CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY
An Initiative of the Clean Energy Ministerial

INTERNATIONAL SOLAR ALLIANCE

International Solar Alliance Expert Training Course

In partnership with the Clean Energy Solutions Center (CESC)

Dr. David Jacobs

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Session 28: PV Integration and the Merit Order Effect

In partnership with the Clean Energy Solutions Center (CESC)

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Supporters of this Expert Training Series

IET International Energy Transition

CLEAN ENERGY
SOLUTIONS CENTER

ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

IET – International Energy Transition GmbH

Dr. David Jacobs

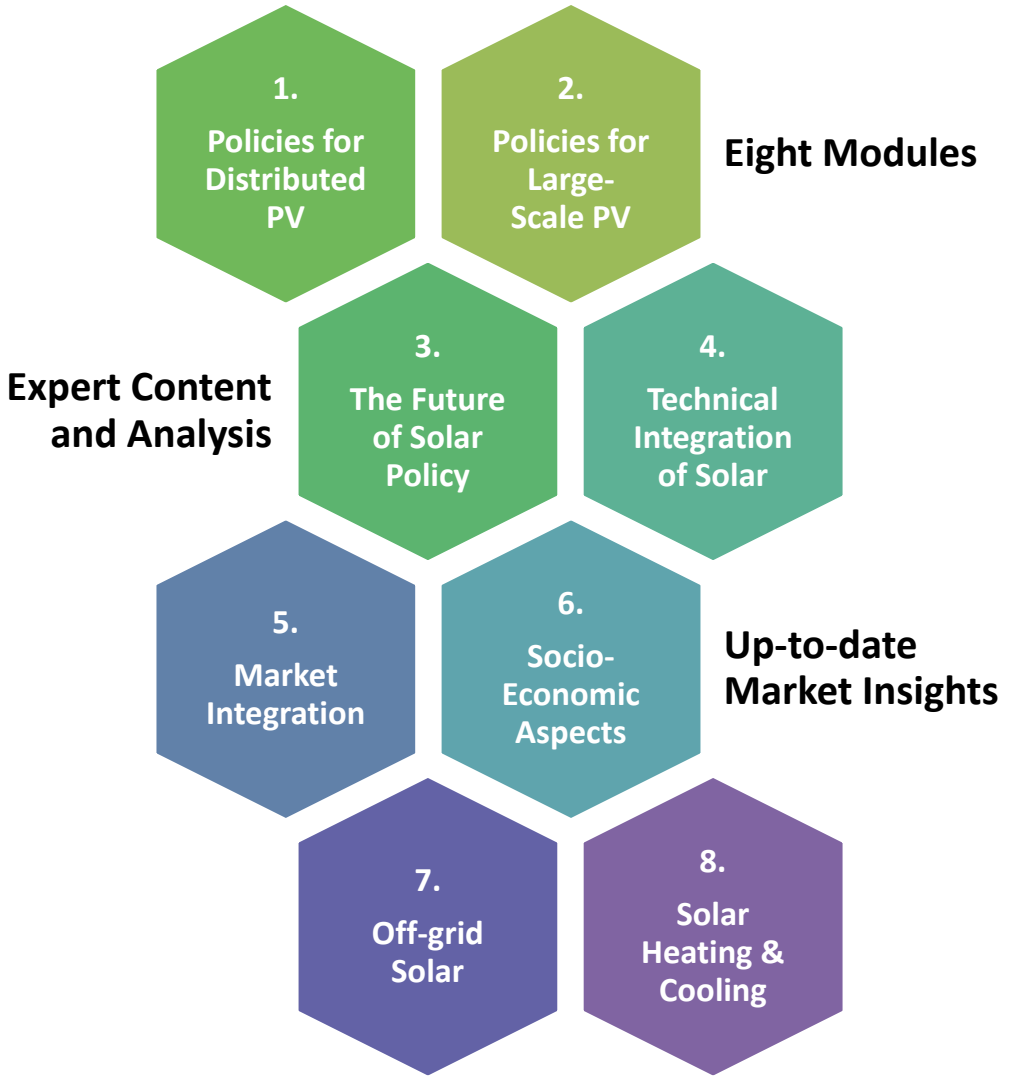
- Founder and director of IET
- Focus on sustainable energy policy and market design
- 14+ years experience in renewable energy policies
- 60+ publications on energy and climate
- 40+ countries work experience (consulting and presentations)

Training Course Material

This training is part of Module 5, and focuses on the merit order effect

Related training units are:

- ✓ 15. Subsidy Free Solar - Pathways forward
- ✓ 27. System integration of solar PV in wholesale electricity markets
- ✓ 29. Dealing with the Duck Curve: Strategies and Best Practices



Overview of the Training Session

1. Introduction: Learning Objective

2. Understanding the effect of increasing shares of solar PV on wholesale market prices (merit order effect)

3. Further Reading

4. Knowledge Check: Multiple-Choice Questions

Introduction:

Learning Objective

Learning Objective

- Understand the basic functioning of wholesale electricity markets and the merit order
- Understand the impact of renewables and solar PV in particular on wholesale electricity markets prices (the merit order effect)
- Learn about countries that have experienced the merit order effect (case studies)
- Understand parameters that allow policymakers to counterbalance the merit order effect

The Merit Order in Competitive Wholesale Market

Wholesale Electricity Markets 1.0.1

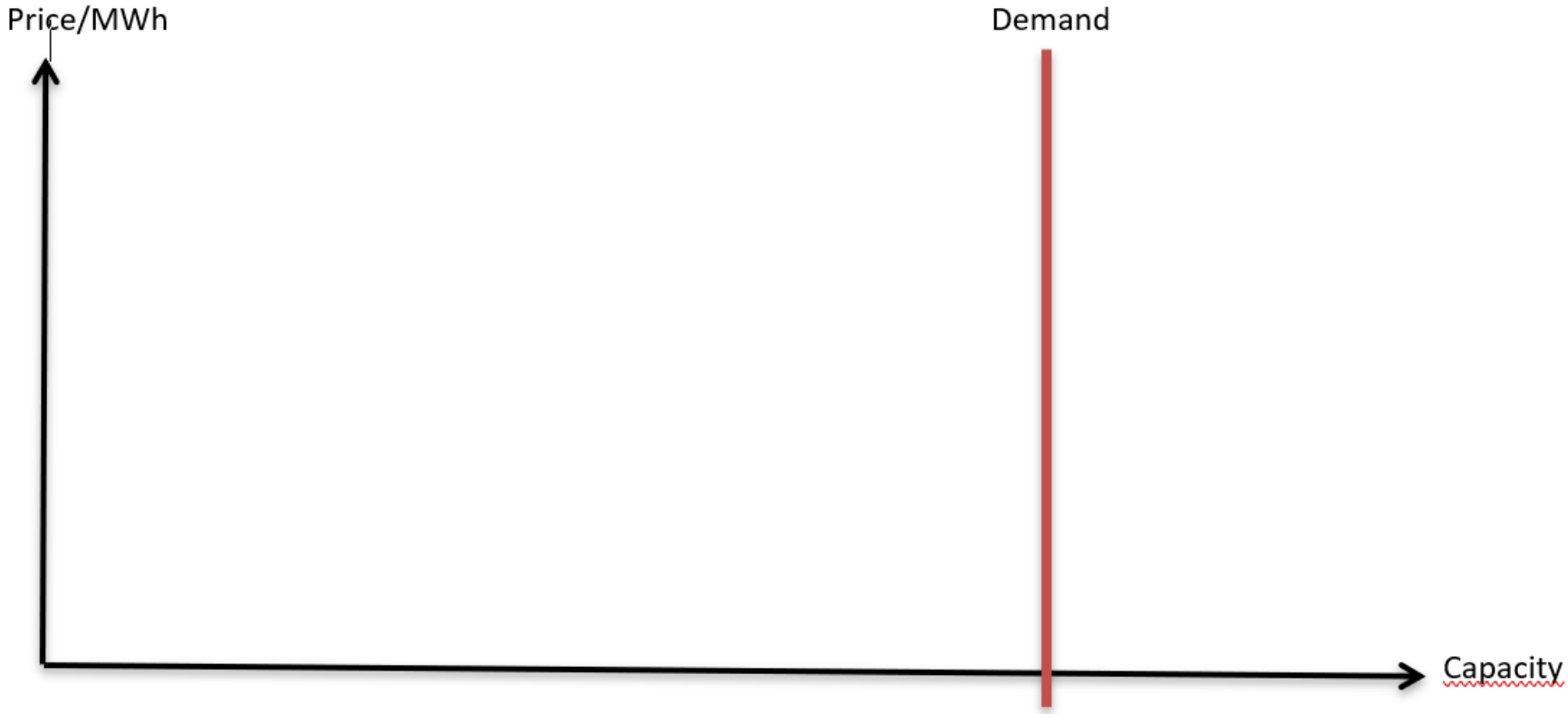
- Buyers of electricity submit bids (defining a quantity and a price they are willing to pay)
- Bids are usually issued for the next day – day-ahead market (15min or 30 min or 60 min intervals)

- Theoretically, sellers offer their “marginal costs” (e.g. fuel costs and cost of carbon
- Bids from sellers are staked up until demand is met.
- The last power plant needed to meet demand sets the market price for all power plants (market clearing price)

➢ Marginal cost pricing was first introduced in the late 1970s and replaced “cost-plus” regulation in regulated markets.

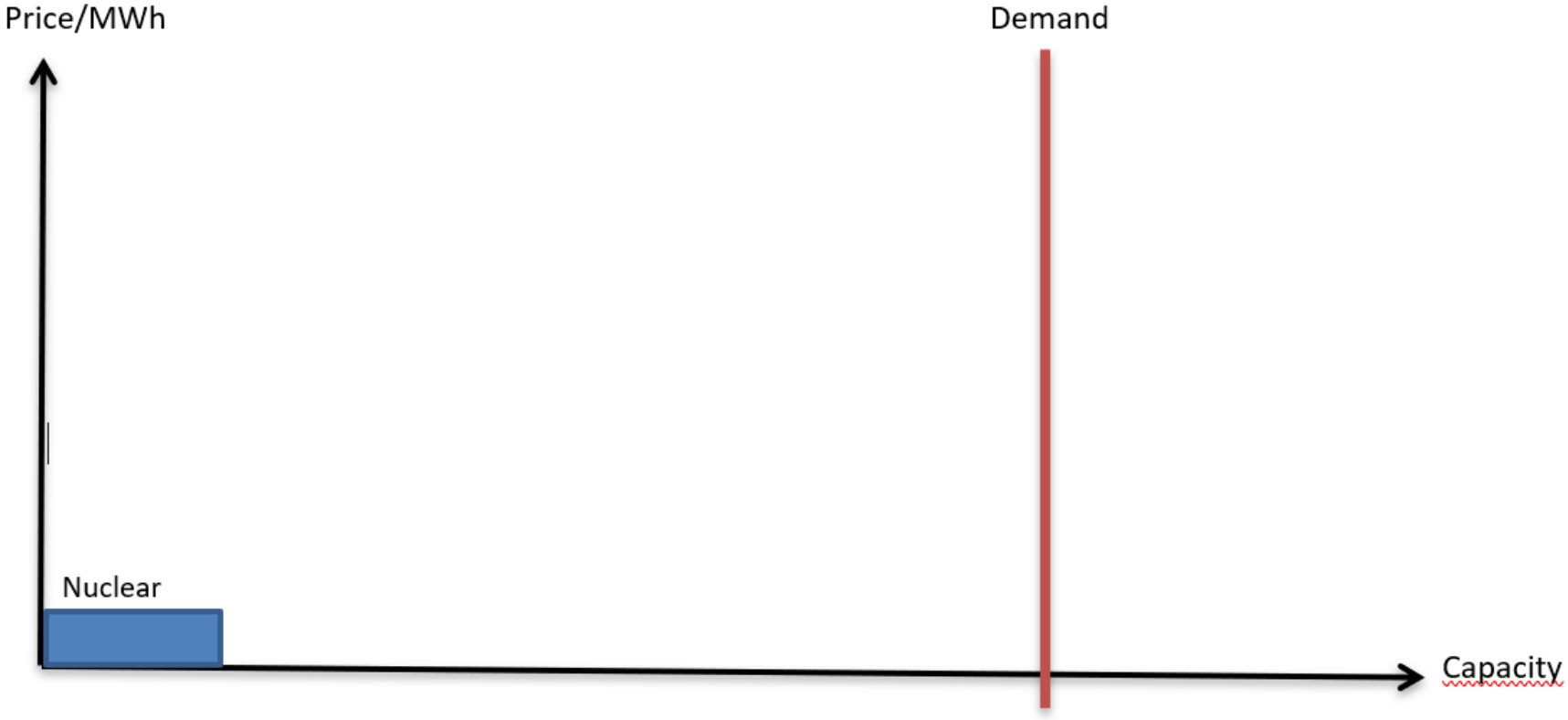
The Merit Order in Competitive Wholesale Electricity Markets

