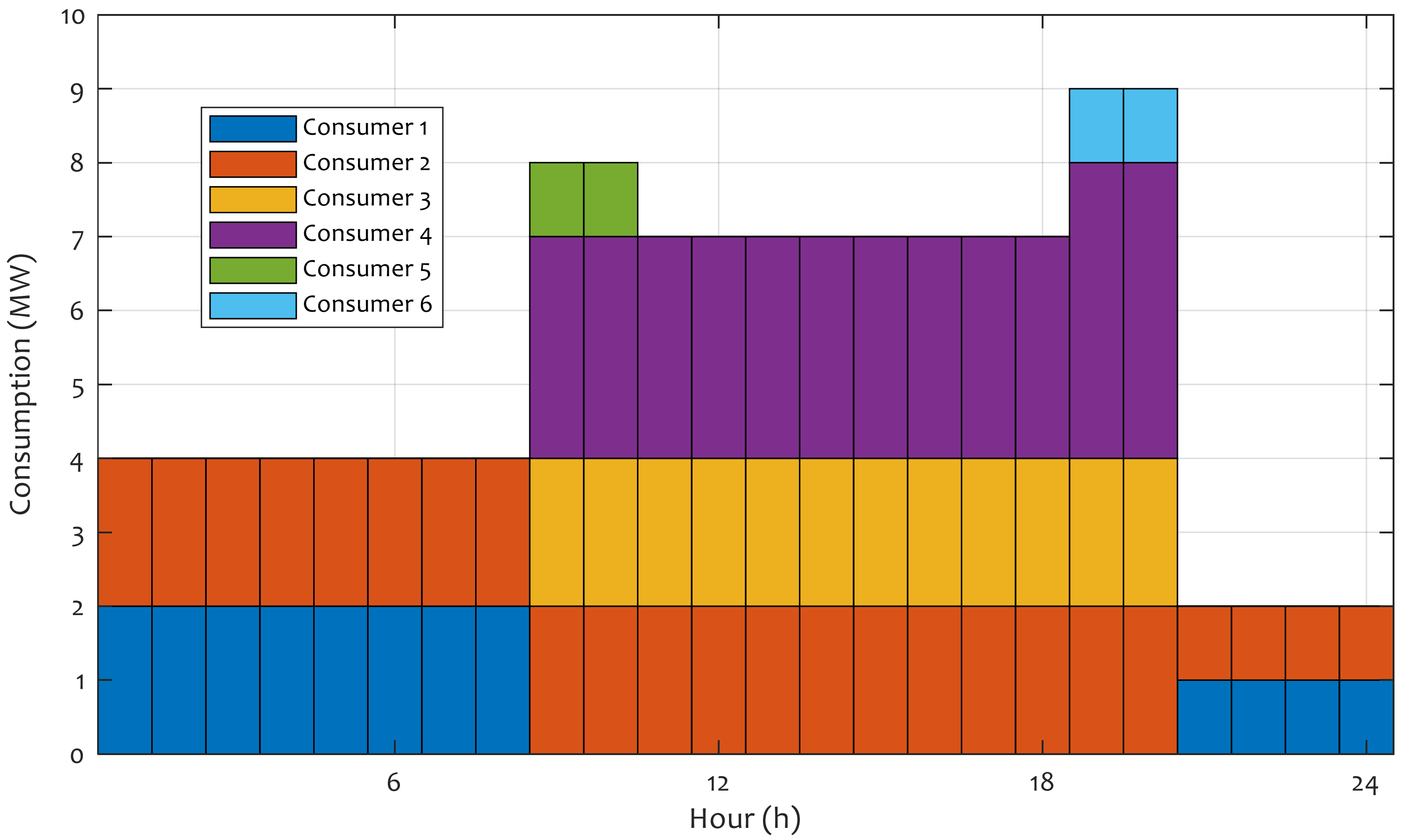
Generation mix

- Generation mix:
  - 10 1-MW thermal power plants
  - 0.9 EFOR

Cost allocation

- Cost allocation among consumers should be determined according to the marginal contributions of each consumer toward the reliability target
- We can compare the result of this calculation between the consumers versus a standard consumption profile (in our case 1 MWh each hour)

