Israeli Market Clearing Price Analysis

9 December 2024

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1.

Presentation of Compass Lexecon

About Compass Lexecon

- One of the world's leading economic consulting firms, Compass Lexecon provides corporations, governments and law firms with clear analysis of complex issues.
- We have been involved in a broad spectrum of matters related to economics and finance – providing critical insight in legal and regulatory proceedings, strategic decisions and public policy debates. Our experience and expertise apply to virtually any question of economics, in virtually any context of the law or business, and in any industry.
- We have more than 500 professionals worldwide and more than 90 professionals in Europe – based in Brussels, Berlin, Düsseldorf, London, Madrid and Paris.

Services

- Accounting litigation services
- Antitrust, competition and M&A
- International litigation & arbitration
- Intellectual property
- Valuation & financial analysis
- Market or sector inquiries
- State aid
- Damages
- Econometric analysis
- Economic and financial regulation

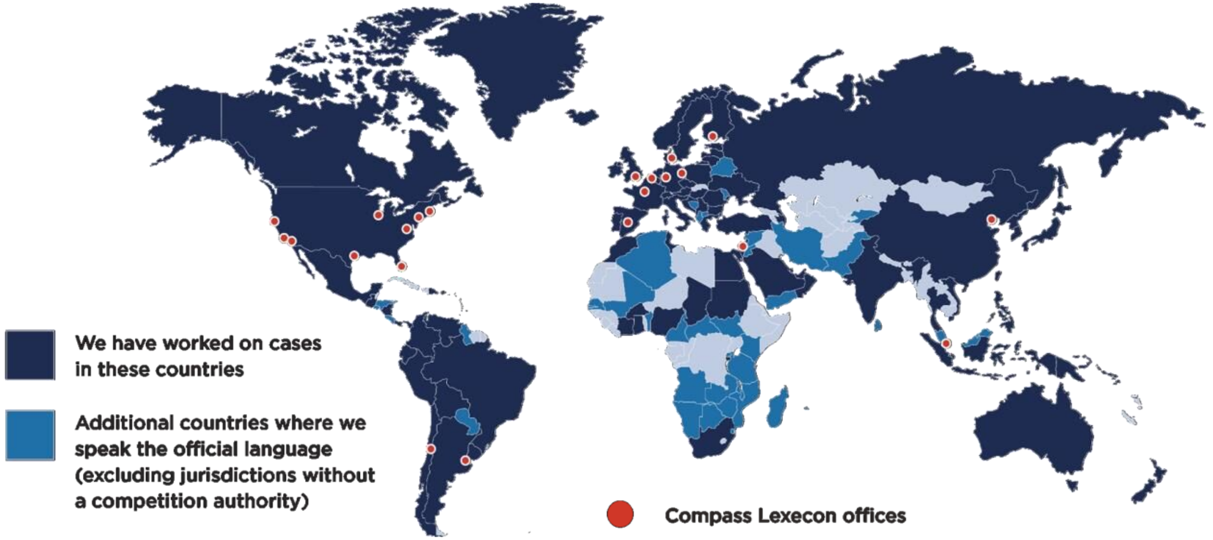
Sectors

- **Energy**
- Healthcare
- High Technology
- Pharmaceuticals
- Telecommunications
- Financial services
- Transportation
- International Trade
- Internet
- Entertainment & media

part of: FTI CONSULTING

Facts and Figures

800+	**Economists**	**200+**	**Ph.D.** economists
23	**Offices** worldwide	**2**	**Nobel Prize** winners
182	**Merger-related** matters advised on in the last 12 months	**84%**	**Of the Fortune 100** companies advised
319	**Antitrust litigation** matters advised on in the last 12 months	**90+**	**Jurisdictions** in which we have advised clients



Compass Lexecon's EMEA Energy Practice Expertise – Overview

Sectors: Electricity; Gas; Emissions (CO_2); District Heating & Cogeneration (CHP)

1 Market outlooks & analysis

- Market price projections
- Tailor made modelling
- Market analysis
- Valuation of market assets
- Policy impact assessment

2 Energy market regulation

- Network regulation & incentives
- Renewable support
- Market design for power and gas markets
- Regulatory review and impact assessment
- Third party exemptions for electricity and gas infrastructure
- Gas storage regulation

3 Strategy

- Policy action recommendations
- Strategy in regulated industries
- New technologies
- Strategy review
- Transition management

4 Transactions

- Regulatory & commercial due diligences
- Deal valuation
- M & A support
- Expert reports for financing

5 Emissions & environmental economics

- Zero emission scenarios
- Carbon market expertise
- Power-to-gas and hydrogen

6 Competition & State Aid

- State Aid
- Investigations of market abuse and competitive behavior
- Mergers and acquisitions
- Competition issues for natural gas storage and LNG terminals

7 Contract design

- Contract valuation
- PPA negotiation
- Long-term contract renegotiation
- Procurement review

8 Litigation, arbitration and disputes

- Gas supply contract arbitration
- RES support revisions
- Damage quantum analysis
- Power Purchase Agreement (PPA) arbitration
- Energy charter treaty and investor-state arbitration

Source: Compass Lexecon

Representative Clients in Energy Sector

We have worked for a range of clients across the energy value chain

Investors

BlackRock, Macquarie, Morgan Stanley, Deutsche Bank, Sumitomo, Brookfield, Centerbridge, Goldman Sachs, John Laing (making infrastructure happen), KKR, JPMorgan Chase & Co., HSBC, UBS, equitix, RBS, Commerzbank, EIG Global Energy Partners

OEMS, Manufacturers

Siemens Gamesa Renewable Energy, GE, Yingli Solar, Vestas, ten K, Applied Materials, Envision, Global Solar, ABB, Ascent Solar, AFC Energy, Siemens, Landis+Gyr, LDK, ecotality, Mitsubishi Heavy Industries, Ltd., Suntech, BARD, Nordex

Governments, Regulators

Department for Business, Energy & Industrial Strategy, Commission de Régulation de l'Électricité, ofgem, National Infrastructure Commission, CREG, JapanGov The Government of Japan, defra, European Commission, The Scottish Government, CER Commission for Energy Regulation, Department of Energy & Climate Change

Developers, Utilities, O&G

Mainstream Renewable Power, SSE, e.on, Iberdrola, Martifer Solar, Shell, Ørsted, ScottishPower, Edison Mission Energy, EDF, Masdar, RWE, enel Green Power, Pacific Ethanol, Inc., Aemetis, NaturEner, Alliant Energy, Aventine Renewable Energy, Inc., Total, ExxonMobil, equinor

Associations

NEDO, KIMS, Hydrogen Council, JRC European Commission, Carbon Trust, ACORE, JWPA Japan Wind Power Association, ITRI Industrial Technology Research Institute, iea International Energy Agency

Note: Relationships listed above are not an exhaustive list and includes clients of our parent company FTI Consulting

Source: Compass Lexecon

Overview of Compass Lexecon's Modelling Expertise

We have developed comprehensive proprietary models spanning the entire energy system.

COMPASS LEXECON Modelling Expertise

Electricity

Power Market Model

Dispatch

Co-optimisation

Capacity expansion

Ancillary Services Model

Modelling of reservation and activation

- FCR
- aFRR
- mFRR

Gas and LNG

Gas Market Model

LNG Model

- LNG Supply/ Demand
- LNG Shipping
- Netback Optimisation
- Small-scale LNG

Green Gases

PtX Model

- Project profitability
- State aid requirements

Biomethane Model

Price scenarios per biomethane fraction for key EU markets

Regulatory framework
Assessing the impact of regulatory changes

Emissions

Carbon Market Model

Modelling
Supply & demand of emission certificates, and resulting **equilibrium price**

Regulatory framework
Assessing the impact of regulatory changes (e.g. revision of the emission cap and supplied volume of certificates) on the market

(District) Heating

District Heating Model

- Dispatch of existing assets
- Optimal asset park expansion

Heating Market Model

- Evolvement of demand
- Simulation of heat technology evolvement

Source: Compass Lexecon

CL Experts have set up and regularly enhance energy system models

Our power system model was developed in Plexos®

- Our model of Power Markets uses the **dispatch optimization software Plexos®,** using data and CL assumptions for demand, supply and interconnections.
- **Plexos® is globally used by regulators, TSOs, and power market participants**. The model is specifically designed to analyse renewable generation and intertemporal storage problems with high-RES penetration level**.**
- **CL's power market model covers the EU-27 countries** as well as the United Kingdom, Switzerland, Norway, the Balkans, Turkey, Ukraine and Moldova.
- We have used the model extensively in markets outside Europe, e.g. **Israel, Oman, Australia, and US**.
- The power market model **determines zonal prices as the marginal value of energy,** accounting for generators' bidding strategies. In each price zone, supply is determined **based on individual plants.**
- The database of powerplants **contains technical parameters of all European thermal plants**. It also takes into account cr**oss-border interconnectors and unit-commitment** plant constraints.