- Aggregated demand “curve” (inelastic demand)



The Merit Order in Competitive Wholesale Electricity Markets

- Staking up different power generators and their price offers



The Merit Order in Competitive Wholesale Electricity Markets

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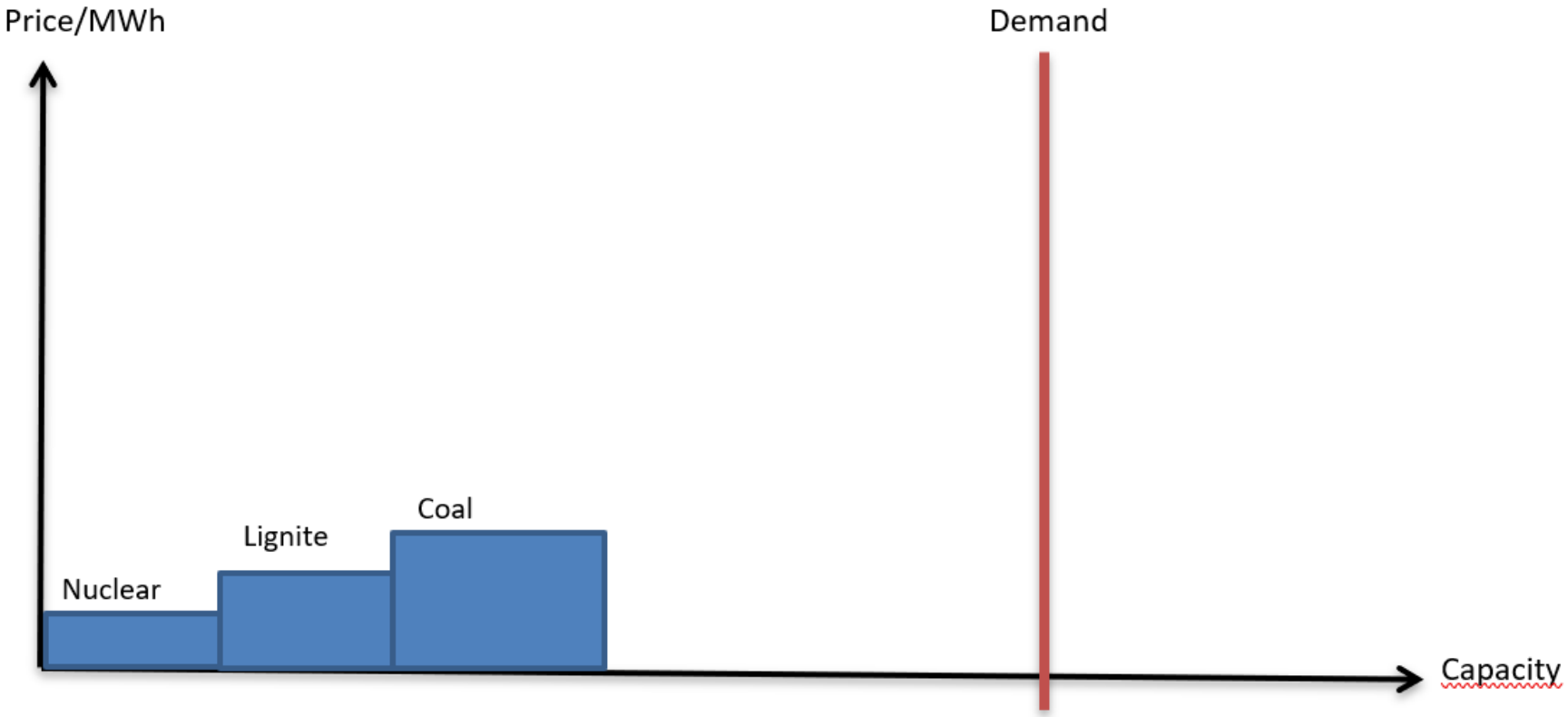

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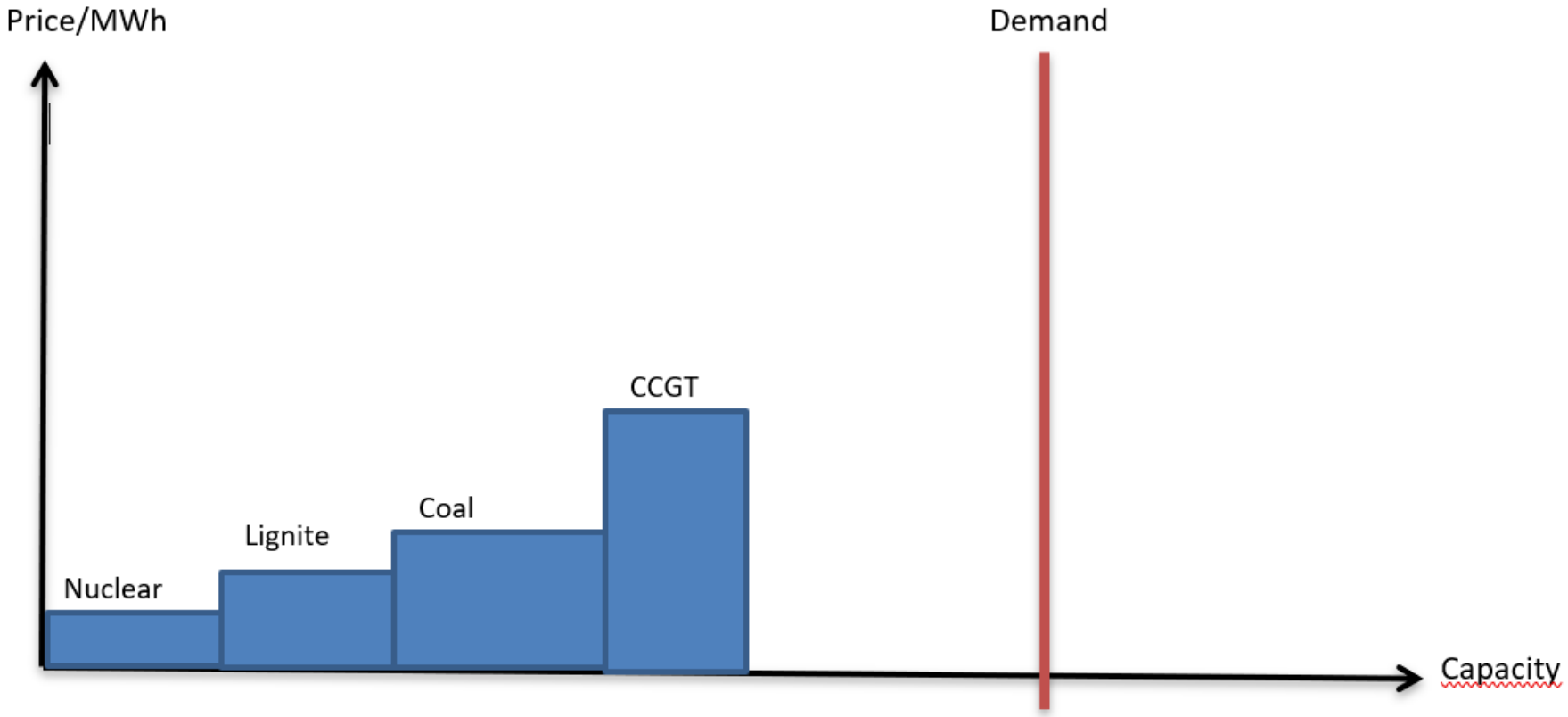
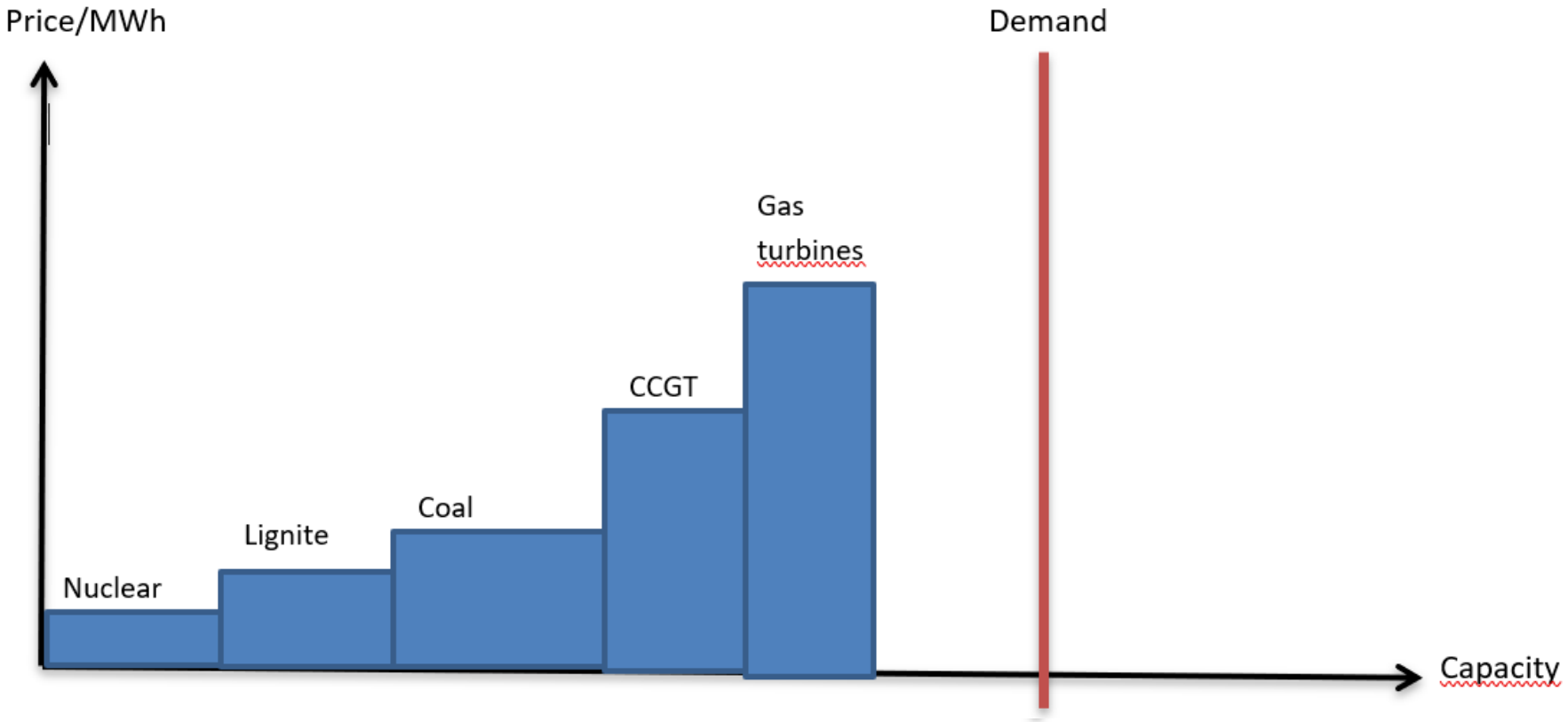


