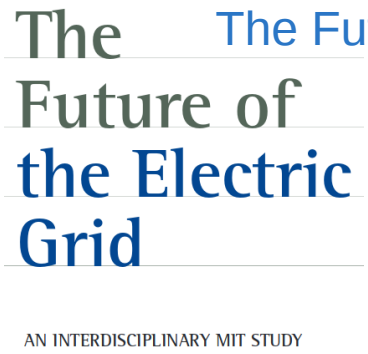
ETM521

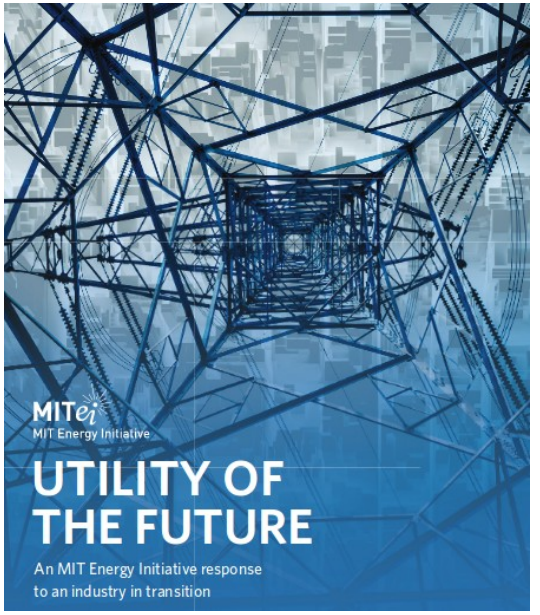
Lecture 7 – Future of the Power System

Barış Sanlı

Resources



The Future of the Electric Grid , MIT



Utility of the Future, MIT

World Energy Outlook 2018, IEA
Special Focus on Electricity

Question

- How to compete among 100 solar panels?
- How to have a competitive battery market?
- How to assess values of zero marginal cost resources to the system and welfare?

The future tales are already fairy tales

- Solar is the future -yes
- EVs are the future – yes
- Prosumer is the future – yes
- So what?
  - The penetration rates?
  - What will be the countervailing forces? (like flexibility)
  - What will be the marginal value of each future ready resource?

Future of ???