Cost allocation: Results



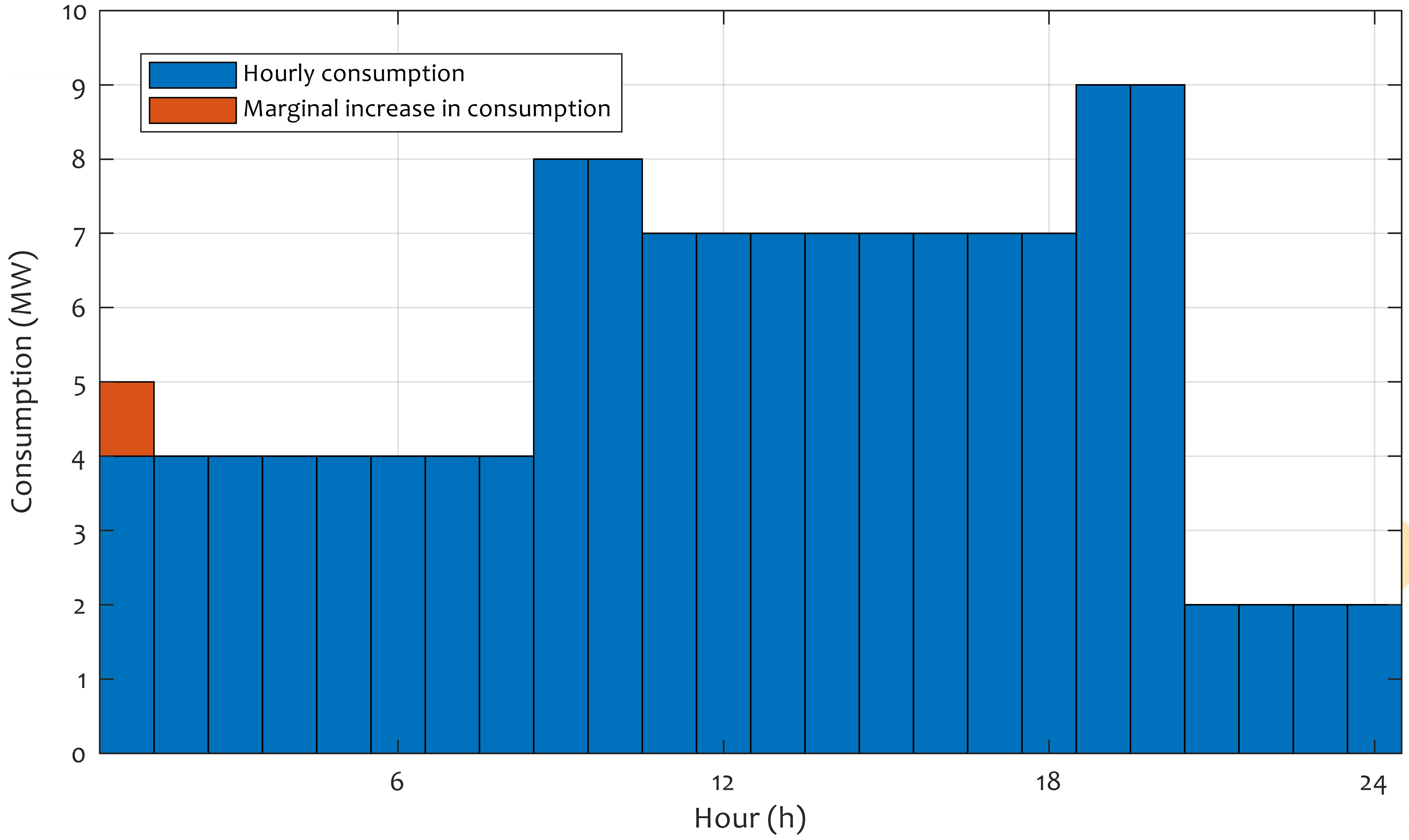
Ratio of cost allocation

Proportional cost	With normalized consumption
1.89 x10^-4	2.2732 x10^-4
2.0000	1.0909
1.9998	1.9998
3.6846	2.3271
0.1822	2.1860
0.6849	8.2189

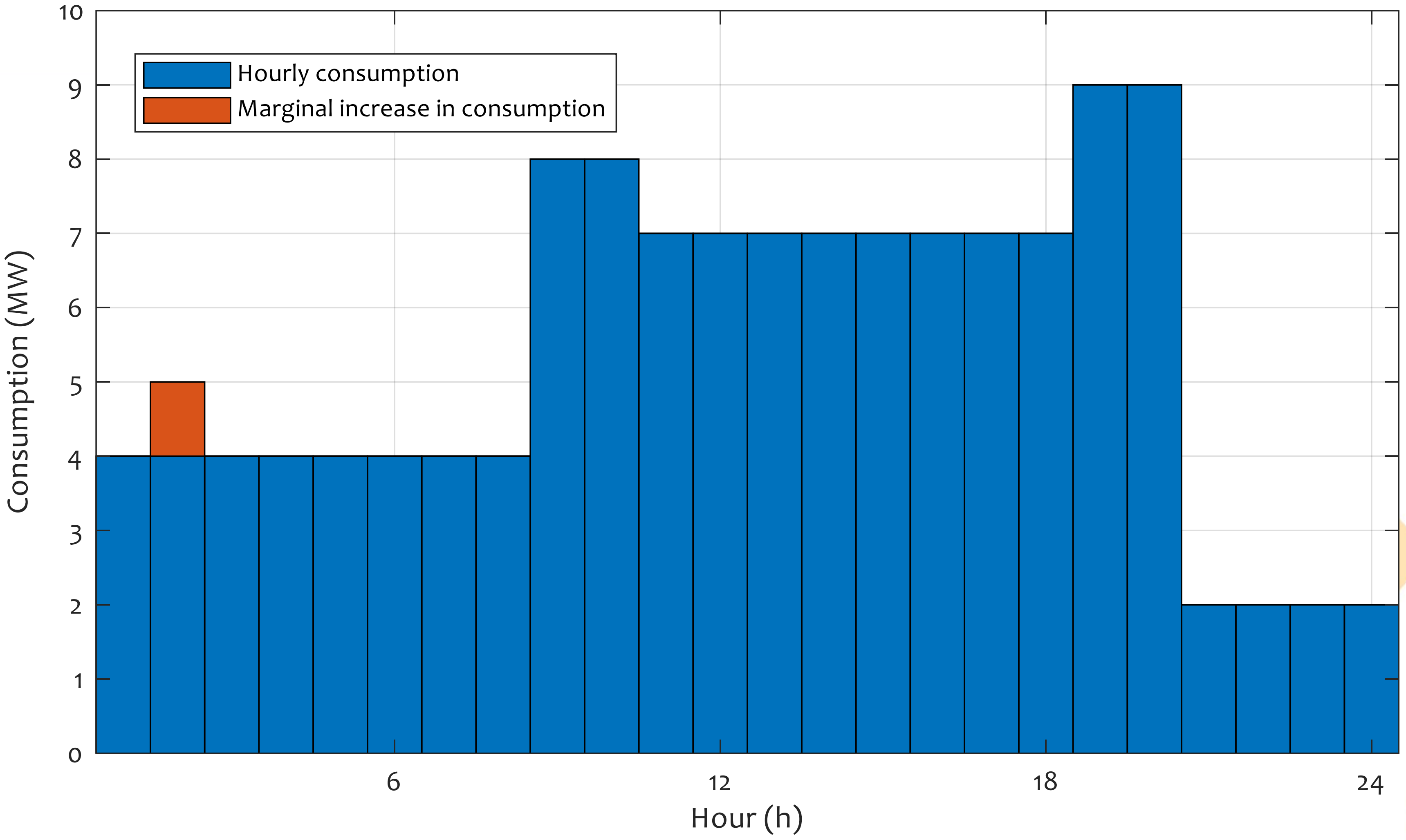
Cost allocation: elaborated alternative

- Instead of analyzing each consumer profile separately, we can analyze the impact of a marginal variation of demand in each hour
- This will reflect how critical each hour is
- This information can then be used to determine cost allocation among consumers