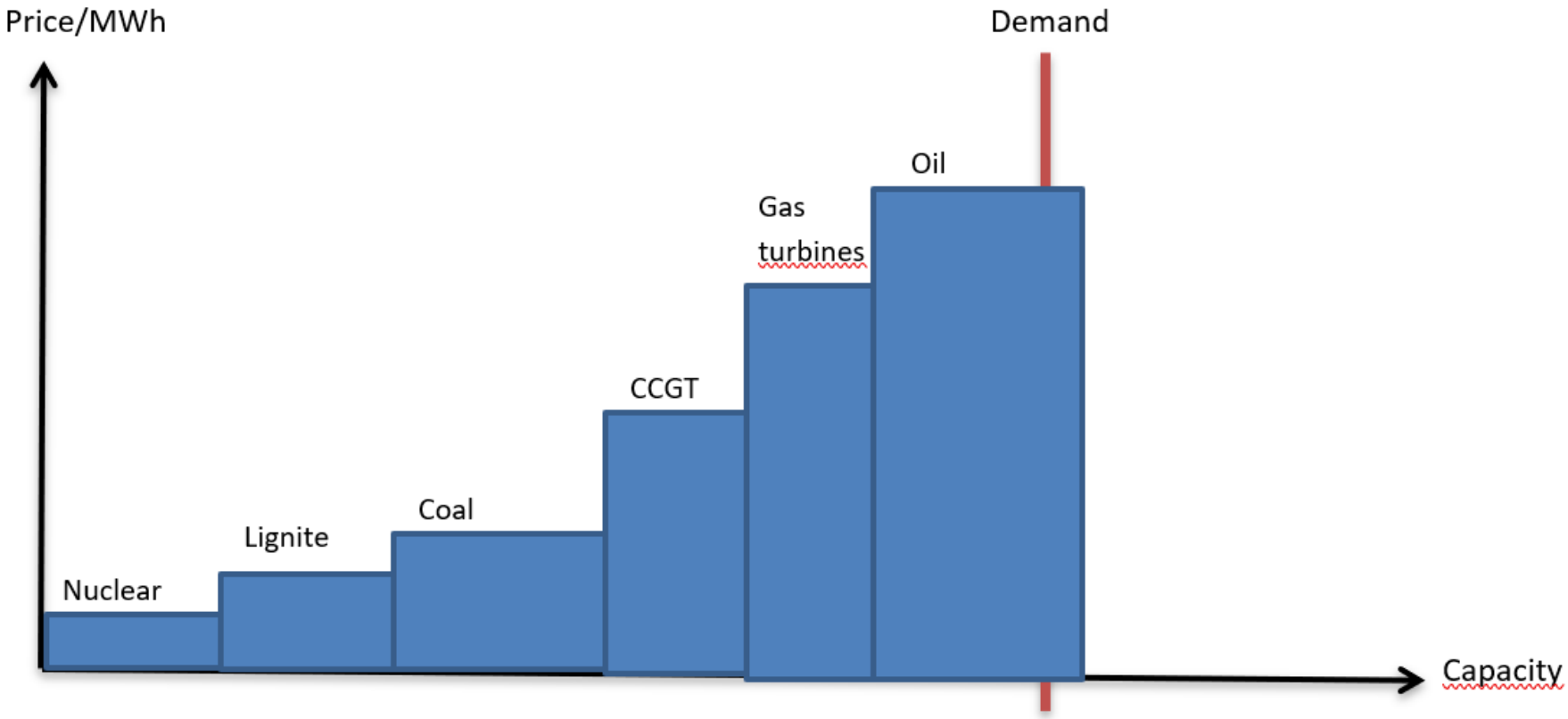
The Merit Order in Competitive Wholesale Electricity Markets

- Staking up different power generators and their price offers



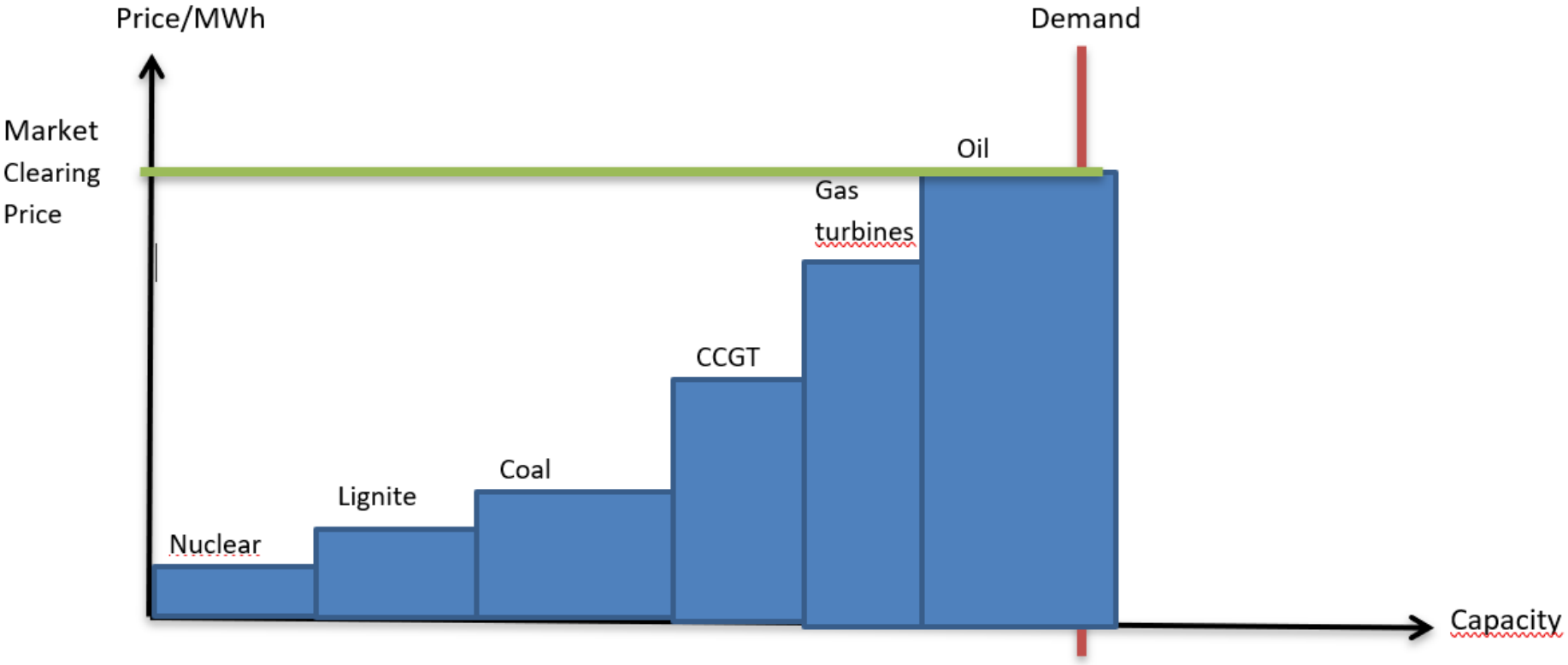
The Merit Order in Competitive Wholesale Electricity Markets

- Staking up different power generators and their price offers



The Merit Order in Competitive Wholesale Electricity Markets

- The last power plant necessary to meet demand sets the market clearing price



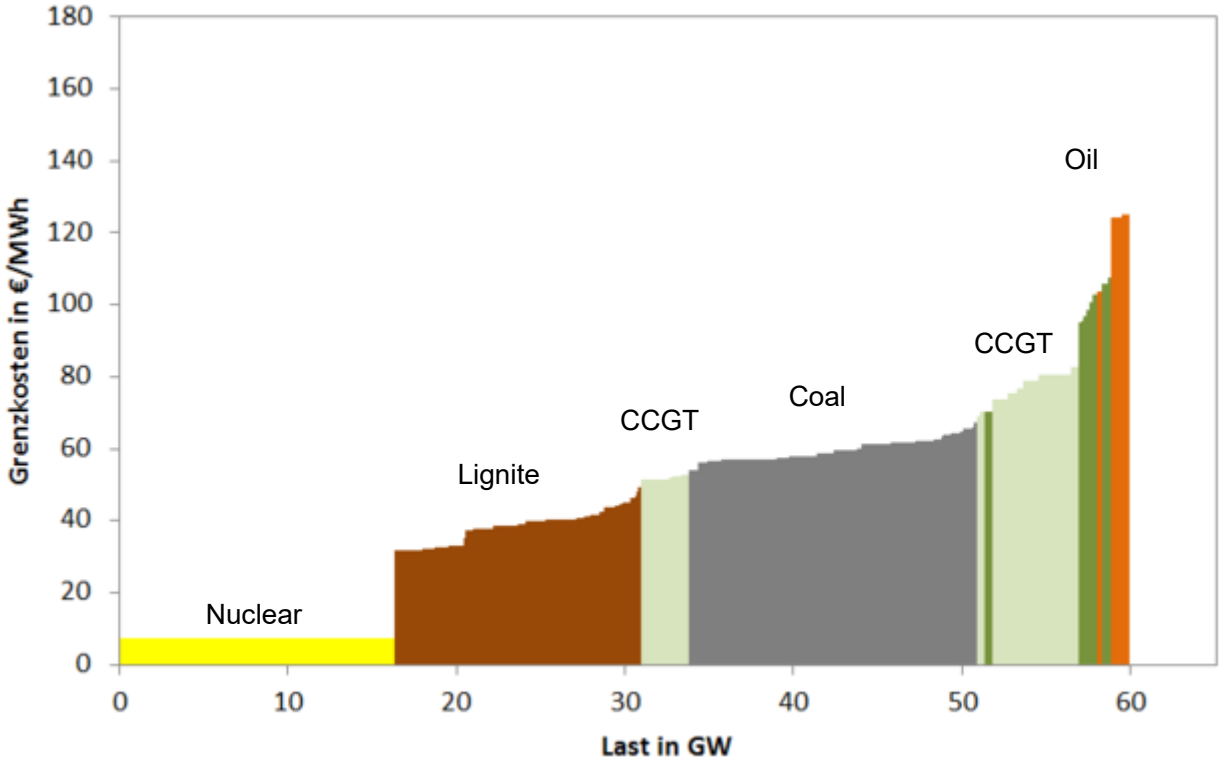
Wholesale Electricity Markets 1.0.1

- By selling their electricity on the wholesale market, power power producers (except for the market clearing plant) earn more than they need to pay their operation costs.