Compass Lexecon's power model (inputs and outputs)

Inputs

- Demand
- Fuel
- Hourly renewable profiles
- Plant build / retirement
- Operating costs / constraints

Regulation

- Regulated generation
- Energy policy
- Regulatory development in spot markets

Outputs

- Wholesale Power Prices and spread at different granularities
- Capacity price
- Emissions
- Fuel Consumption
- System costs
- Imports & Exports
- Asset valuation
- Policy and regulation comparison

2.

Presentation of N-SIDE

We are N-SIDE

Founded in 2000, university spin-off

Offices in **Belgium, Japan & US**

200+ people (Energy + LS)
10% PhD **30** Nationalities

25% annual growth

N-SIDE

We are a blend of passionate Software Engineers and Energy Experts combining our knowledge to help **Power Exchanges** and **System Operators** in creating better, safer and more efficient **markets** and **grids**

Our Technologies

- Mixed Integer Programming
- Supervised Learning
- Unsupervised Learning
- Reinforcement Learning
- Constraint Programming
- Stochastic Optimization

The complexity of the power sector is growing across several dimensions

More unpredictable and variable

Balancing, inertia, closer to RT operation…

More interconnected

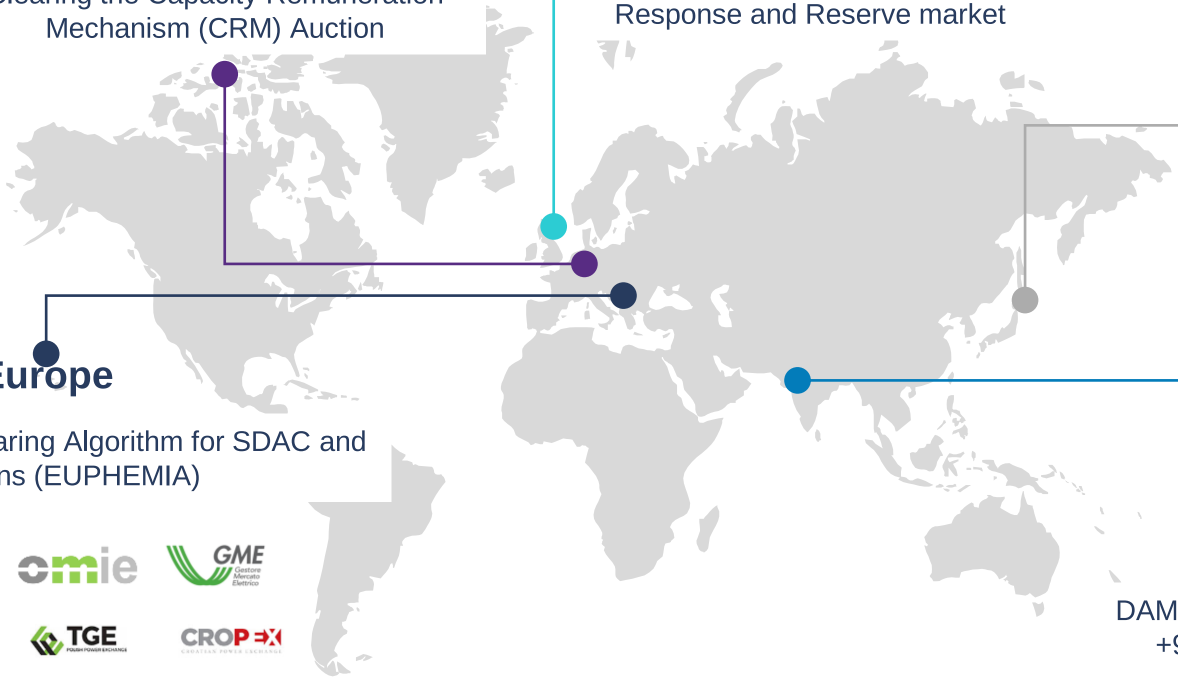
X-border, T&D, Markets and Grids, Energy and Capacity

More distributed (and localised)

More local assets, flex markets,

We believe Optimization and AI must be leveraged in order to create **better, safer and more efficient** power markets and grids

At N-SIDE, we design and build power markets, maximizing social welfare for more than 2 billion people



Belgium

elia

Clearing the Capacity Remuneration Mechanism (CRM) Auction

UK

nationalgridESO

Clearing the Ancillary Services Response and Reserve market

UK Power Networks | epexspot

DAM Clearing Algorithm UKPN (DSO)

Japan

JEPX

DAM Clearing Algorithm for JEPX

Europe

Provider of European Clearing Algorithm for SDAC and SIDC Auctions (EUPHEMIA)