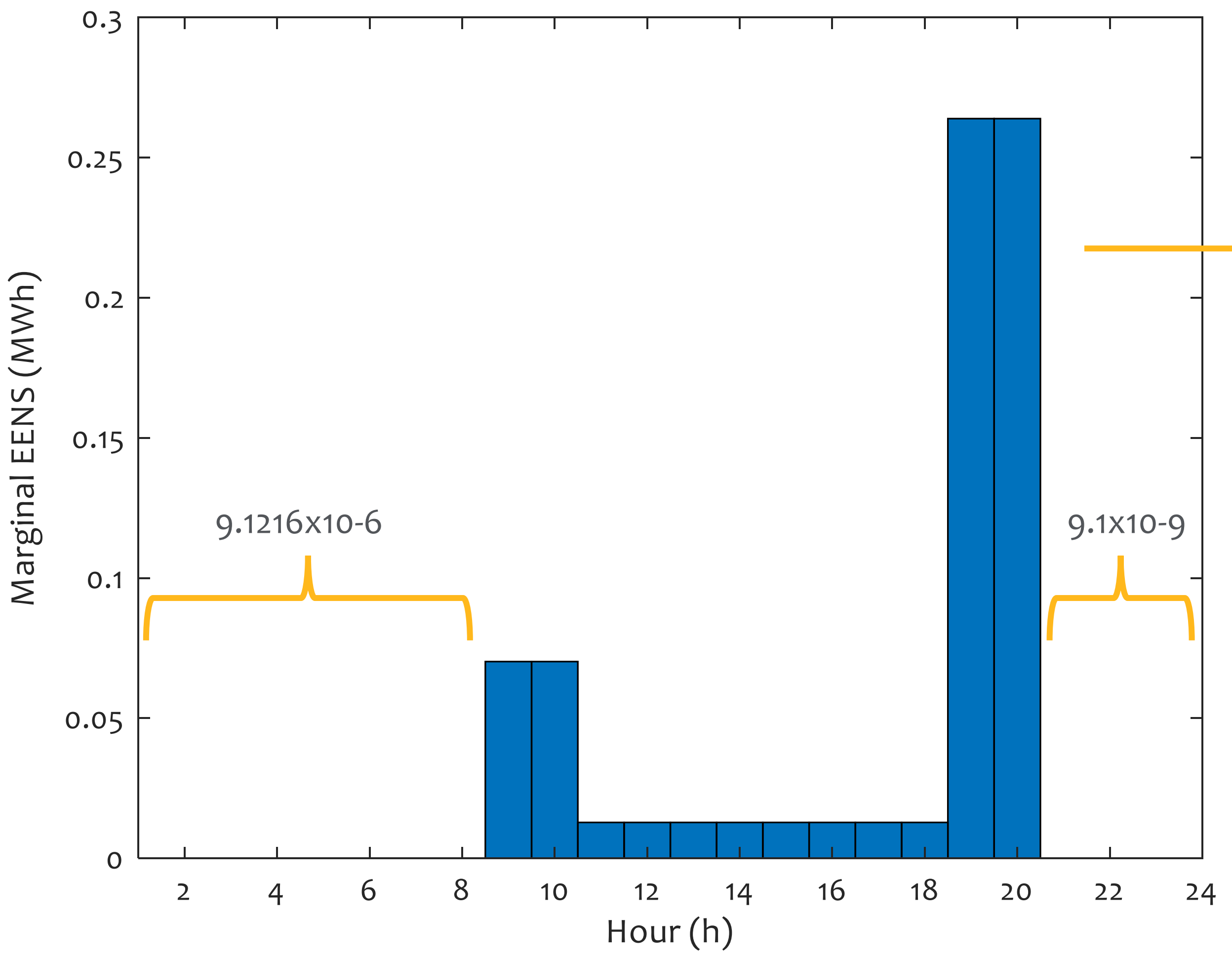
Hourly marginal analysis



Hourly marginal analysis

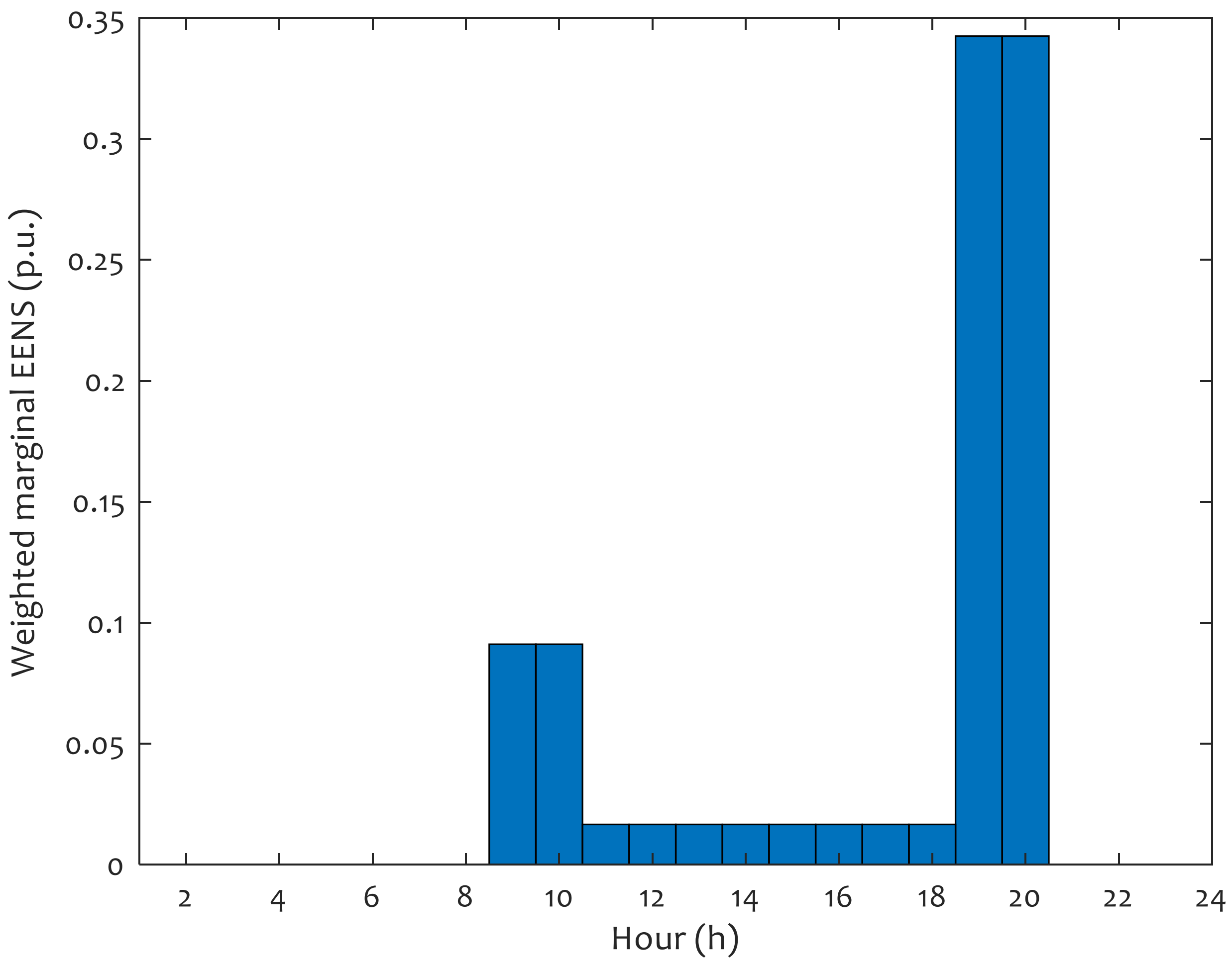


Marginal EENS



Dividing each hourly value by the total marginal EENS we can assign a weight to each hour