- The „profit margin“ allow power plants to finance their fixed costs/CAPEX.

Merit Order in Reality

- Prices offered by power plants also differ within each power plant category
- Reason: Different types of technologies, different levels of efficiency

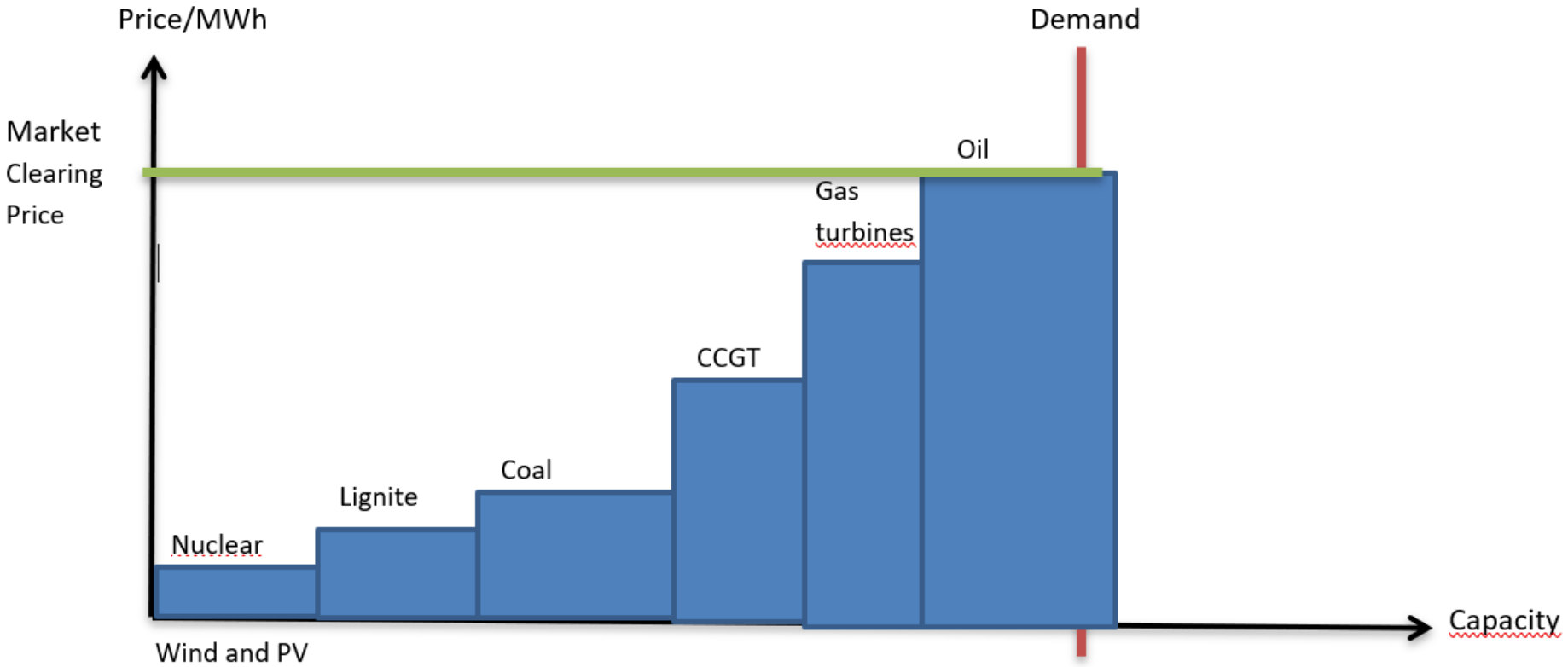


Example of the German merit order
(Source: https://de.wikipedia.org/wiki/Merit-Order)

The Merit Order Effect of Solar PV (and other RE Technologies)

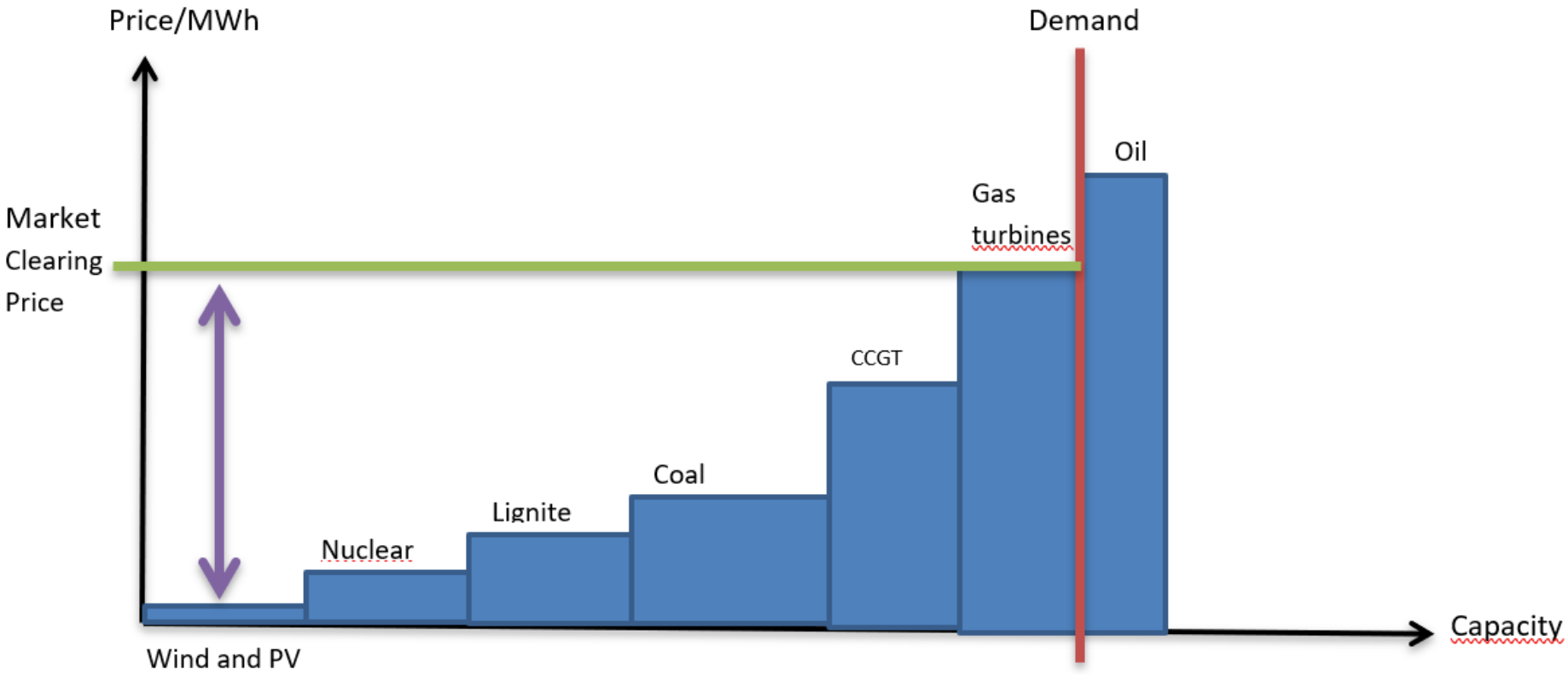
Effects on the MOE: The Share of Renewables

- Wholesale market with no share of RE (wind and solar PV)



Effects on the MOE: The Share of Renewables

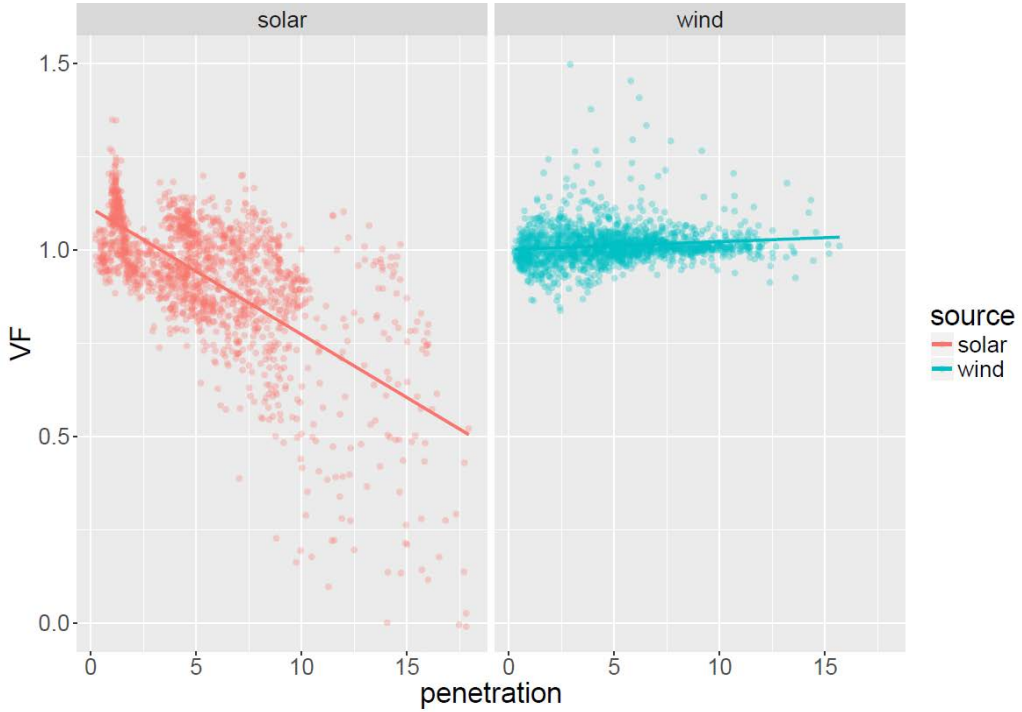
- Wholesale market with low share of RE (wind and solar PV)