epexspot, NORD POOL, omie, GME, HEnEx, semopx, TGE, CROPEX

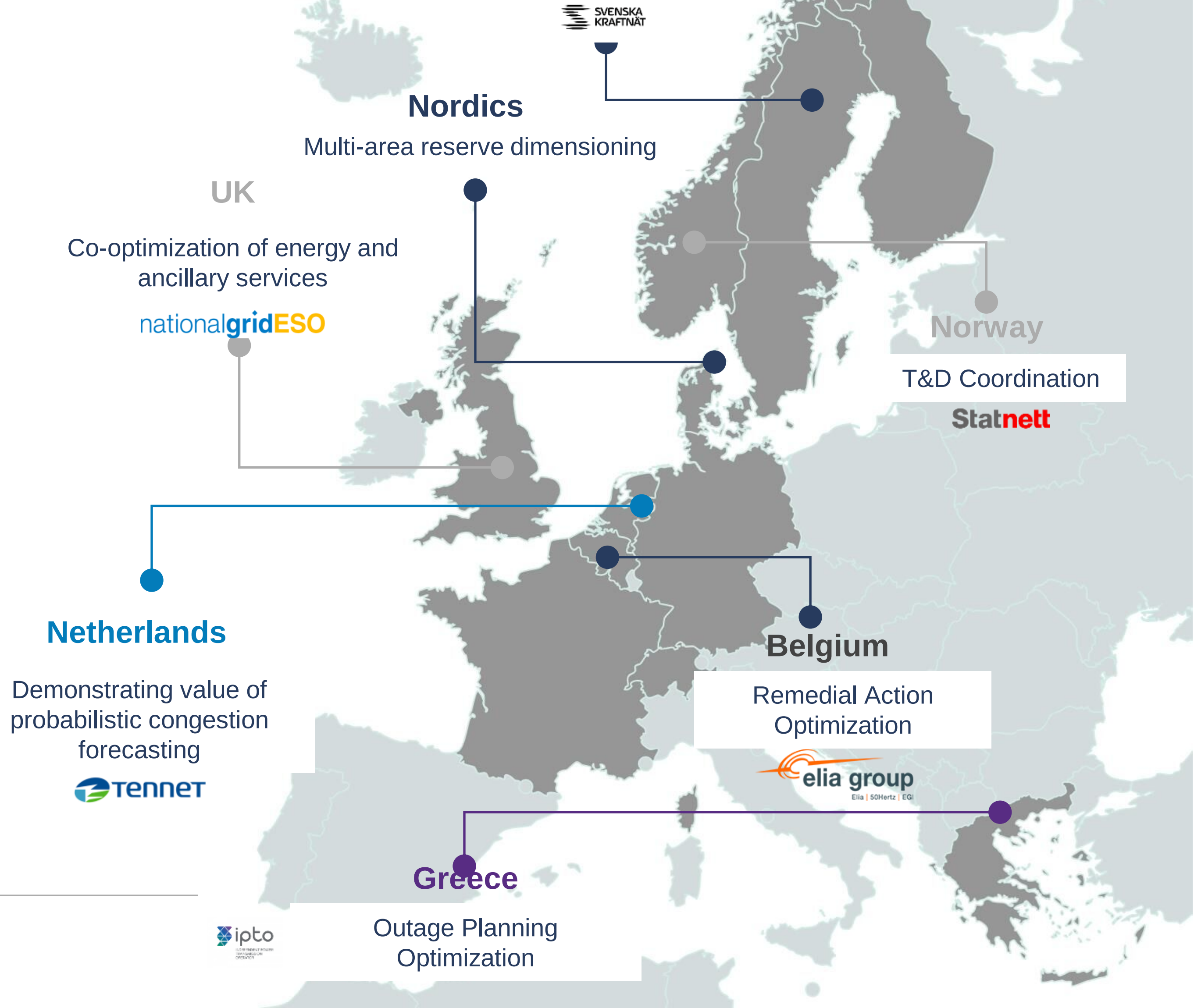
India

IEX

DAM clearing algorithm for IEX (clearing +90% of the Indian power market)

N-SIDE supports system operators with advanced analytics and advisory services

- Providing state-of-the-art **optimization & AI solutions** as well as **advisory services** to system and market operators seeking to address key energy challenges.
- Improving **informed decision making** across balancing, congestion management, adequacy.
- Delivering **consulting and software** projects with high-reliability.



We help SOs in keeping the lights on thanks to a unique combined expertise on 3 key topics

Maintain the balance of the grid

- Imbalance Forecasting
- Balancing Market Design
- Balancing Auction Clearing
- Balancing Market Platform

Ensure System Adequacy

- Dynamic Reserve Dimensioning
- Capacity Mechanism Design
- Capacity Auction Clearing
- Capacity Mechanism Platform

Avoid Grid Congestion

- Congestion Forecasting
- Remedial Actions Optimizer
- Maintenance Planning Optimization
- Flow Forecasting
- Flexibility Market Design
- Flexibility Auction Clearing
- Flexibility Market Platform

3.

Insights from the Israeli Market Clearing Price analysis

Objective of our work and task carried out

Objective

- Given the specific electricity market context of Israel, our work aimed to identify ways to improve the existing pricing methodology.

Tasks carried out

- For that purpose, we carried out the following tasks:

Identification of gaps in the current approach to set MCP and recommendations

N-SIDE, COMPASS LEXECON

- We analyzed the current pricing methodology in Israel and identified recommendations for improvement.

Backcast analysis of 2021

- We generated a model representing the Israeli electricity market in 2021, ensuring its accuracy in replicating historical results. (COMPASS LEXECON)
- This model was used to explore potential modifications to the market clearing price calculation. (N-SIDE)

Forward analysis 2024-2026

- We implemented the Israeli electricity market model for 2024-2026 based on the forward scenario assumptions (COMPASS LEXECON)
- We assessed the market impact (prices, make-whole payments, etc.) of the recommended pricing methodologies (N-SIDE)

Our analysis of the best pricing principles applicable in the Israeli context revolves around three pillars

Marginal pricing fixes

- The current Israeli pricing approach uses rules for setting the MCP that approximate, but sometimes do not match optimal pricing.
- Due to various optimization trade-offs, such as intertemporal constraints and reserve-related constraints, the optimal price may deviate from the minimum marginal cost of the marginal unit.

Constrained vs unconstrained models

- This element adds practical and political aspects to the previous pillar by considering the benefits of accounting for specific dispatch constraints while computing the MCP.

Non-convexities

- This stream includes an aspect of how to manage non-convexities to the two previous discussions (e.g. in order to account for the impact of start-up/minimum load costs on the MCP).

Current Israeli pricing methodology deviates from the system marginal price

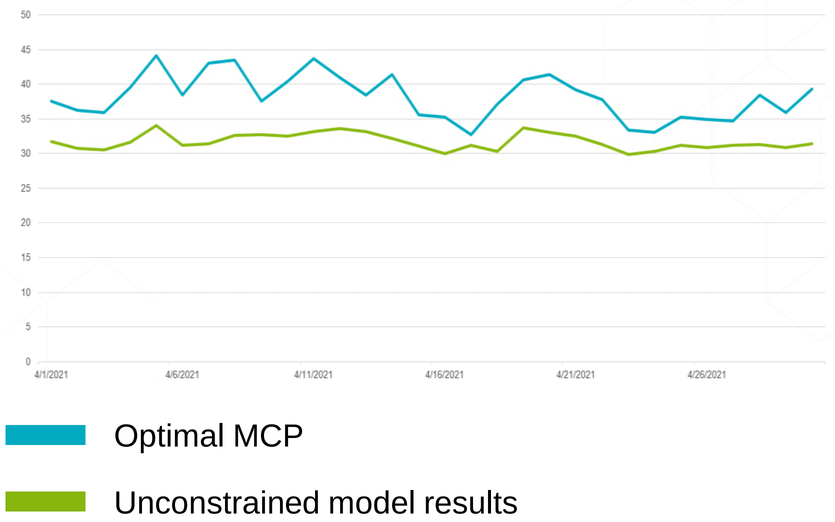
The current pricing methodology does not properly define the system marginal cost

- In the current pricing approach, the price is set by the partially loaded plant with the lowest marginal cost, i.e. the cheapest partially loaded unit.
- However, such units may be partly loaded due to constraints that prevent them from providing additional energy, e.g. reserves requirements or ramp constraints. Hence, such units can be seemingly marginal.
- Calculations in the current pricing approach do not account for these constraints, which may result in underestimation of the true cost of supplying an additional MW of load.
- Graph on the right illustrates the impact of that in April 2021.

Further departures of NOGA's approach from optimal pricing

- The exclusion of coal bids and downward bids from the definition of the MCP may create another deviation from optimal pricing. Nevertheless, this may be justified in the Israeli context due to their very specific status.