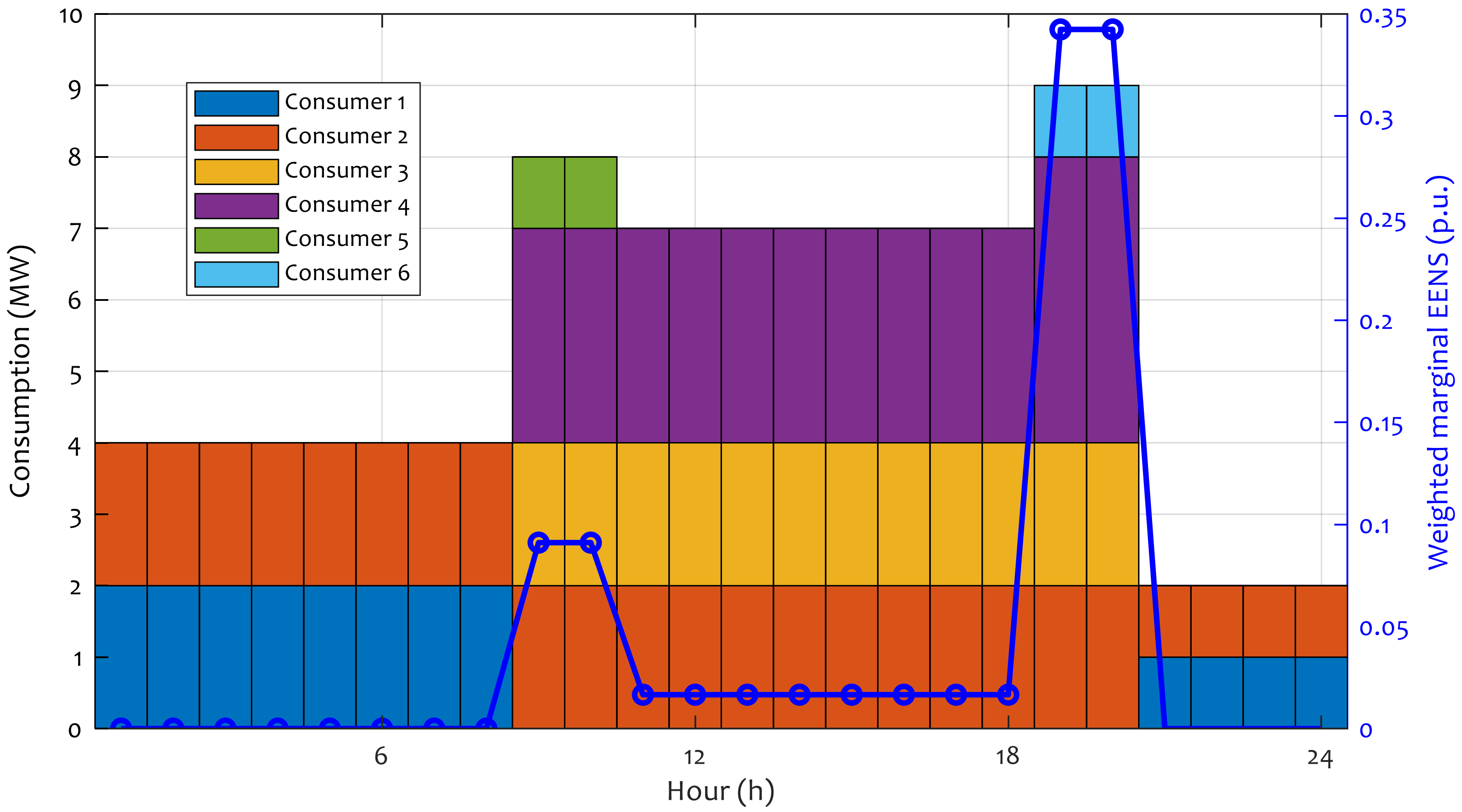
Weighted marginal EENS



Cost allocation: elaborated alternative

- **Cost allocation** is proportional to the marginal EENS in each hour
- **Cost allocation for each consumer** is determined by their hourly consumption and the weighted marginal EENS
- We can compare the result of this calculation between the consumers versus a standard consumption profile (in our case 1 MWh each hour)

Cost allocation: Results



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CRM cost allocation

Spanish case study

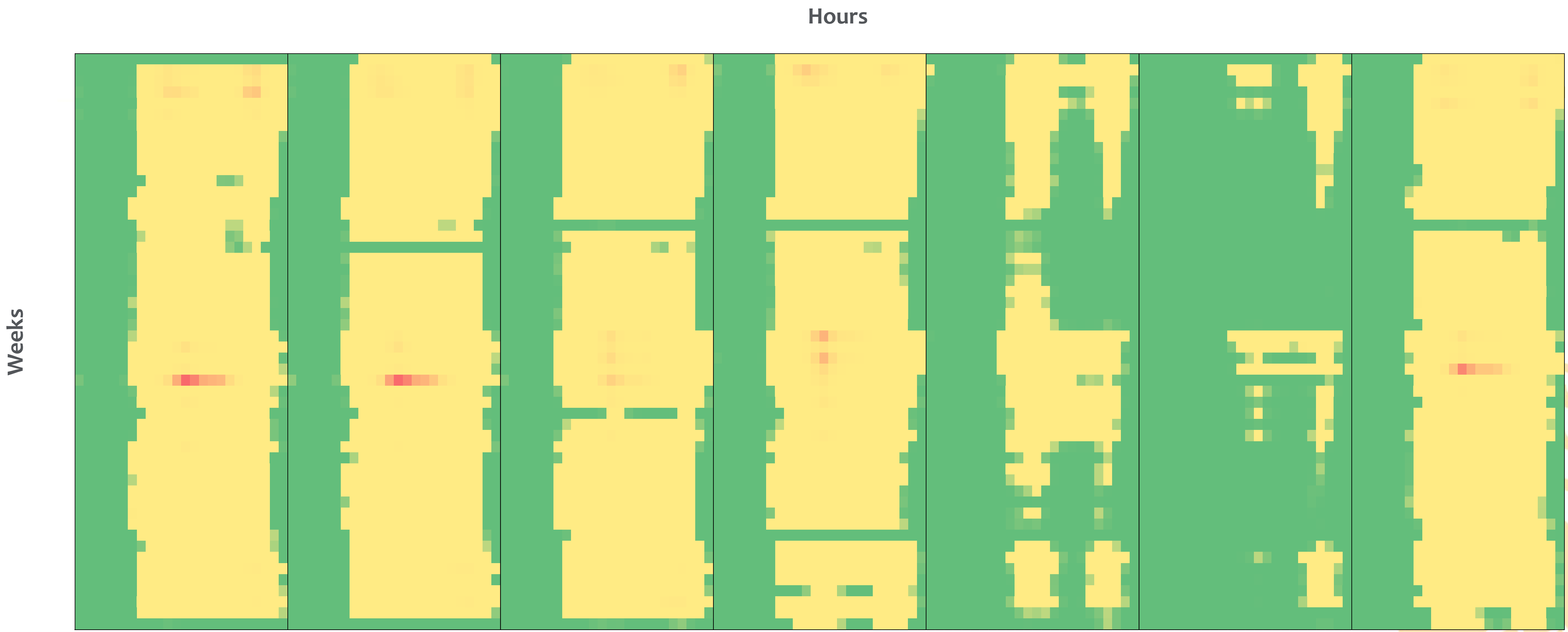
Real-size case study

- Spanish electricity demand of 2019
- Fully thermal electricity mix
  - Calibrated to comply with the reliability target
  - Normalized EENS ≤ 0.002% (as in AEMO)
- Results analyzed using EENS as a reliability metric