Future of Power System

Future of Market Design

Future of Demand

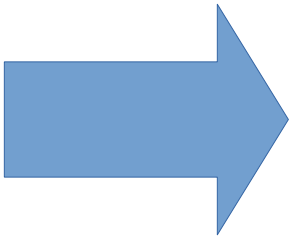
Future of Grid

Future of Supply

Future of Policies

Future of Actors

Future of Technology

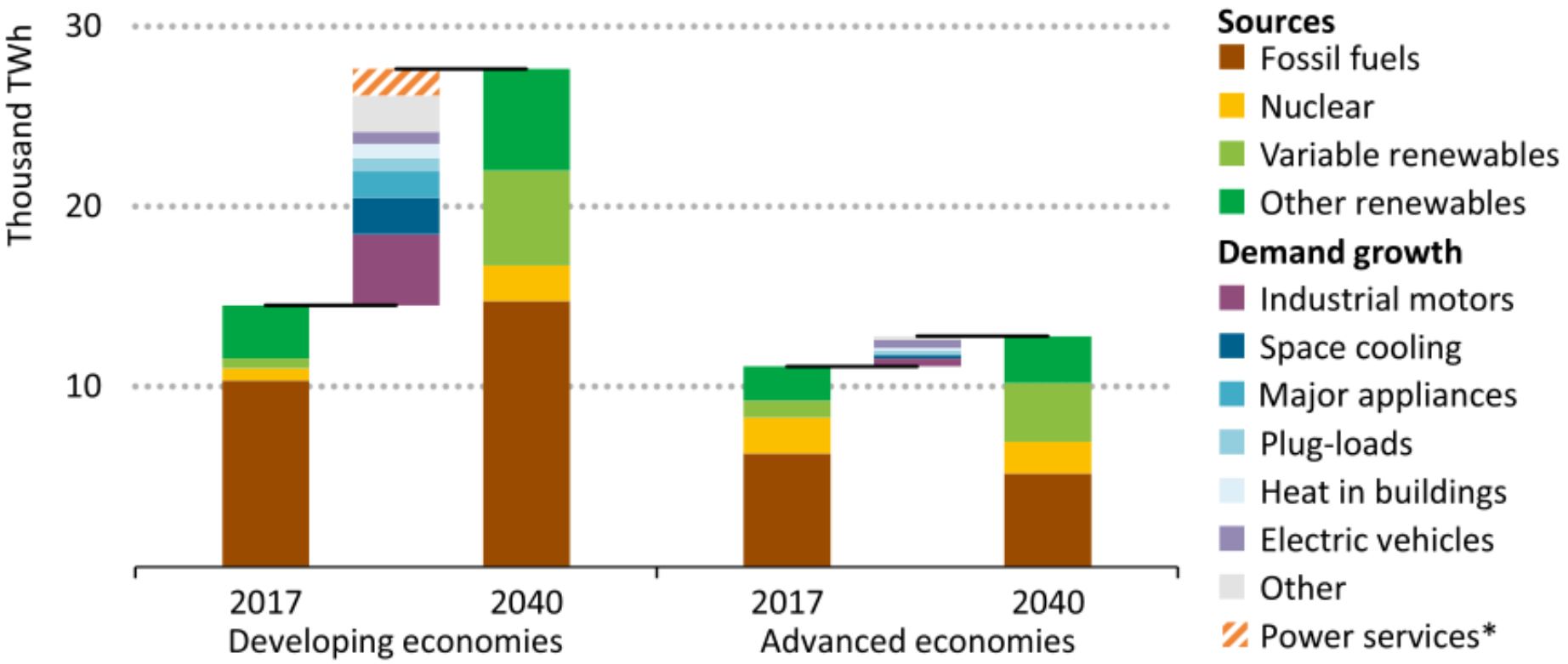


A cluster of Unknown Futures

Policy is very important

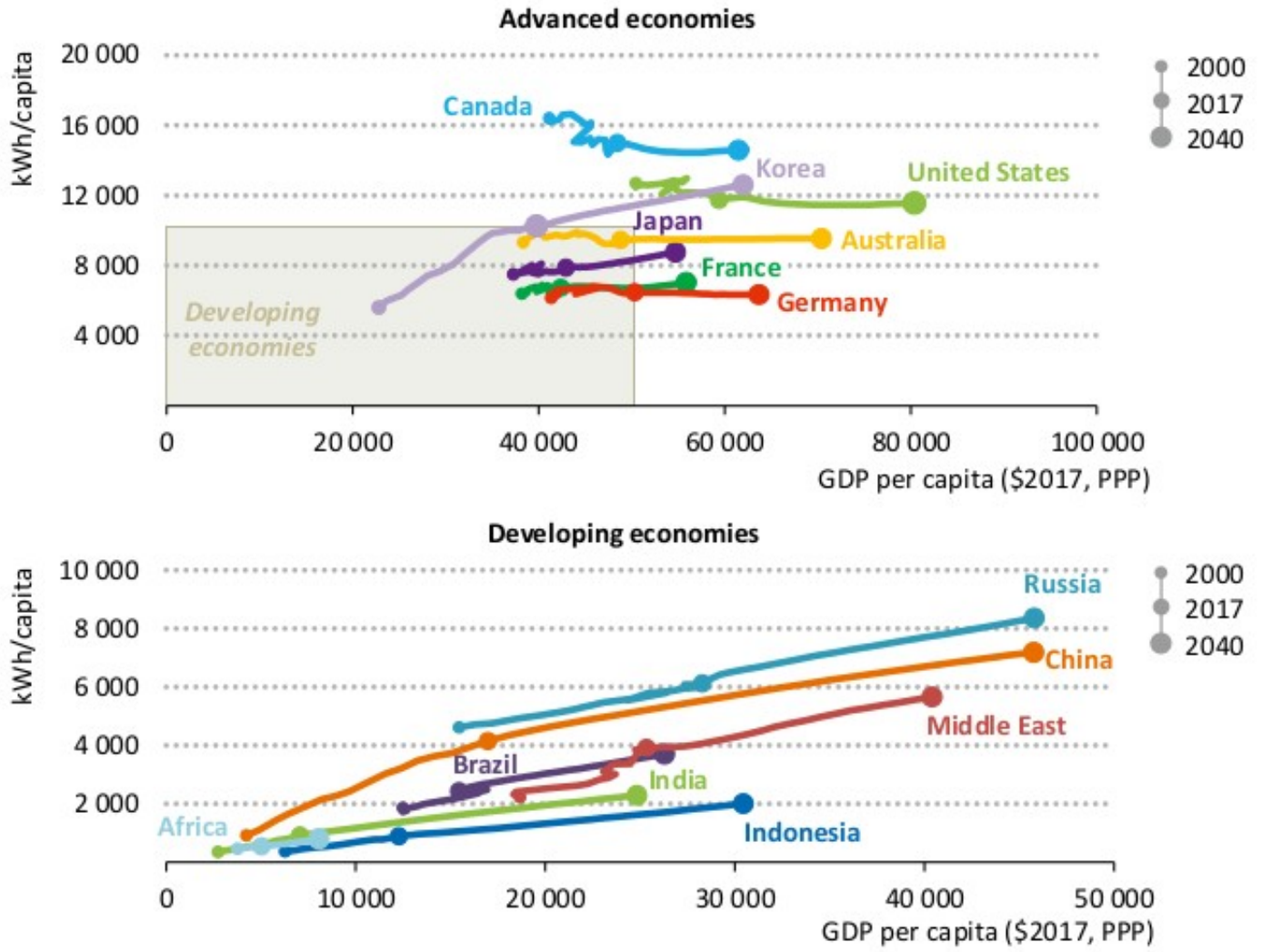
- Effect of climate change policies on energy system
- Support for new technologies
- Support for electrification of transport
- Future of energy crises
- International trade - Globalisation