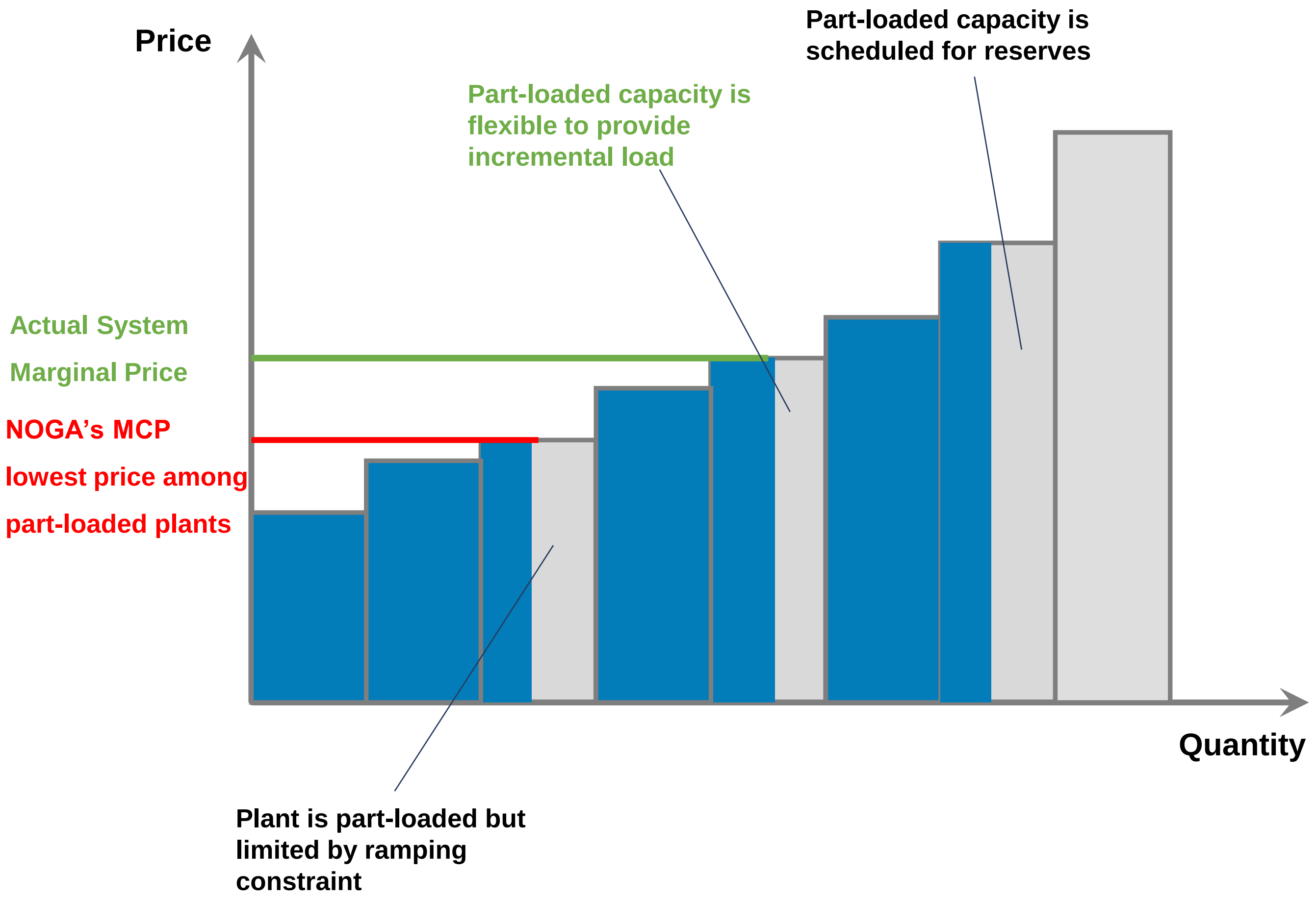
Comparison of average daily prices ($/MWh) obtained for April 2021



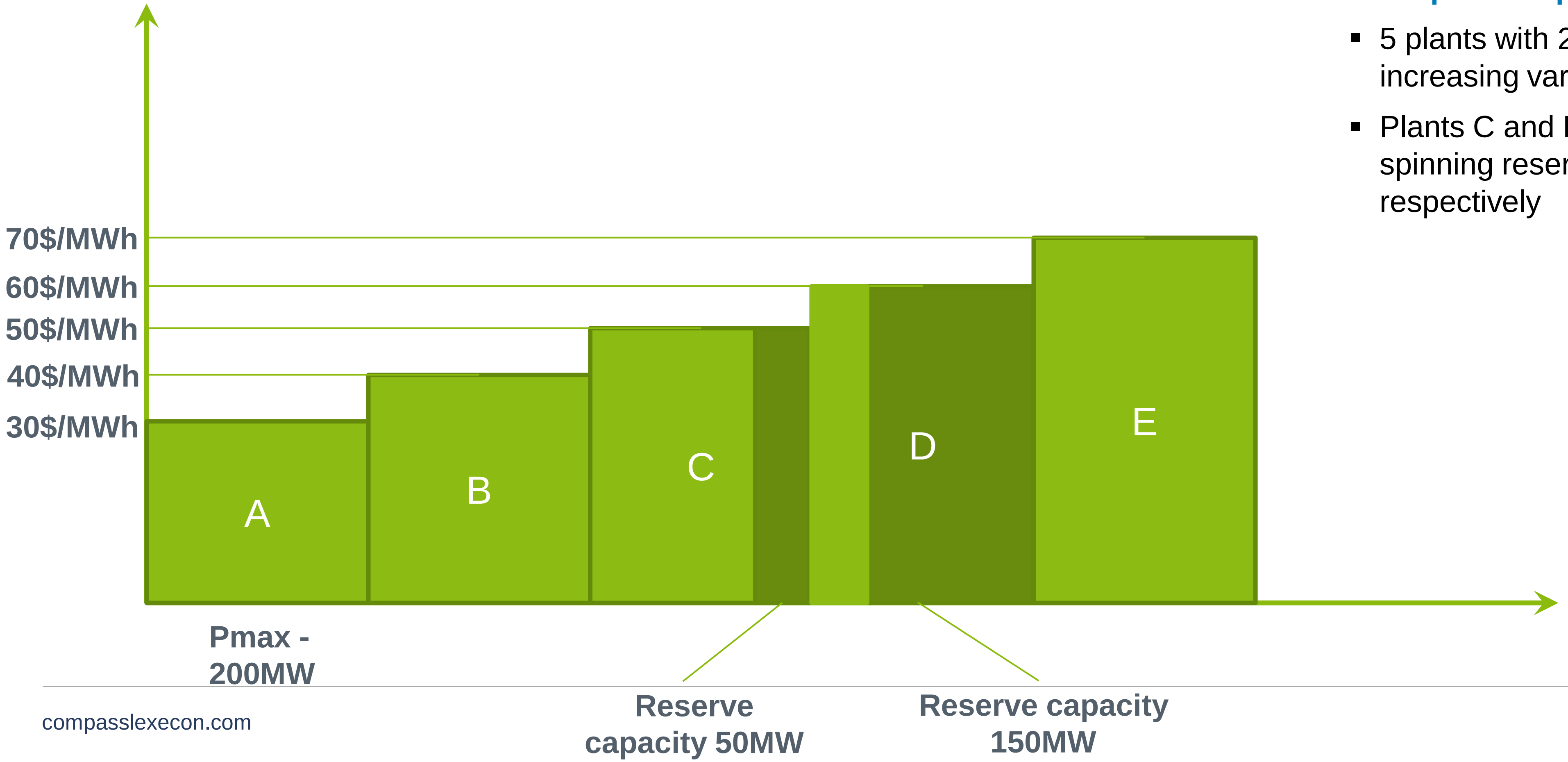
A part-loaded plant does not always indicate the system marginal cost

A plant can be part-loaded because of various constraints

- Optimal dispatch accounts for a number of constraints that may result in part-loading plants, e.g. ramping constraints, provision of reserves, inter-temporal constraints of hydro and battery storage.
- Such constraints imply that a part-loaded plant cannot meet an incremental energy demand and does not represent the system marginal cost.
- **Hence, the current approach to calculate the MCP by using the bid/cost of the lowest part-loaded plant results in a systematic downward bias**