Empirical Evidence of the Merit Order Effect in Different Jurisdictions

The Value of Solar PV and Wind in the California Power Market

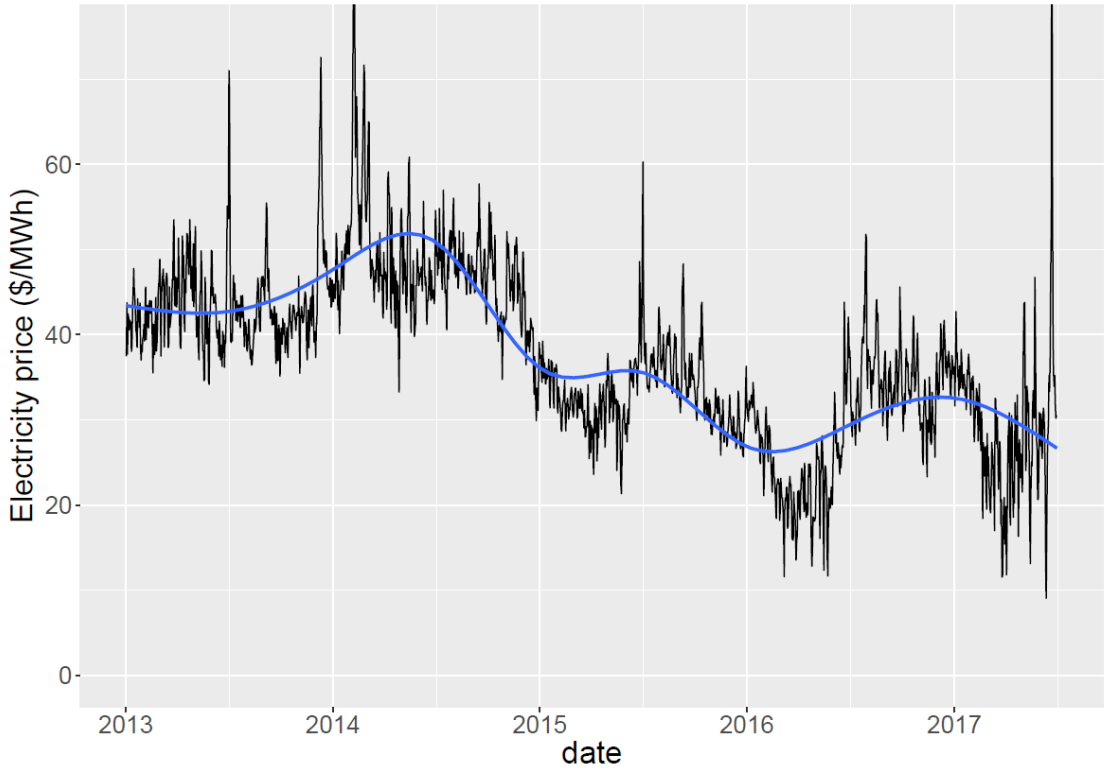
- The value factor of solar PV and wind energy in the California electricity market



Source: López Prol et al. (2017), The Cannibalization Effect of Wind and Solar inthe California Wholesale Electricity Market

The Value of Solar PV and Wind in the California Power Market

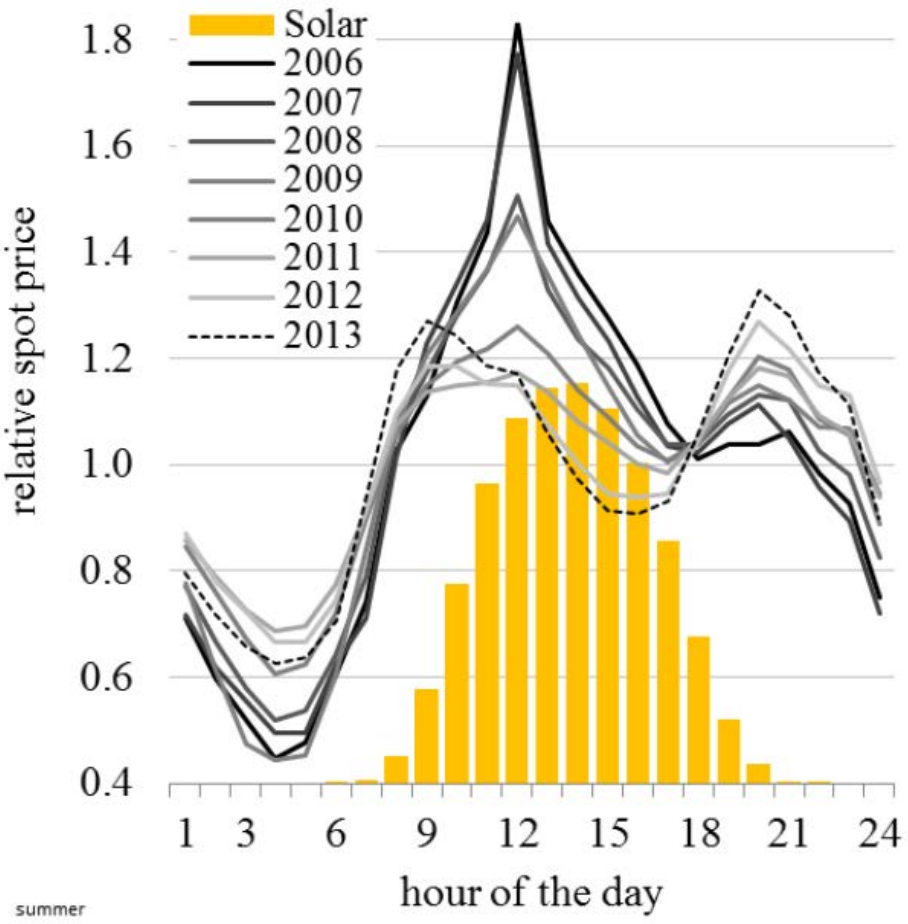
- The wholesale electricity price in the California electricity market



Source: López Prol et al. (2017), The Cannibalization Effect of Wind and Solar inthe California Wholesale Electricity Market

The Value of Solar PV and Wind in the German Power Market

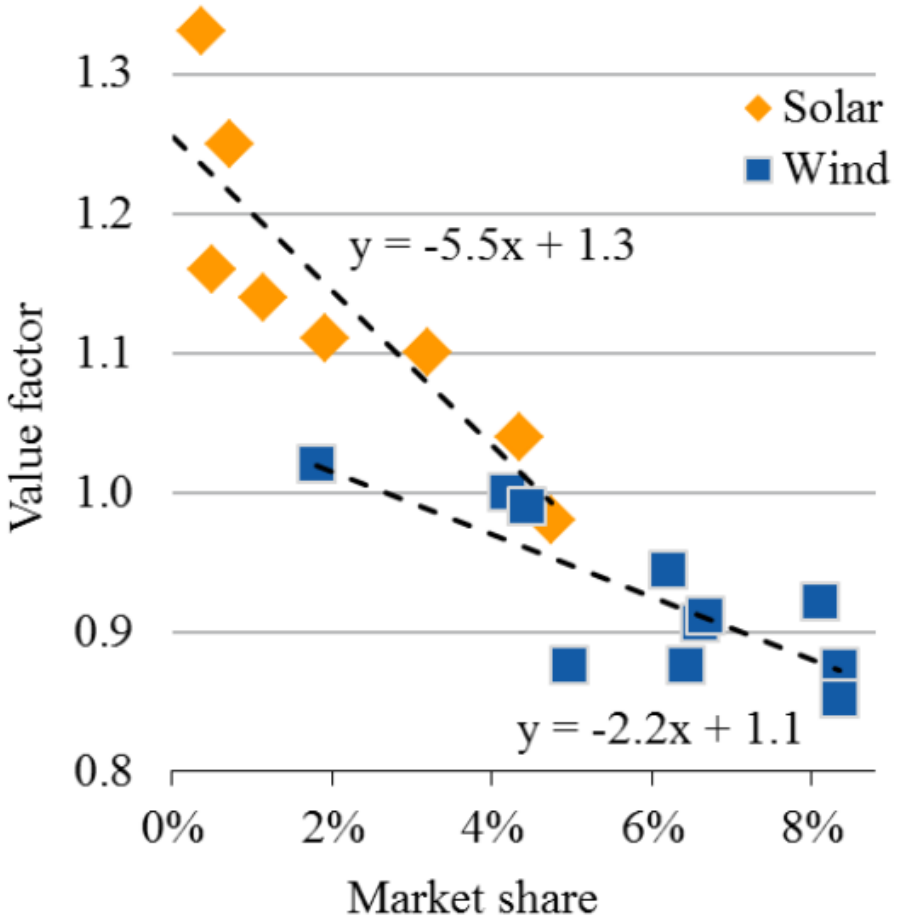
- The value of solar PV has decreased over the past years due to increasing shares of RE.



Source: Hirth (2015), The Market Value of Solar Power, https://www.mcc-berlin.net/fileadmin/data/pdf/Lion-Hirth-2015-Market-Value-Solar-Power-Photovoltaics-Cost-Competitive.pdf

The Value of Solar PV and Wind in the German Power Market

- Increasing market shares of RE lead to lower value of solar PV and wind energy



Source: Hirth (2015), The Market Value of Solar Power, https://www.mcc-berlin.net/fileadmin/data/pdf/Lion-Hirth-2015-Market-Value-Solar-Power-Photovoltaics-Cost-Competitive.pdf

Other Jurisdictions

- Australia:
  - „Electricity prices to fall 2.1% in two years due to wind and solar"
  - „Lower wholesale prices will give typical household a saving of $55 a year in next two years"

- Spain:
  - An increase of renewable electricity production by 1 GWh reduces the daily average of the Spanish electricity price by 2 €/MWh (Gelabert el al. (2011)).

- Austria/Germany:
  - Additional RE generation by 1 GWh reduces the daily average price by roughly 1 €/MWh in German and Austrian integrated markets (Wurzburg et al. (2013)).

Factors to Reduce the Impact of the Merit Order Effect

How can you reduce the impact of the merit-order-effect

- **The share of renewables**
- **CO2 costs and fuel costs**
- **Flexibility of demand**
- Grid expansion and market coupling
- Flexibility of fossil-fuel based power plants (otherwise risk of negative prices)

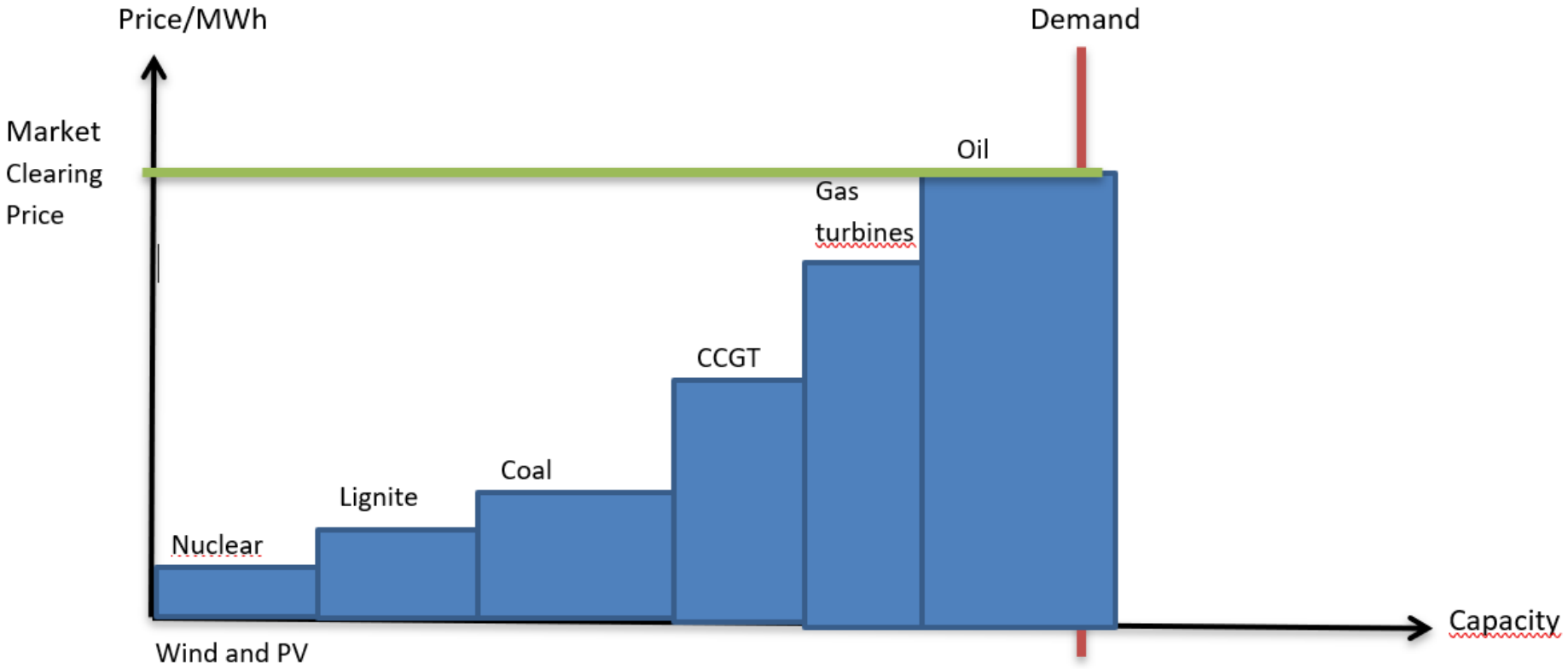
Source: Pudlik et al. (2014), Welche Faktoren beeinflussen die Entwicklung des Marktwerts der Erneuerbaren Energien?