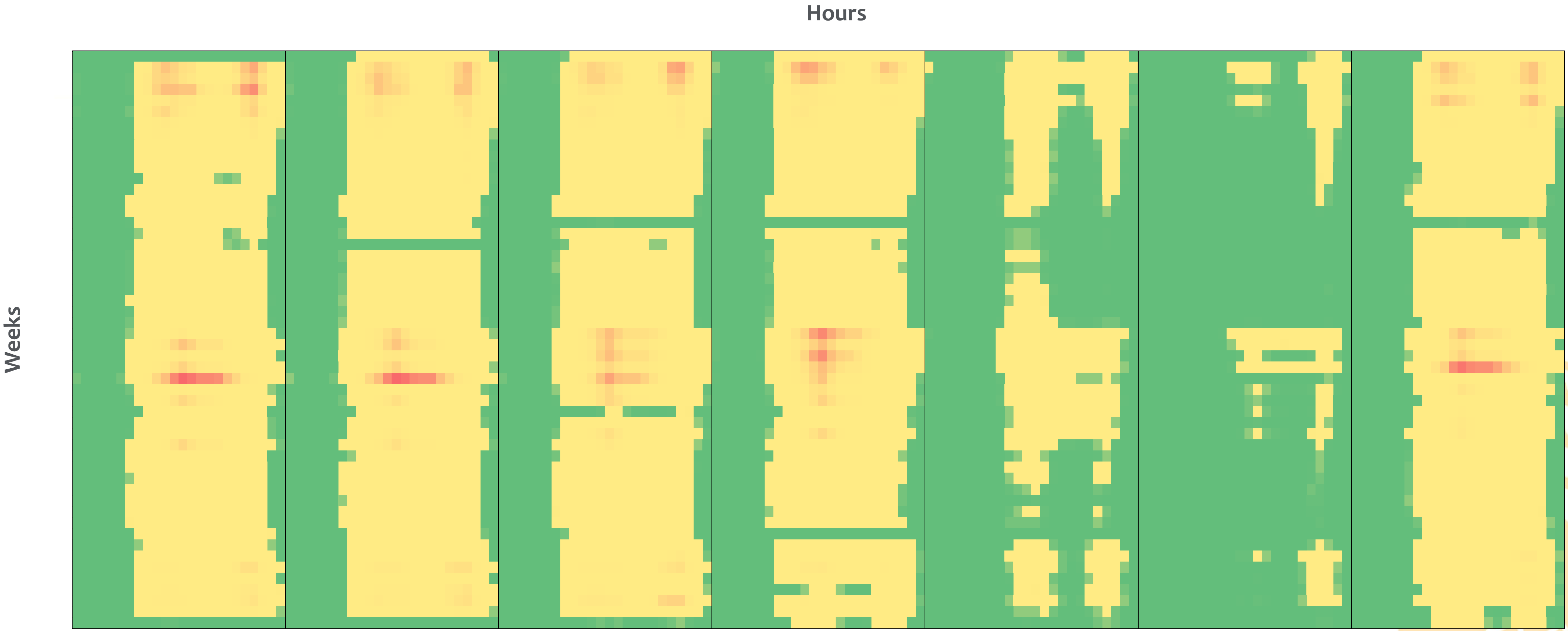
Weighted marginal EENS

- Changing the reliability target will change the hourly weights
- We can see the change in the weighted marginal EENS if we vary the reliability target from 0.002% to 0.025%

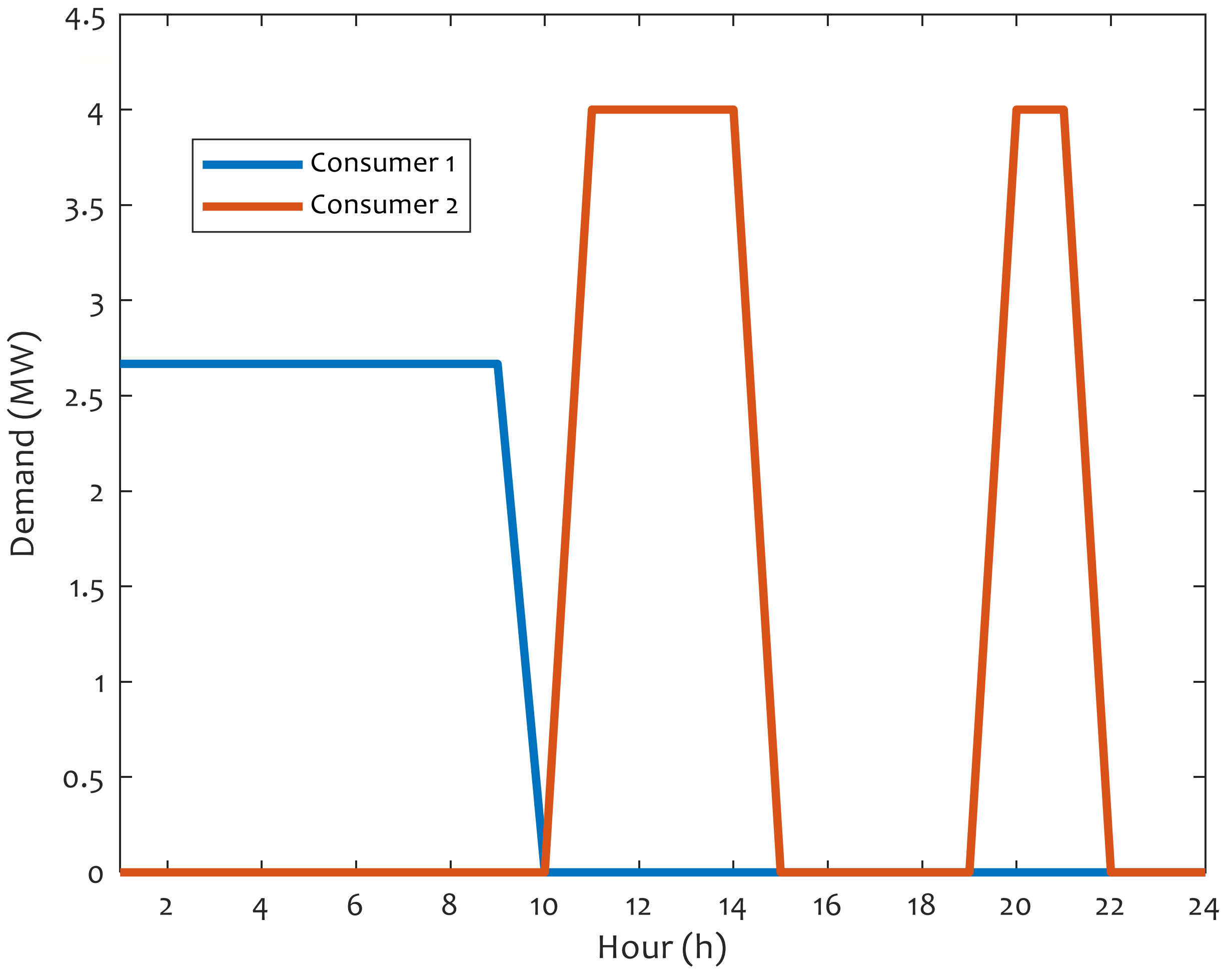
Weighted marginal EENS (0.002%)



Weighted marginal EENS (0.025%)



Cost allocation



Ratio of cost allocation (0.002%)

Consumer 1	0.0037
Consumer 2	3.5423

Ratio of cost allocation (0.025%)