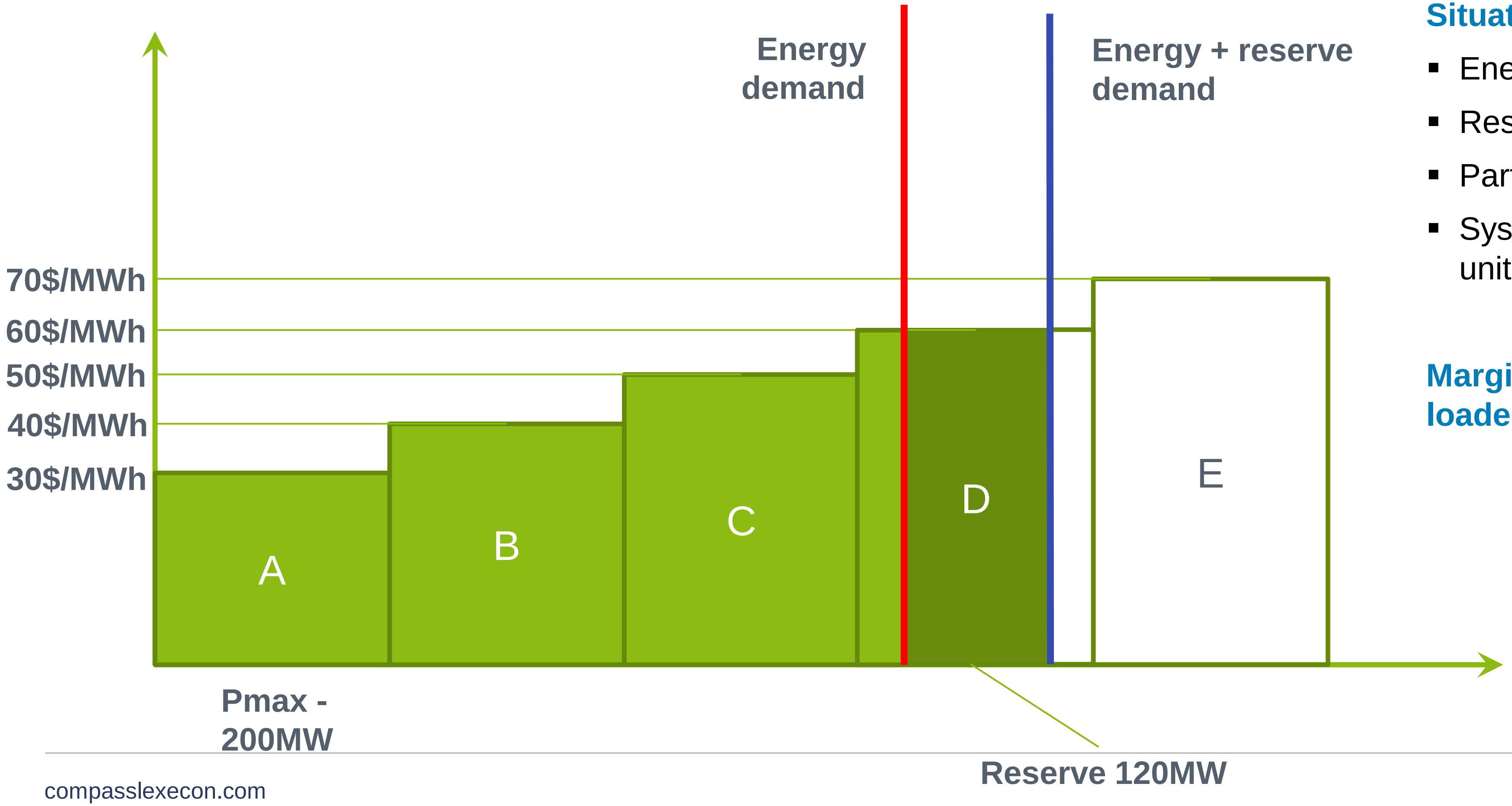
Example: Reserves and energy co-optimisation can result in low MCP under the current pricing approach



Example set-up

- 5 plants with 200W capacity each and increasing variable cost
- Plants C and D have capacity to provide spinning reserve of 50MW and 150MW respectively

Example: Situation 1 – A part-loaded unit represents the system marginal cost

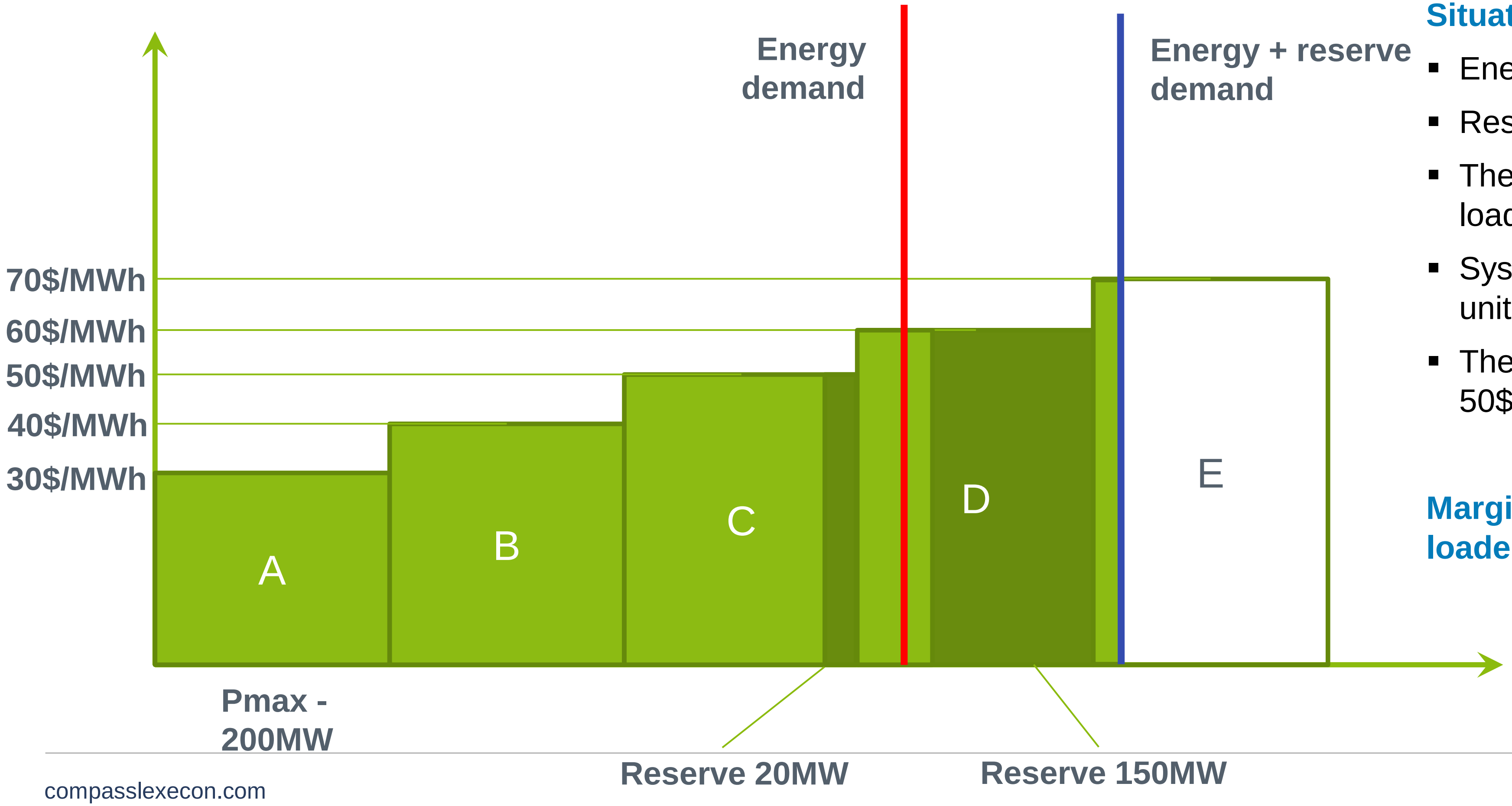


Situation 1

- Energy demand: 640MW
- Reserves demand: 120MW
- Part-loaded unit – D
- System marginal cost of energy – provided by unit D at 60$/MWh

Marginal cost of energy = cost of the part-loaded plant

Example: Situation 2 – the minimum cost of a part-loaded unit is lower than the system marginal cost