The Share of Renewables

- Higher shares of RE further decrease the wholesale market price
- This is especially true for solar PV because generation typically takes place simultaneously in one jurisdiction
  - **Market coupling** and interconnectors between countries can reduce this effect.
  - **Electricity storage** can also help to balance out variations in electricity supply (store in times of high RE penetration and discharge in times of low RE penetration)
- In hours with high penetration of solar PV (and wind energy), the wholesale market price is lowered

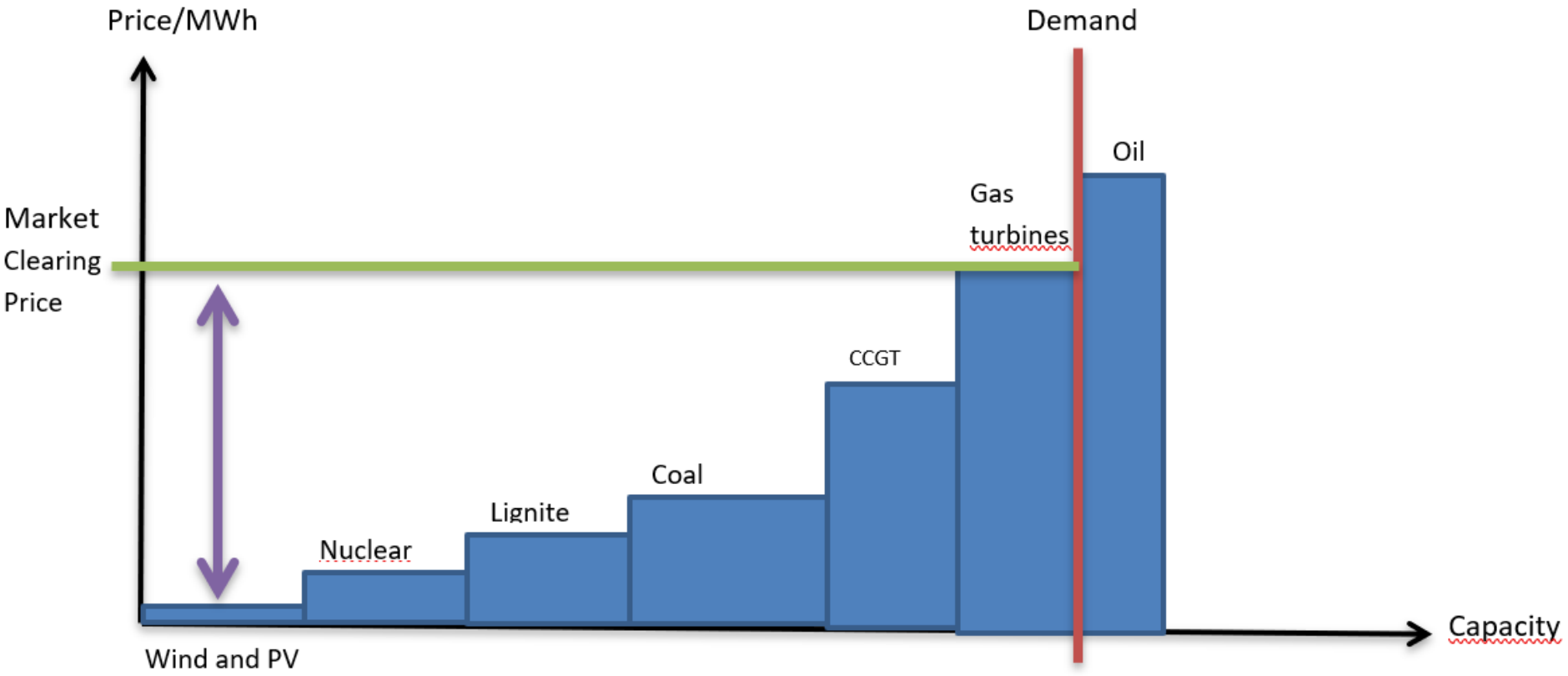
The Share of Renewables

- Wholesale market with no share of RE (wind and solar PV)



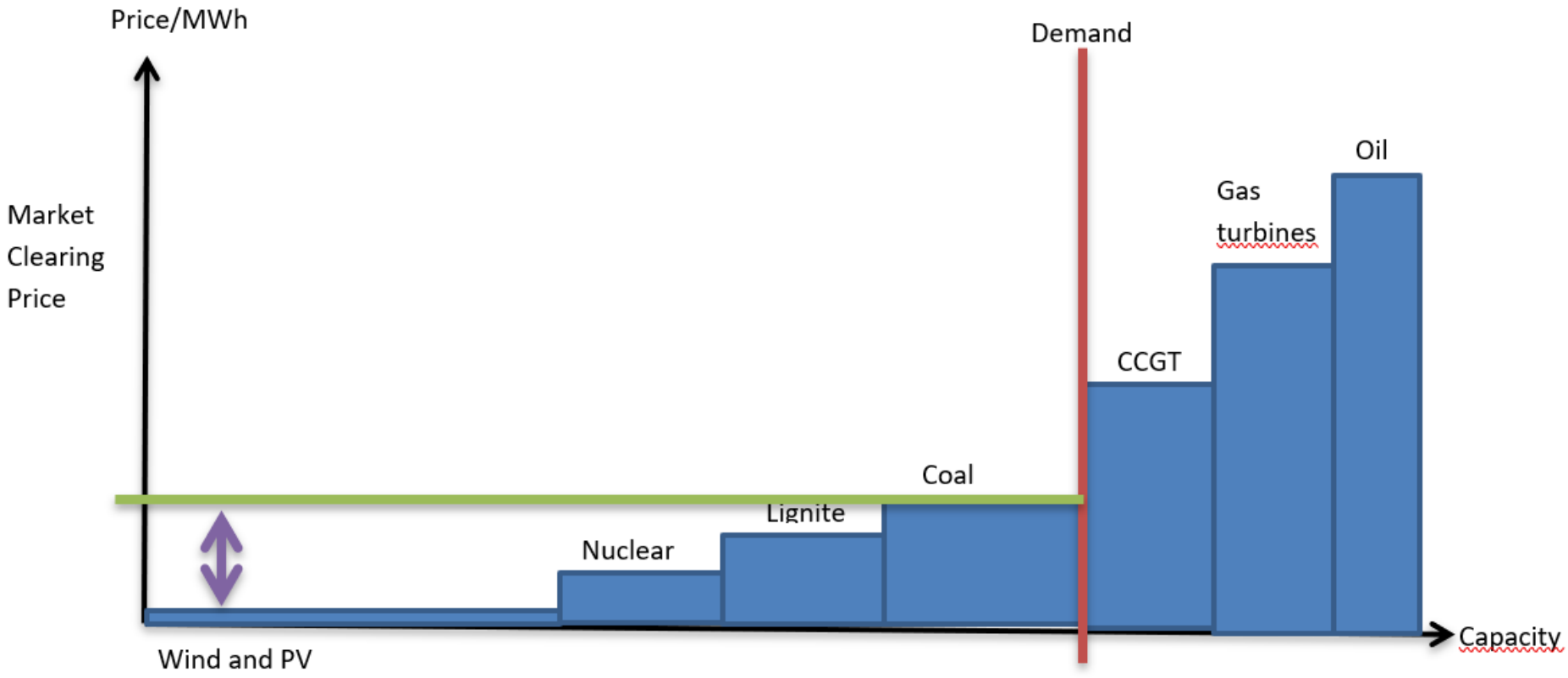
The Share of Renewables

- Wholesale market with low share of RE (wind and solar PV)



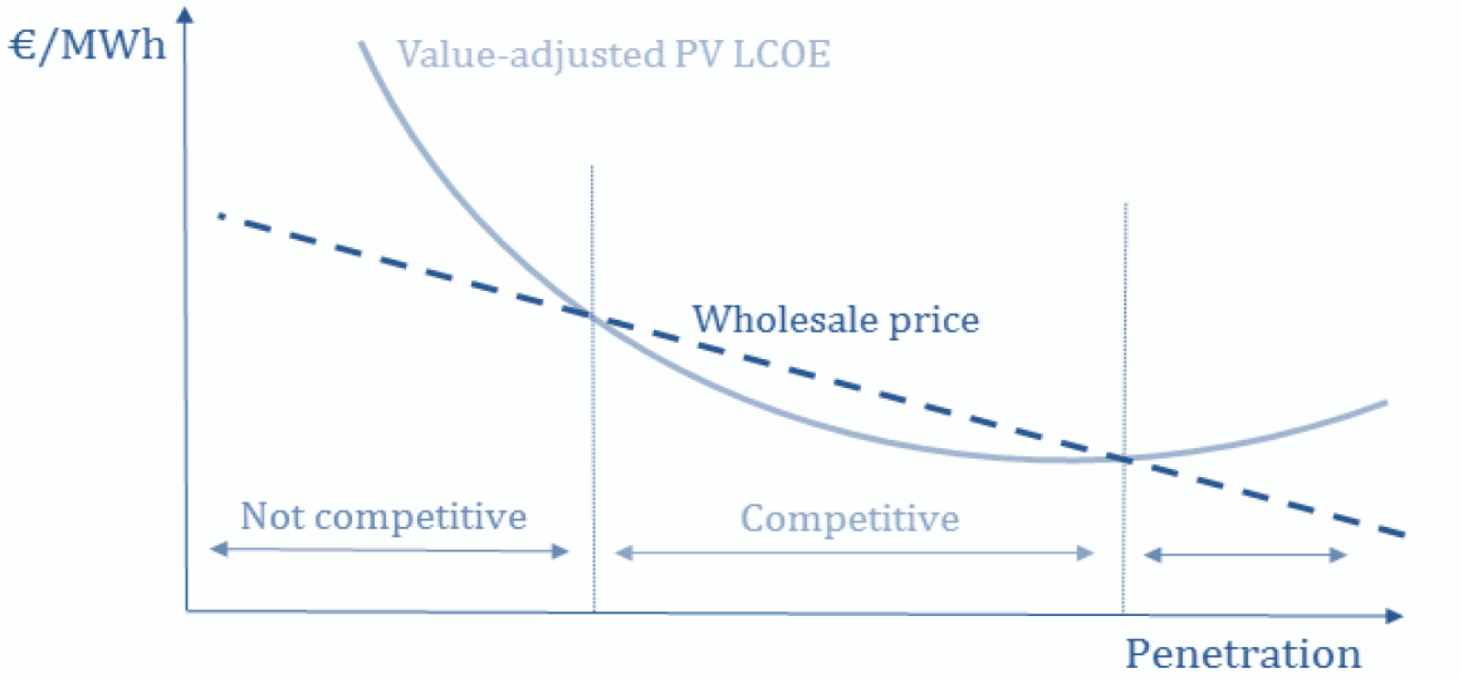
The Share of Renewables

- Wholesale market with low share of RE (wind and solar PV)