Consumer 1	0.0151
Consumer 2	3.2850

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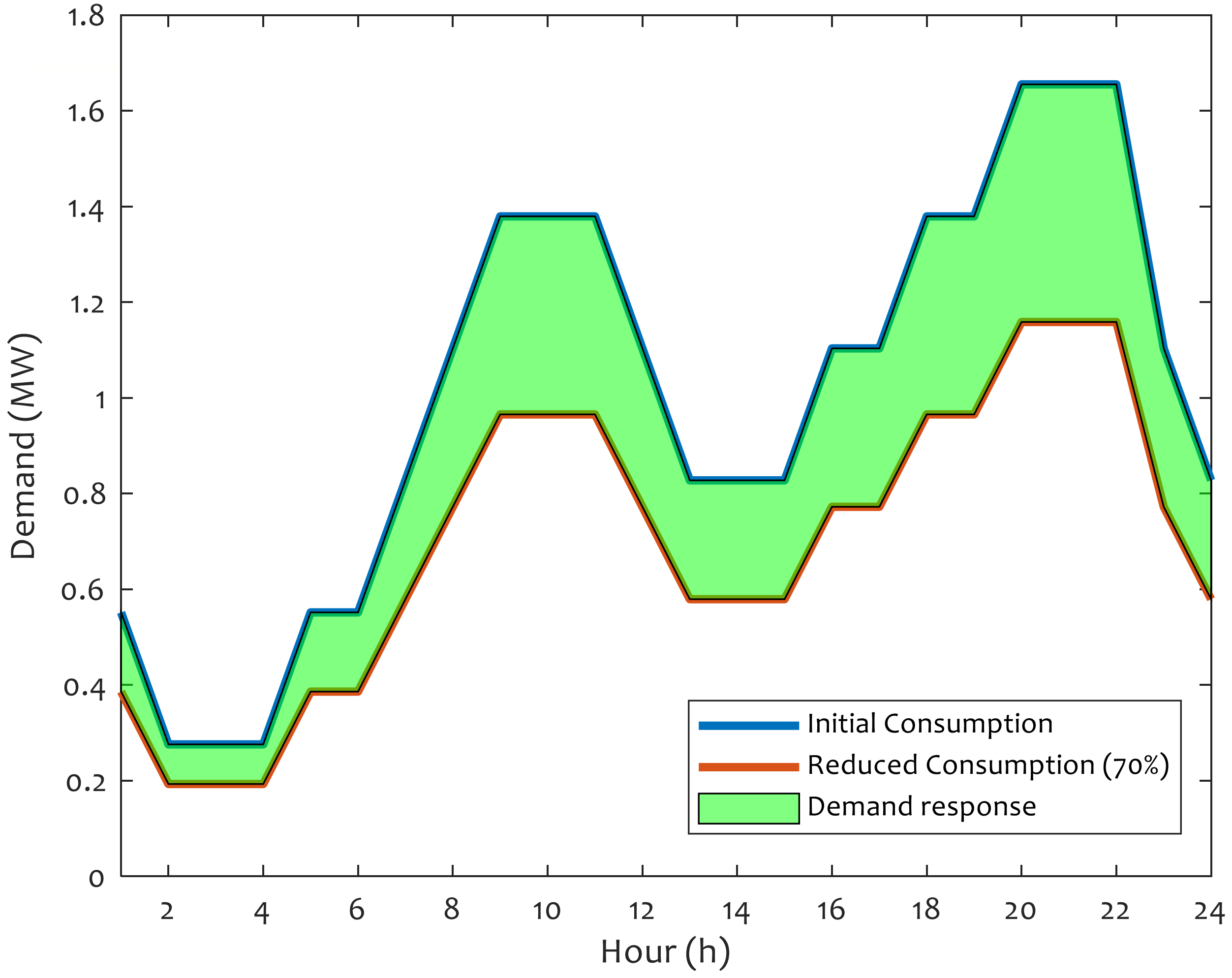
Firm supply of demand resources

Cost allocation = DR firm supply

- The same method used to determine cost allocation should be used to determine firm supply of demand resources
- This leads to an equivalence of both methods of participation of demand resources in CRMs
  - Non-arbitrage principle