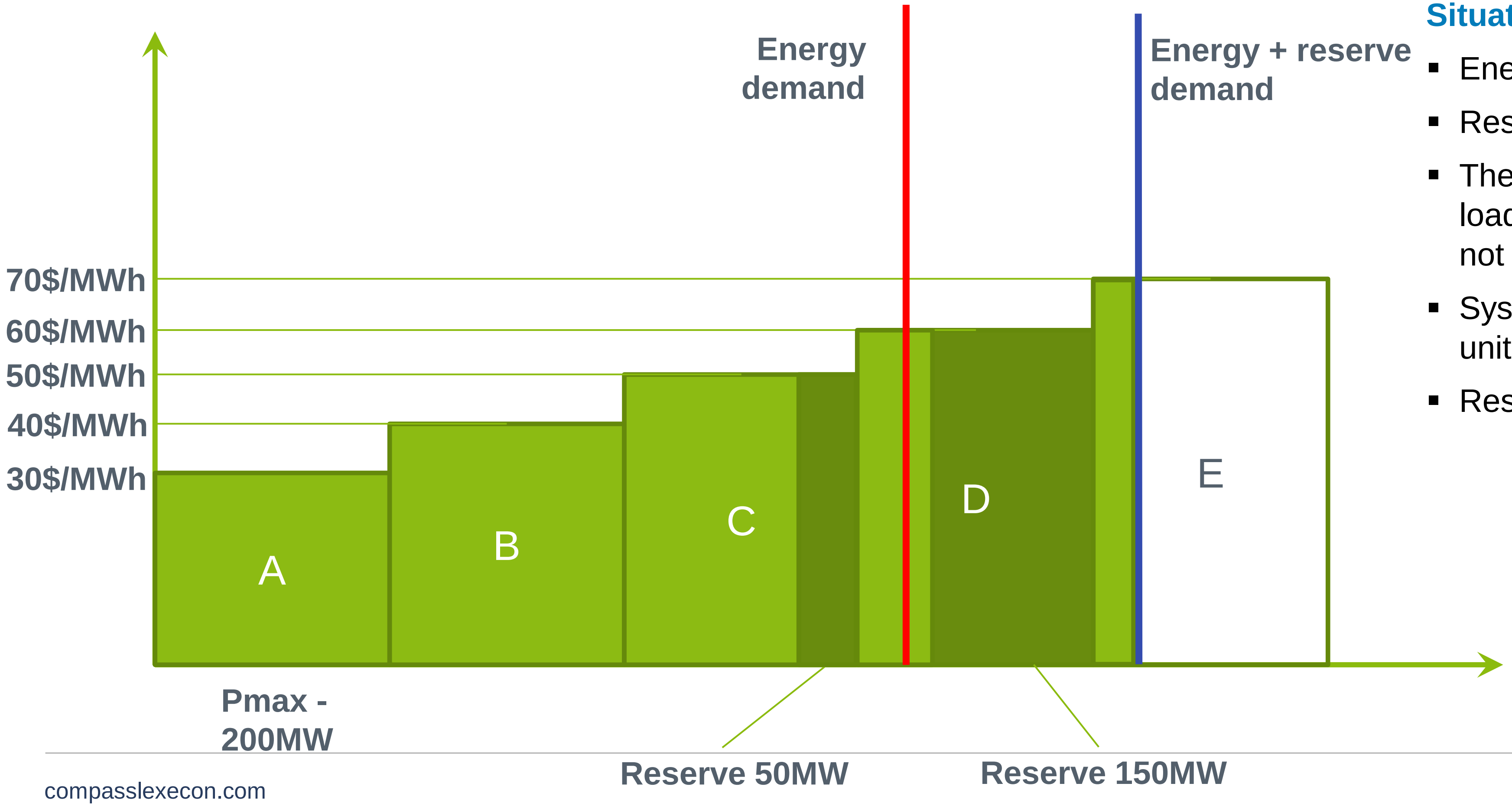


Situation 2

- Energy demand: 640MW
- Reserves demand: 170MW
- The reserve requirement requires part-loading units C and E
- System marginal cost of energy – provided by unit E at 70$/MWh
- The lowest cost of a part-loaded plant C is 50$/MWh

Marginal cost of energy > cost of the part-loaded plant

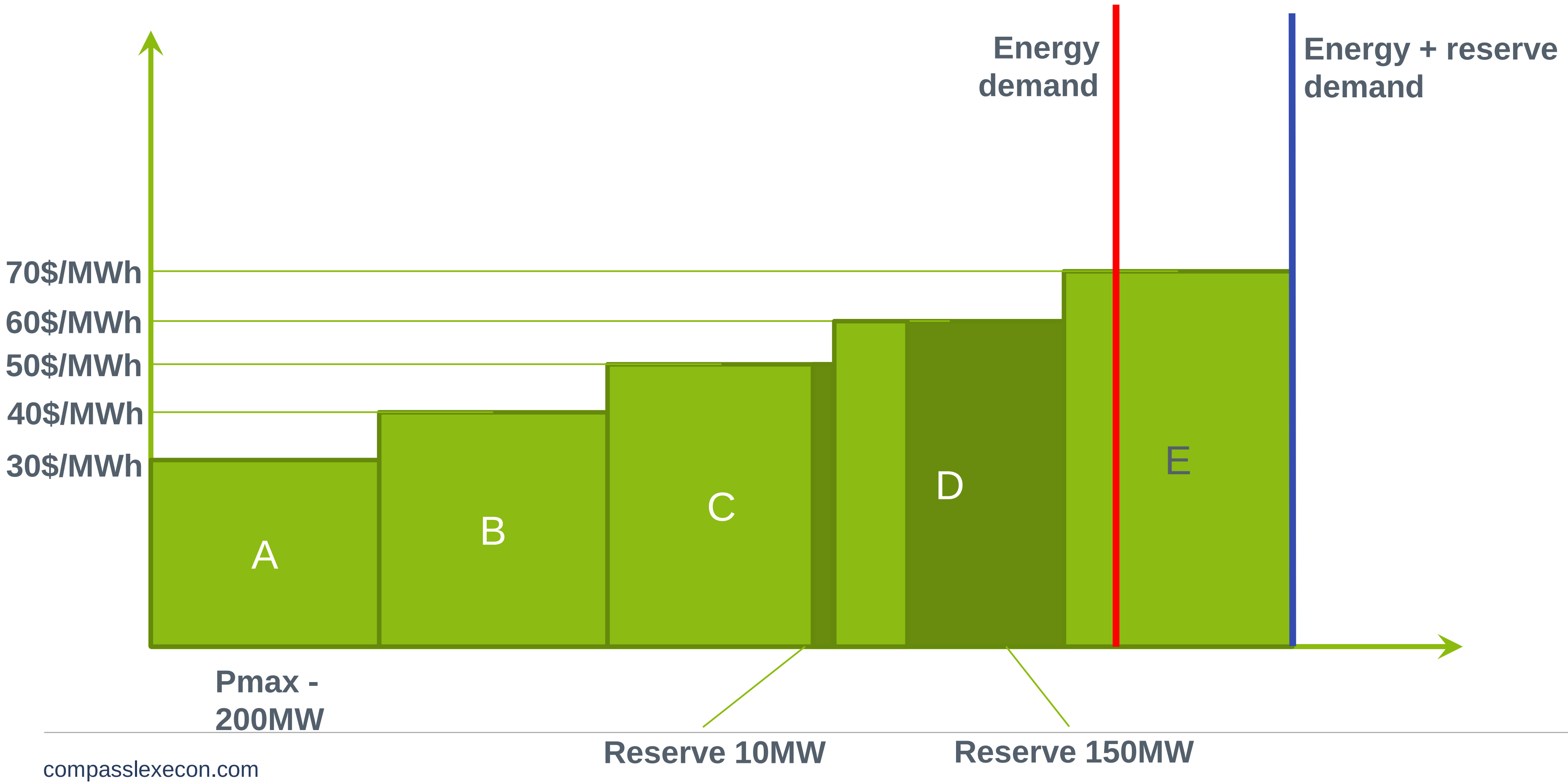
Example: Situation 3 – reserve scarcity



Situation 3

- Energy demand: 640MW
- Reserves demand: 210MW
- The reserve requirement requires part-loading units C and E, but reserve capacity is not enough
- System marginal cost of energy – provided by unit E at 70$/MWh
- Reserve shortage premium 1000$/MWh

Example: Situation 4 – reserve and energy scarcity



Situation 4

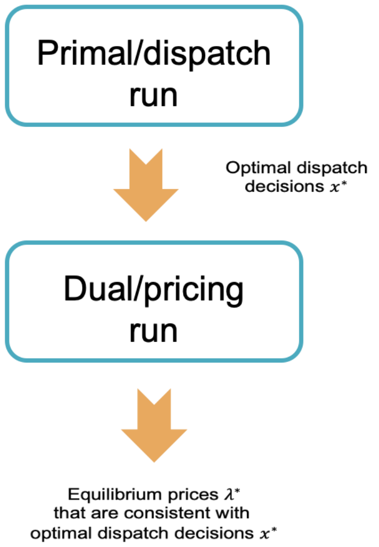
- Energy demand: 840MW
- Reserves demand: 210MW
- The reserve requirement requires part-loading units C and E, but reserve capacity is not enough
- System marginal cost of energy – provided by unit C at 50$/MWh and the reserve premium price of 1000$/MWh, so 1050$/MWh

The proper way to address these issues is by setting the MCP at the system marginal price

Identified solution

- The proper way to address the previous issues is to replace the current business rules by setting the MCP at the level of the "shadow price" of the energy balance constraint in each period.
- These optimal prices are also named optimal Lagrangian multipliers or optimal dual variable values.
- They reflect the exact marginal cost of energy in each period in the system accounting for all the constraints, without specific business rules to identify part-loaded plants, or exclusion of specific bids and offers.