The Future of Energy Demand



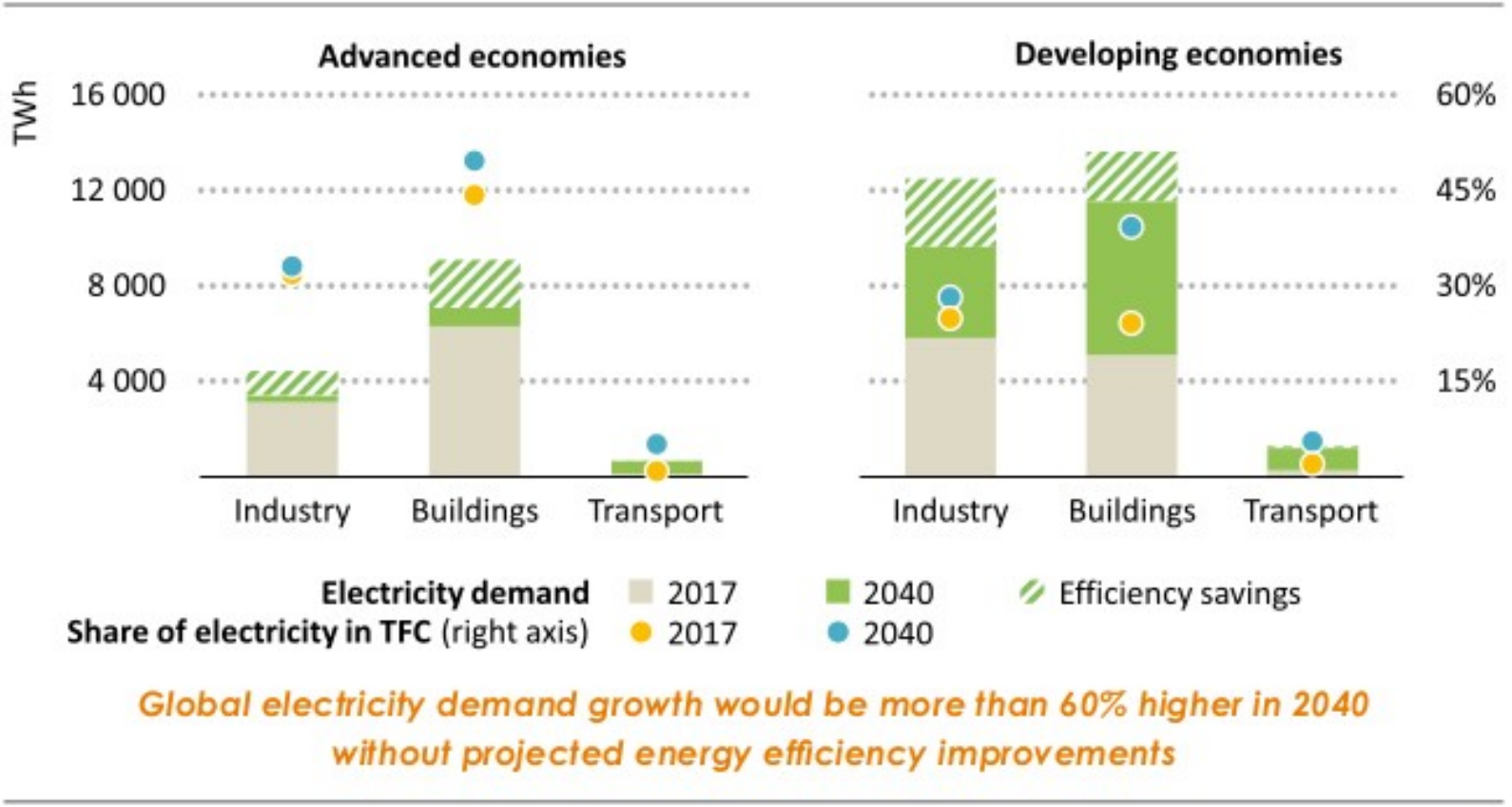
Electricity demand grows at twice the rate of overall energy demand, from a variety of end-uses, while renewables and gas increase to meet new demand