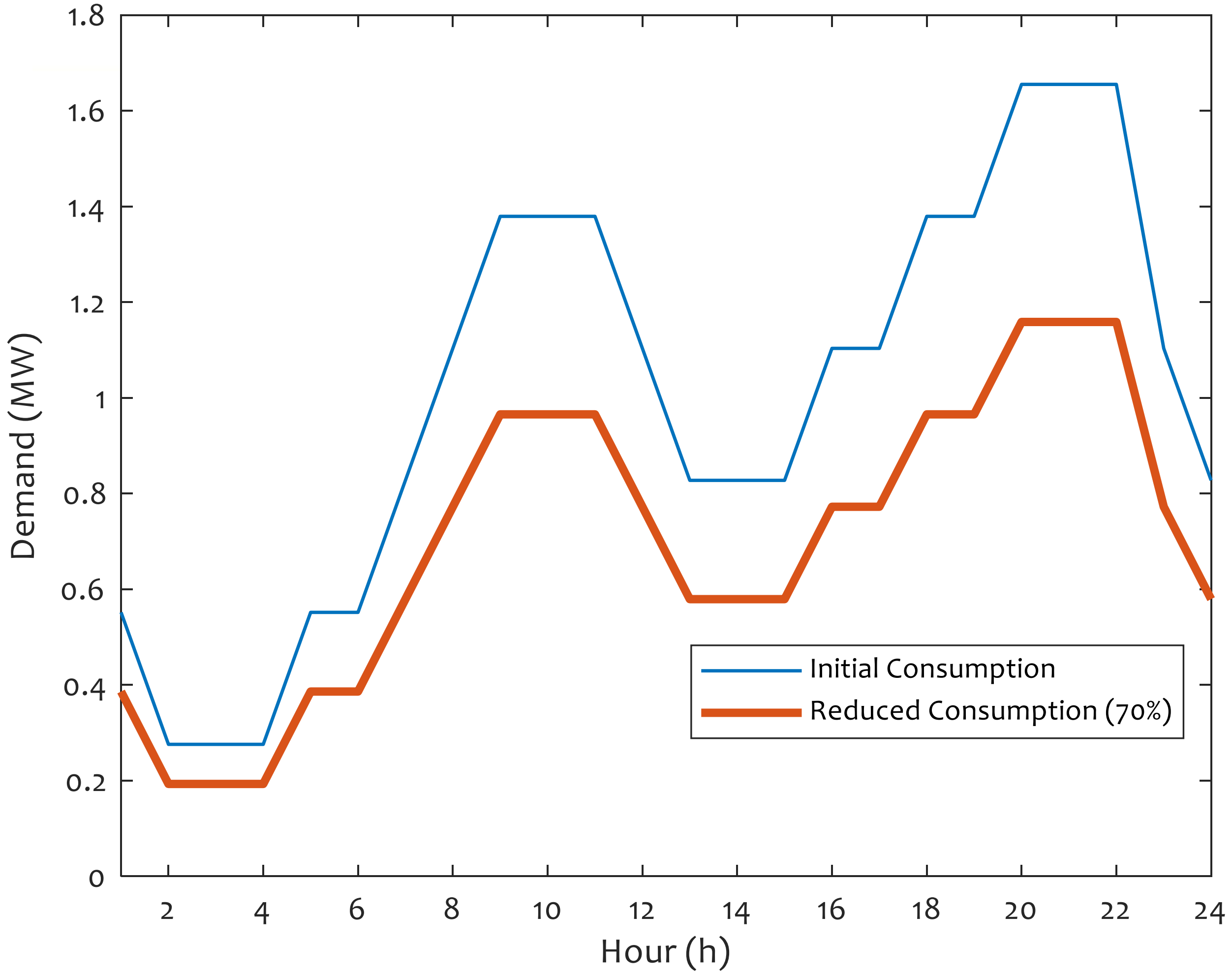
Supply side participation



Supply side participation results

Element analyzed	Ratio of cost allocation
Initial consumption	1.0787
Demand response	-0.3236
Final ratio of cost allocation	**0.7551**