Recommended approach: System marginal price (dual values)



Dual of a linear/convex optimization problem

Primal (*Optimizing the Dispatch*)		*Dual* (*Computing prices*)	
Min	$b^T y$	**Max**	$c^T x$
s.t.	$A^T y \geq c \quad [x]$	**s.t.**	$Ax \leq b$
	$y \geq 0$		$x \geq 0$

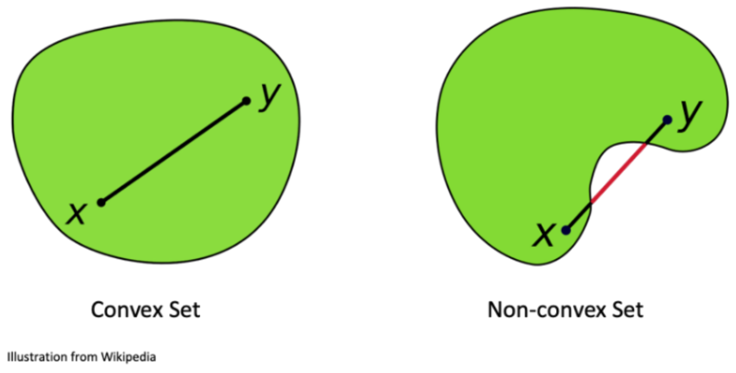
x : dual variables 'pricing' constraints $A^T y \geq c$

- To a given (linear/convex) optimization problem is attached a closely-related "dual optimization problem".
- Under basic assumptions, optimal primal and dual variable values will satisfy relations leading to interpret dual variables as "optimal prices" (so-called x).

We analyse two approaches to address the non-convexities issue: Convex Hull Pricing and Integer Relaxation

- Non-convexities refer to the cost structure and technical constraints of specific units which lead to market models that are "non-convex" in the sense that the corresponding mathematical optimization problems are "non-convex".
- An example of non-convexities is given by commitment costs such as minimum load costs and startup costs.
- Marginal prices by definition do not reflect commitment costs (minimum load, start-up, etc) and may then lead to high make-whole payments. These make-whole payments are typically required because minimum load costs and/or startup costs are not recovered via the payments which would depend on the MCP alone.
- In the presence of non-convexities, market equilibrium prices do not exist.
- Various approaches are used in international electricity markets in order to address this challenge:
  - Convex Hull Pricing
  - Integer relaxation

Graphical representation of non-convexities

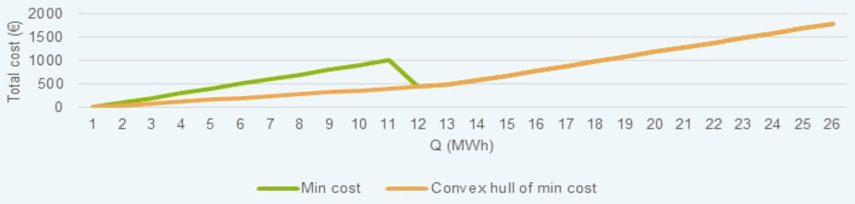


Note: a set is convex if, for any two points of the set, the line that connects the two points lies within the set. In the opposite case, the set is non-convex.

We analyse two approaches to address the non-convexities issue: Convex Hull Pricing and Approximate Convex Hull Pricing

Convex Hull Pricing

- Convex Hull Pricing ("CHP") aims at minimizing the impact of non-convexities in terms of lost opportunity costs (missed revenues) or losses.
- Figure below represent how CHP are computed. The green curve represent the cheapest way to produce Q MW. The orange curve depicts the convex hull of this system cost function: this is the closest convex function sitting underneath the green curve.



- CHP incorporates start-up and no-load costs into the price, minimizes total uplift and allows block-loaded resources and those operating at their minimum or maximum limits to affect the price when appropriate.
- However, CHP is computationally demanding and may not be feasible. Thus, an approximate convex-hull solution can be calculated using separate dispatch and pricing.

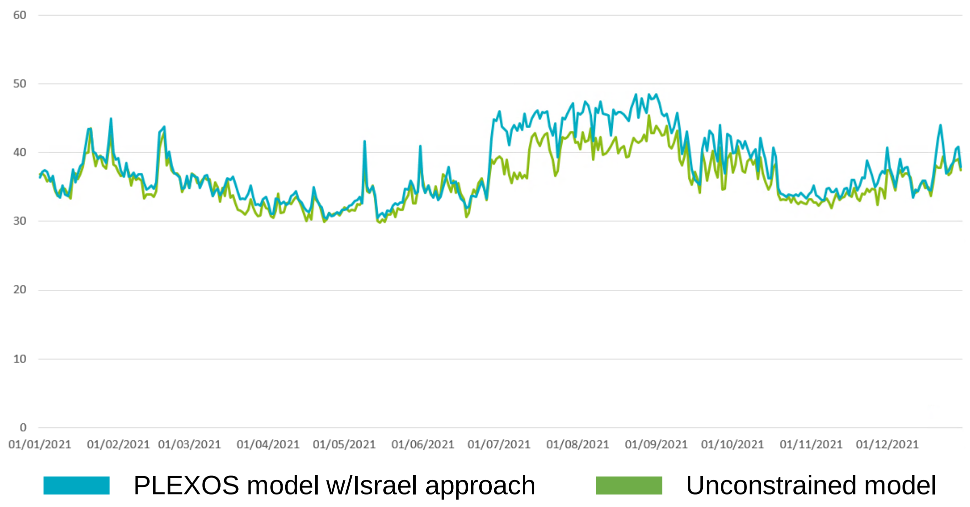
Approximate CHP via the integer relaxation

- The intuition on the integer relaxation methodology ("Approximate CHP") is as follows: the same standard marginal pricing principles are used, but are applied to a pricing run where:
  - Binary commitment decisions are allowed to take fractional values (e.g., a minimum load level is enforced only at 60%)
  - Costs associated to these commitment decisions are treated as "variable costs" depending on the percentage of acceptance of the decision and are somehow "adders" to what is otherwise setting the MCP.
- In certain specific technical contexts, the "integer relaxation" provides exact CHP, and in other cases it leads to market prices that are close to the exact CHP.
- Approximate CHP is computationally less demanding; however, its results may not be completely intuitive (e.g. unit working virtually working below its Min Stable Level).

Replication of the 2021 prices

- **Objective:** generate a model that replicates historical prices with sufficient accuracy so that it can be used to analyse the impact of different options to modify the market clearing price calculation.
- **Methodology:** the model of the Israeli market was constructed in the commercial platform Plexos® based on the data and assumptions provided by and agreed with NOGA. Based on the Plexos® dispatch results, the MCP calculated based on NOGA's approach was replicated using a bespoke XLS model.
- **Results:**
  - Actual MCP and replicated MCP based on NOGA's approach are aligned.
  - Differences are observed mainly in the months of July and August.
    - In the actual solution, partially loaded units (due to operational constraints that were not simulated in the replication) set the price. While in the replication, these partially loaded units were fully loaded. And as a result, more expensive units were partially loaded and set the price.