The Share of Renewables and Competitiveness of solar PV

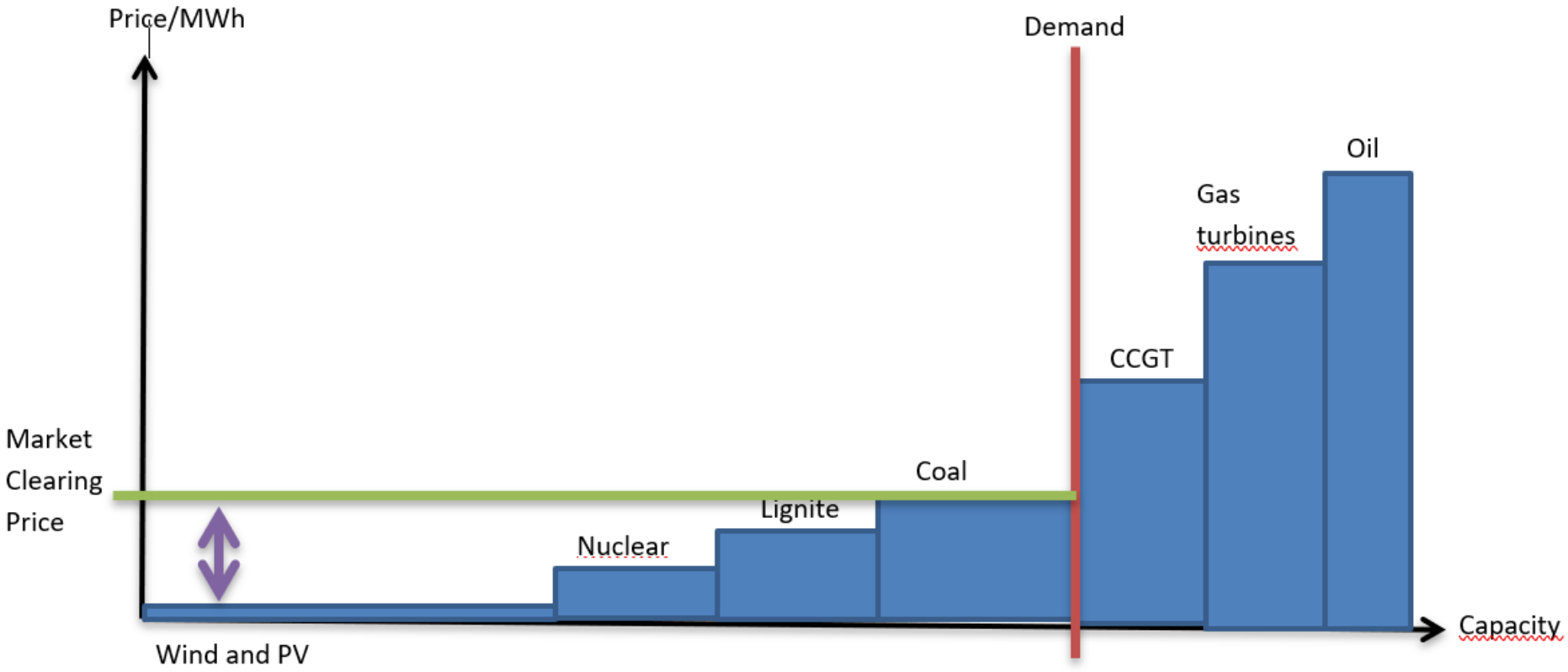
- Solar PV might not reach „competitiveness“ in wholesale markets once and for all
- With increasing shares of solar PV, it might become „non-competitive“ again in the future



Source: López Prol et al. (2017), The Cannibalization Effect of Wind and Solar inthe California Wholesale Electricity Market