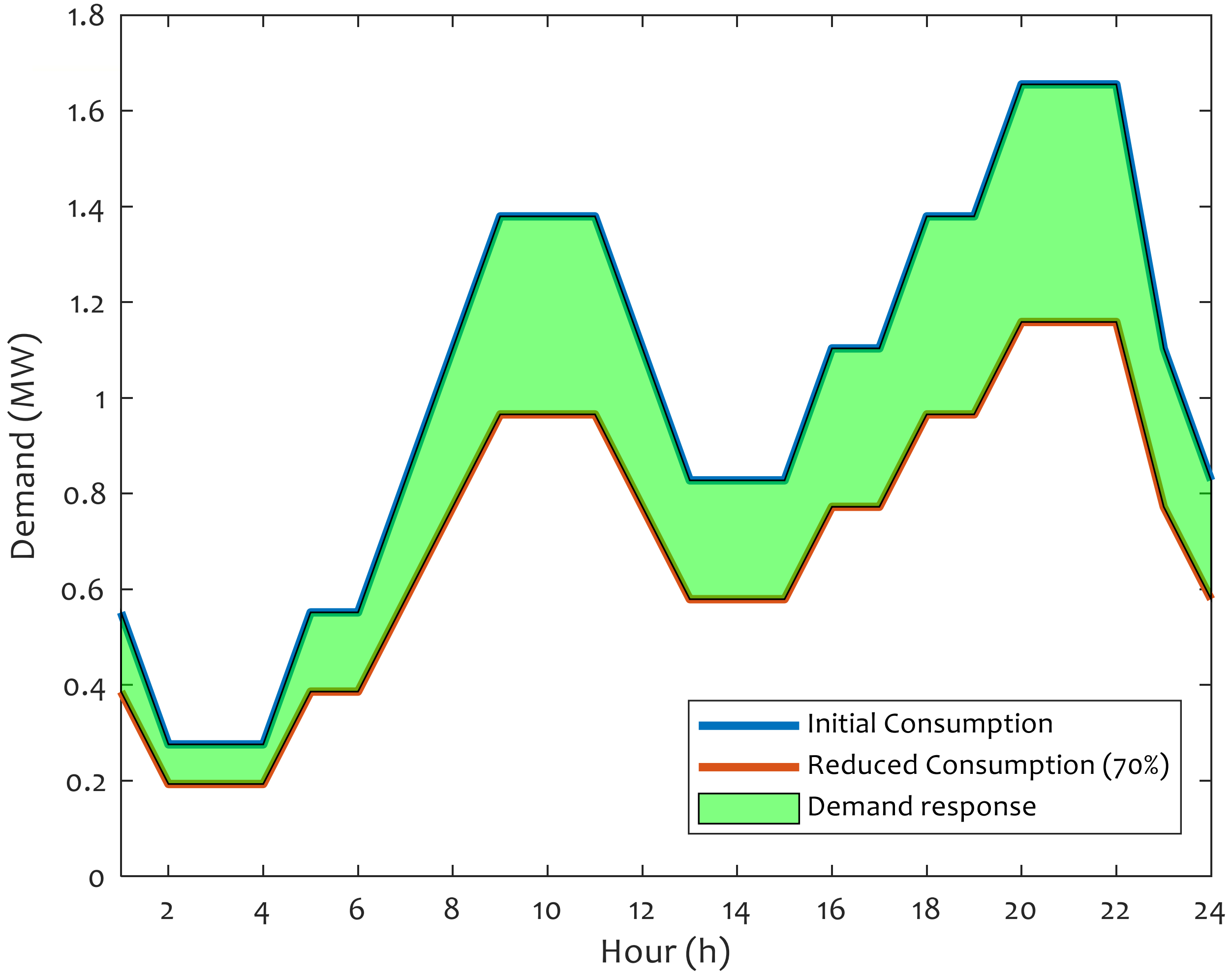
Demand side participation



Demand side participation results

Element analyzed	Ratio of cost allocation
Reduced consumption	0.7551

Cost allocation = DR firm supply



Supply side participation results

Element analyzed	Ratio of cost allocation
Initial consumption	1.0787
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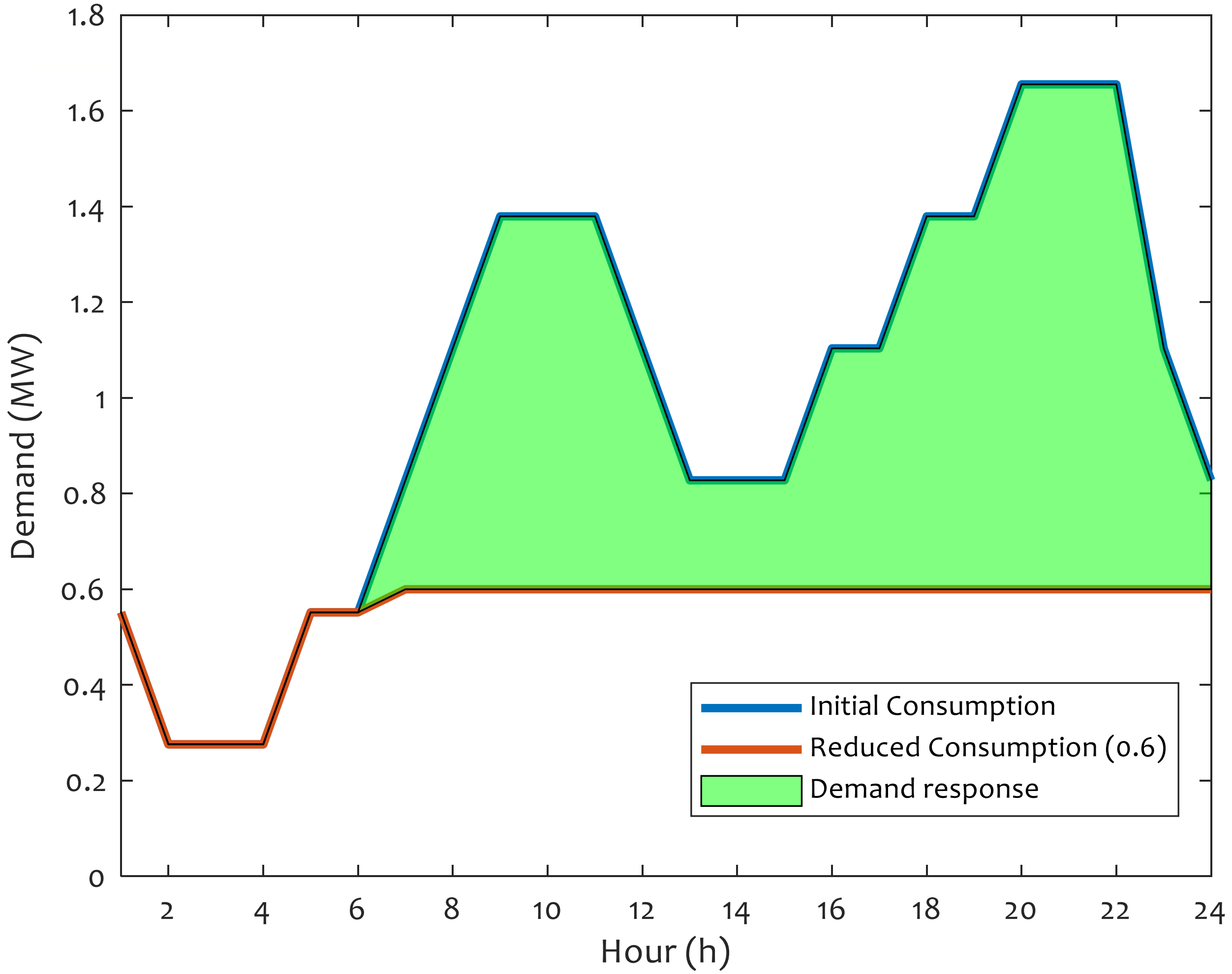
Demand side participation results

Element analyzed	Ratio of cost allocation
Reduced consumption	0.7551

Cost allocation = DR firm supply



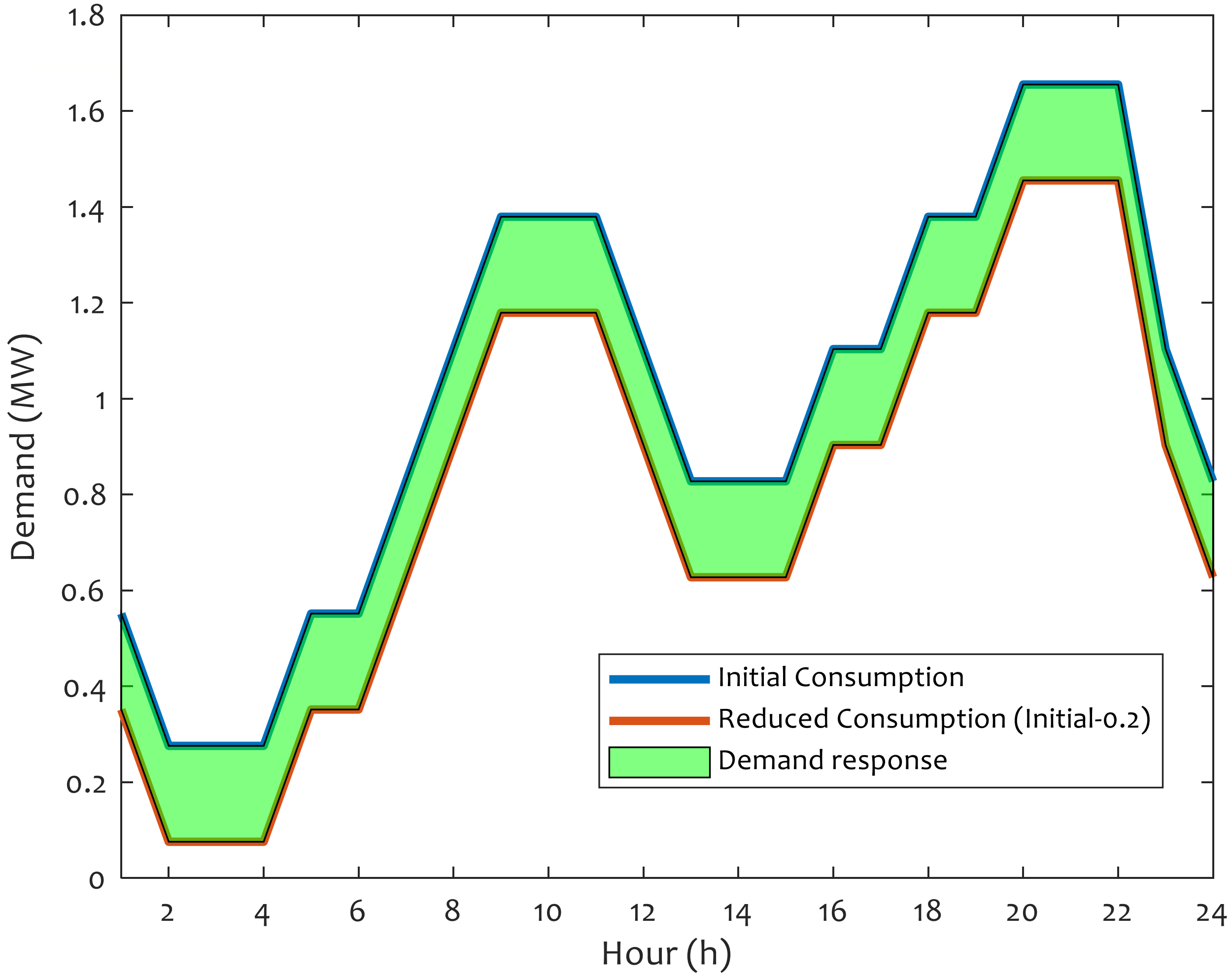
Supply side participation results

Element analyzed	Ratio of cost allocation
Initial consumption	1.0787
Consumption reduction	-0.4787
Final ratio of cost allocation	**0.6000**

Demand side participation results

Element analyzed	Ratio of cost allocation
Reduced consumption	0.6000

Cost allocation = DR firm supply



Supply side participation results

Element analyzed	Ratio of cost allocation
Initial consumption	1.0787
Consumption reduction	-0.2000
Final ratio of cost allocation	**0.8787**

Demand side participation results

Element analyzed	Ratio of cost allocation
Reduced consumption	0.8787

Key findings

- Cost allocation must be proportional to the marginal impact of each demand profile on the reliability metric
  - The focus should not be exclusively on peak demand hours, but on all the hours (according to the probability of suffering scarcity conditions)
- The same theoretical framework can be used to determine firm supply of demand response resources
- Arbitrage opportunities of demand resources can be prevented if the same methodology is used for cost allocation and firm supply calculation
- The proposed methodology can be also applied with more sophisticated resource adequacy assessments (e.g., UC-based)

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