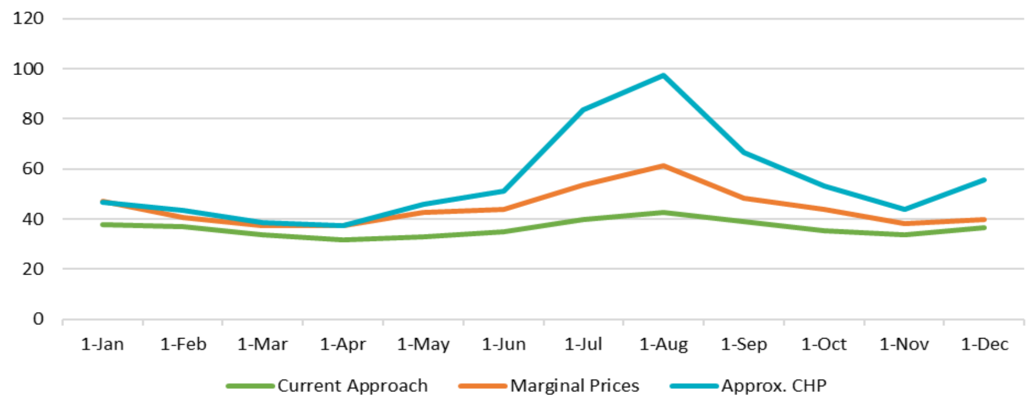
Actual unconstrained MCP and the replicated price following NOGA's approach ($/MWh) in 2021



Comparison of the alternative MCP calculations in 2021

- We simulated the MCP for 2021 under different pricing methodologies and compared the results against the ones obtained with the current Israeli approach:
- **Standard Marginal Pricing:**
  - Marginal Pricing leads to results that are correlated with the current approach, but which are consistently higher.
  - This is mainly due to the proper definition of the units which are "partly loaded" (e.g., properly taking into account ramp conditions). It is also due to the effect on prices of intertemporal constraints originated from the operation of the hydro pumped storage units.
- **Approximate CHP:**
  - Approximate CHP results are higher than marginal pricing results, because they reflect more accurately in the MCP the commitment costs (such as start-up and minimum load costs).
  - Approximate CHP are, on average, substantially higher during the peak season from July to September. The reason is that more units need to be committed during summer, leading to higher commitment costs (startup costs and minimum load costs), which are better reflected in the MCP with approximate convex hull price.

Average monthly prices for the different pricing approaches ($/MWh)



Standard marginal pricing was considered a preferred option:

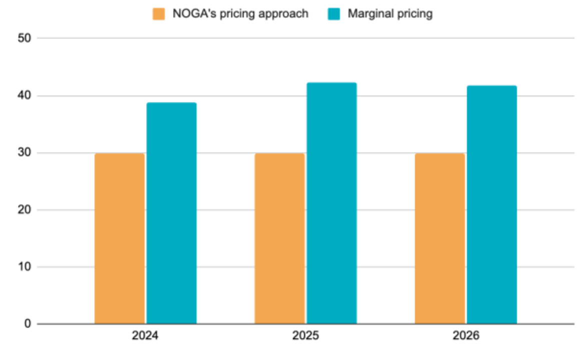
- Standard marginal pricing is easier to interpret and implement than convex hull pricing
- CHP prices lead to lower make-whole payments but higher total settlements costs.

Base Case Results in 2024-2026

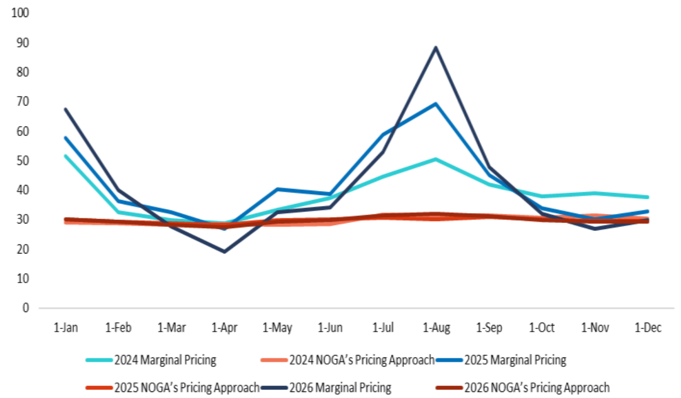
Average prices

- We compare the prices obtained with the current Israeli approach and the ones estimated with the standard marginal pricing.
- Annual average prices obtained using marginal pricing are higher than those obtained using current Israeli method. This can be explained by the fact that marginal pricing allows to better reflect the scarcity that the system would experience due to the phase out of coal.
- Main price differences occur in high demand periods (January and summer months), when, due to the limit on the daily gas consumption, more expensive gasoil units are needed to cover the demand

Comparison of annual average prices: current vs marginal pricing [$/MWh]



Comparison of monthly average prices: current (red palette) vs marginal pricing (blue palette) [$/MWh]



Base Case Results in 2024-2026

Make-whole payments and the total procurement costs

- We also compared the make-whole payments and the total procurement costs simulated using the marginal pricing approach against those obtained with the Israeli current pricing approach.
- It is possible to observe that by using a marginal pricing approach there is a decreases in make-whole payments with respect to the current pricing approach.
- Indeed, since pay-as-clear units are directly recovering a larger share of their incurred costs through market clearing prices, the remaining portion of their incurred costs that needs to be compensated is diminished.
- At the same time, the results suggest a slight increase in the total procurement costs in the marginal pricing approach as compared to the current approach.

Yearly make-whole payments and total procurement cost of pay-as-clear units % of marginal pricing with respect to current approach

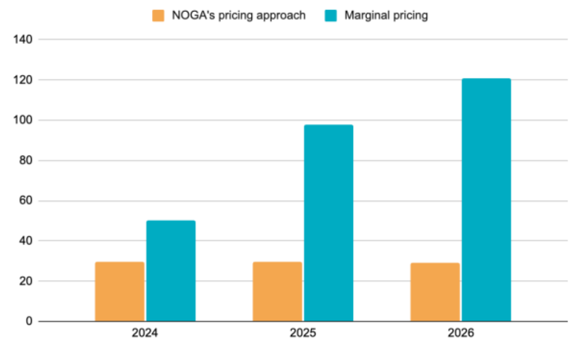
Year	Make Whole Payments (%)	Total Procurement Cost (%)
2024	38%	104%
2025	22%	108%
2026	14%	108%

Gas Shortage Scenario Results in 2024-2026

Average prices, Make-whole payments and the total procurement costs

- Additionally, we simulated a scenario with a stricter daily gas consumption limit. The daily gas limit was reduced to 1,400,000 MMBTU as compared to 1,800,000 MMBTU of the base case. All other inputs were kept the same as the base case.
- Similarly, to the results of the base case, prices of the gas constraint scenario obtained using marginal pricing are higher than those obtained using NOGA's current method. Main differences occur in high demand periods, when due to gas constraints, gasoil units are needed to cover the demand
- Under this scenario, it is possible to observe a significant increase of the difference between marginal pricing and the current approach in terms of procurement costs of pay-as-clear units and total procurement cost.
- This significant increase is due to larger observed prices during January and summer months than in the base case scenario due to a stricter daily gas consumption limit.

Comparison of annual average prices: current vs marginal pricing [$/MWh]



Yearly make-whole payments and total procurement cost of pay-as-clear units % of marginal pricing with respect to current approach

Year	Make Whole Payments (%)	Total Procurement Cost (%)
2024	32%	112%
2025	15%	154%
2026	5%	145%

Preventing MCP manipulations by monitoring

Pay-as-clear electricity markets require market power mitigation approaches

- Benefits of a pay-as-clear market would assume a competitive market
- Market power can reduce competition, distort the market and result in higher prices for consumers.
- Potential market power should be addressed through market power mitigation and monitoring

Wholesale electricity markets apply various approaches to mitigate and monitoring market power

- **Europe:** Investigations by regulators ex-post after the market clearing upon receiving specific signals or complaints.
- **US:** Ex-ante screening tests of the bids before market clearing. Regulation of the bids by RTOs/ISOs in case of risk of market power
- **Monitoring:** Includes various techniques of data analysis to effectively detect and address market power issues. Market monitoring could also involve requiring market participants to explain the reasoning for the submitted bids.

Bid price caps

- Could be used to complement market power mitigation, but do not replace the need for a stringent market monitoring effort
- If price caps are applied, they should be set with great care and be flexible enough to allow for unforeseeable market situations (e.g. EU gas crisis in 2022).

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