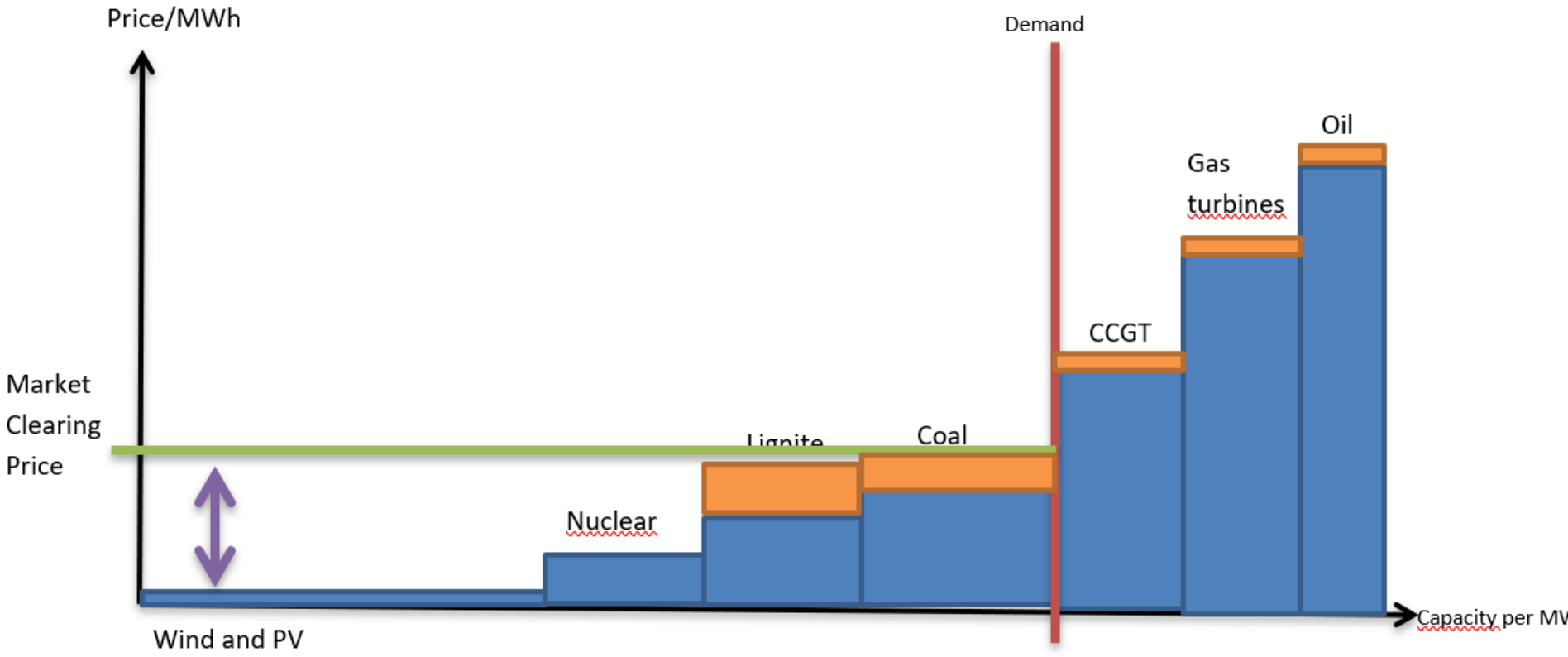
Carbon price

- High shares of variable renewables and no CO2 price



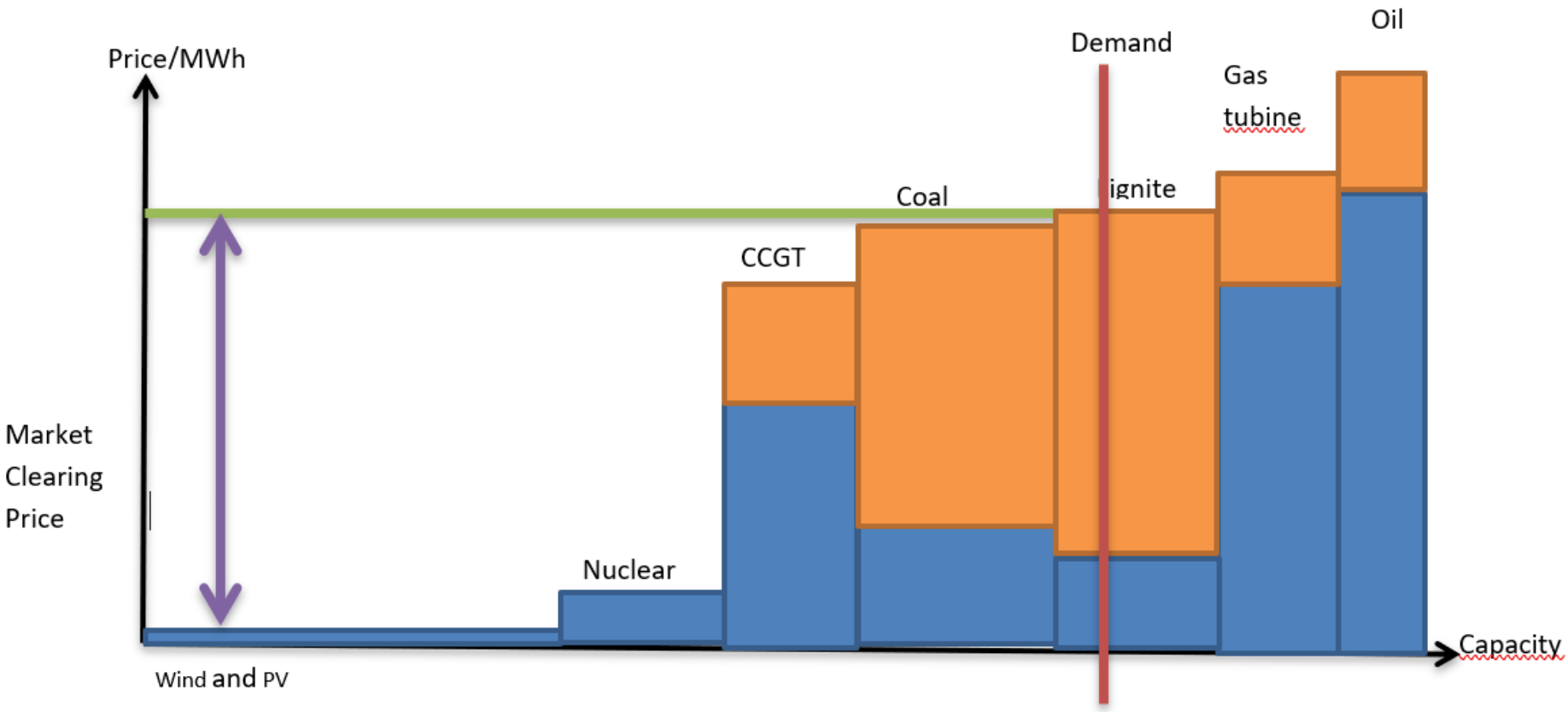
Carbon price

- High shares of variable renewables and low CO2 price



Carbon price

- High shares of variable renewables and high CO2 price

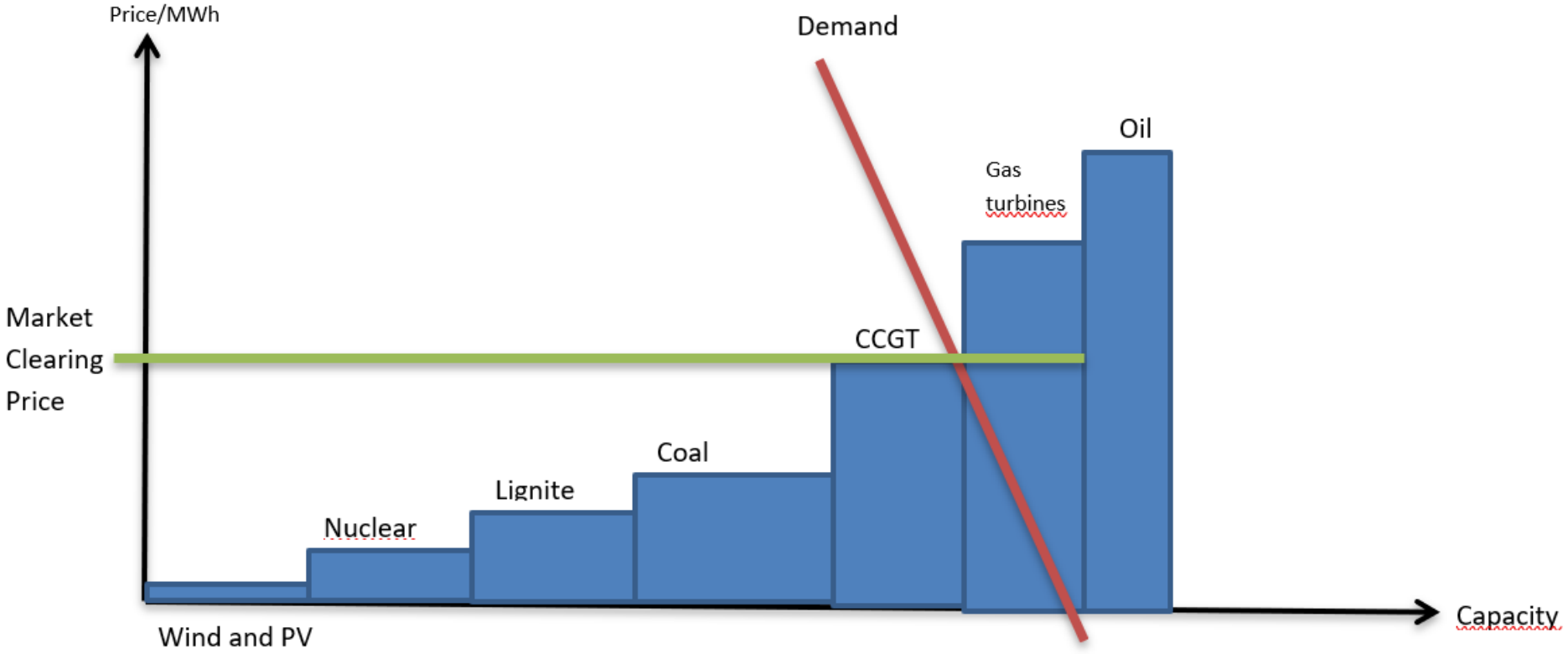


Carbon price/fuel price

- Similar effect via fuel price variations/increases:
  - Variations of technologies which relatively high variable costs (e.g. technologies that determine the wholesale market price) can have an significant impact on the merit order effect
  - E.g. higher prices for gas and oil can increase the market clearing price and thus lower the merit order effect.

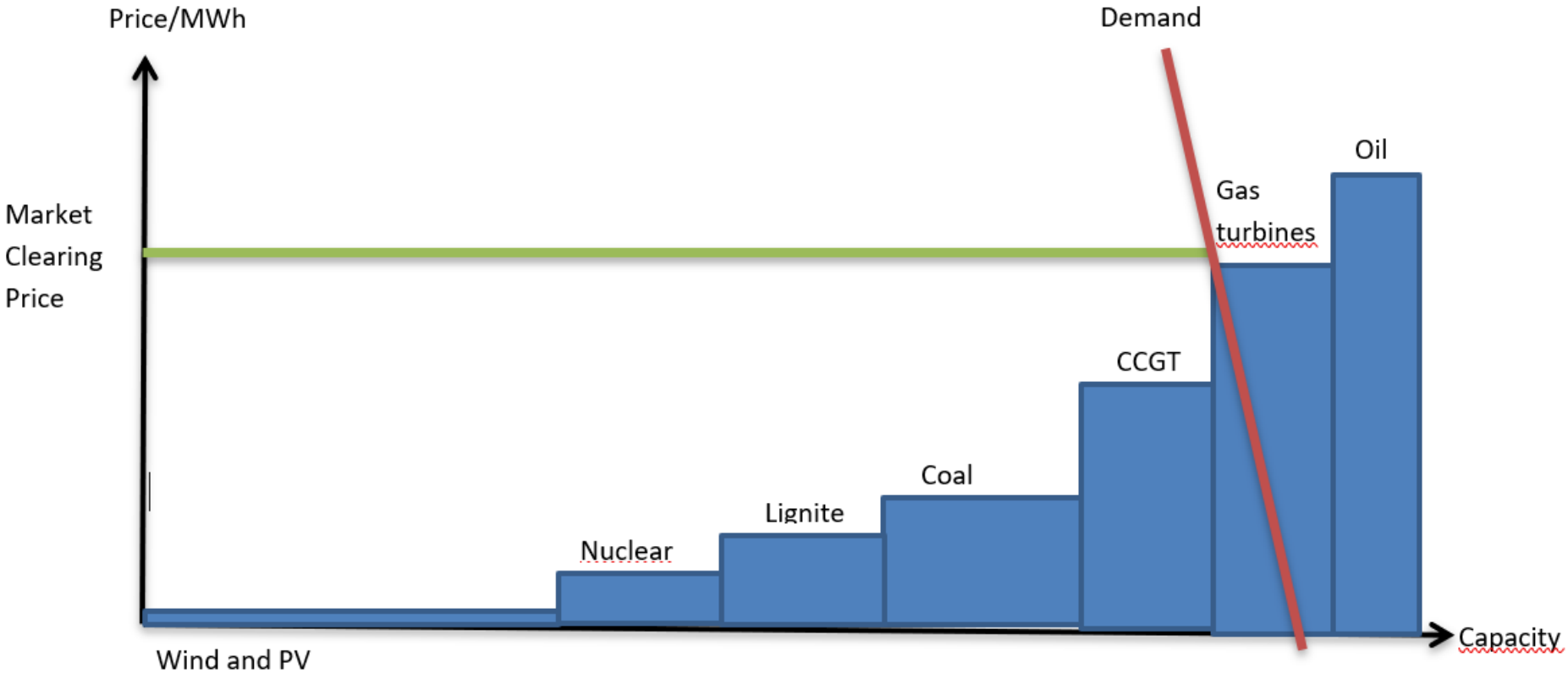
Flexibility of Demand

- Demand-side flexibility
- More „elastic demand“ can impact the market clearing price



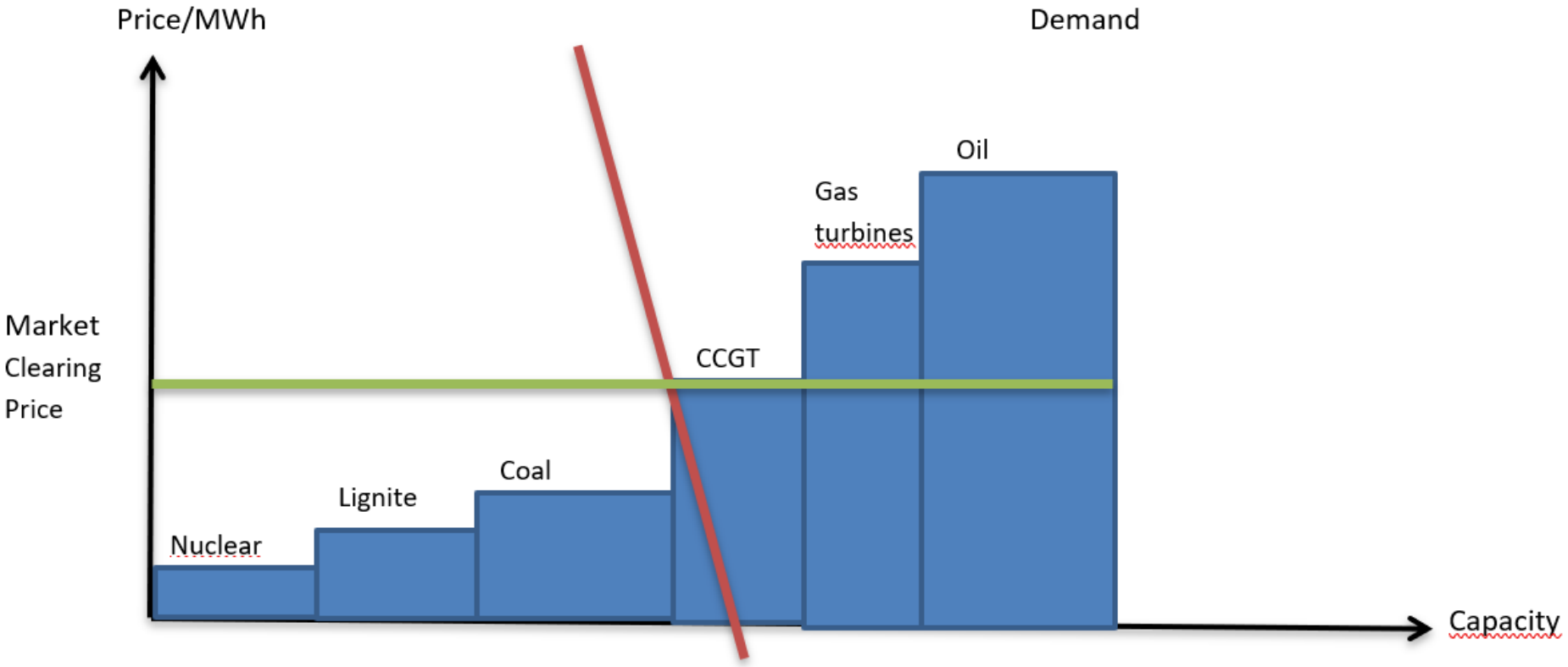
Flexibility of Demand

- Demand-side flexibility
- Increase in demand in the case of high shares of solar PV



Flexibility of Demand

- Demand-side flexibility
- Decrease in demand in the case of high shares of solar PV



Summary

Summary: PV and the Merit Order Effect

- PV reduces the wholesale market price.
- With increasing shares, this might undermine the competitiveness of PV in wholesale markets
- Policymakers can apply various measures to counteract this trend (e.g. by coupling electricity markets, expanding grid, introducing carbon prices).
- The wholesale market value of PV in fully decarbonized electricity markets need further investigation.

Further Reading/List of References

List of References

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- Cludius, J., et al. (2014). "The merit order effect of wind and photovoltaic electricity generation in Germany 2008–2016: Estimation and distributional implications." Energy Economics 44(0): 302-313.

Thank you for your time!

6. Knowledge Checkpoint: Multiple Choice Questions