GDP per capita vs Demand



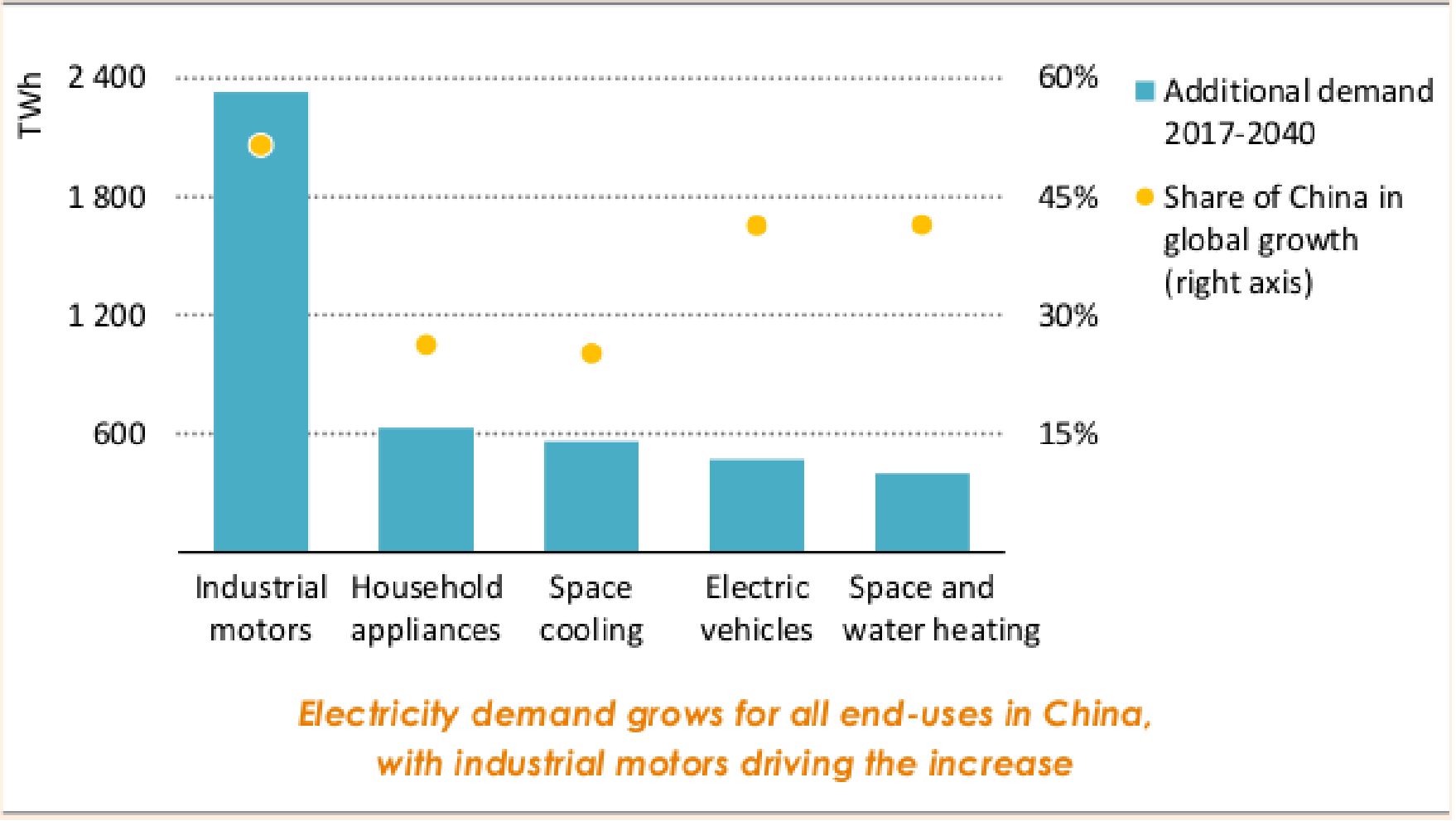
Income levels in developing economies look far from the point where electricity demand growth might flatten out

Demand growth by sector



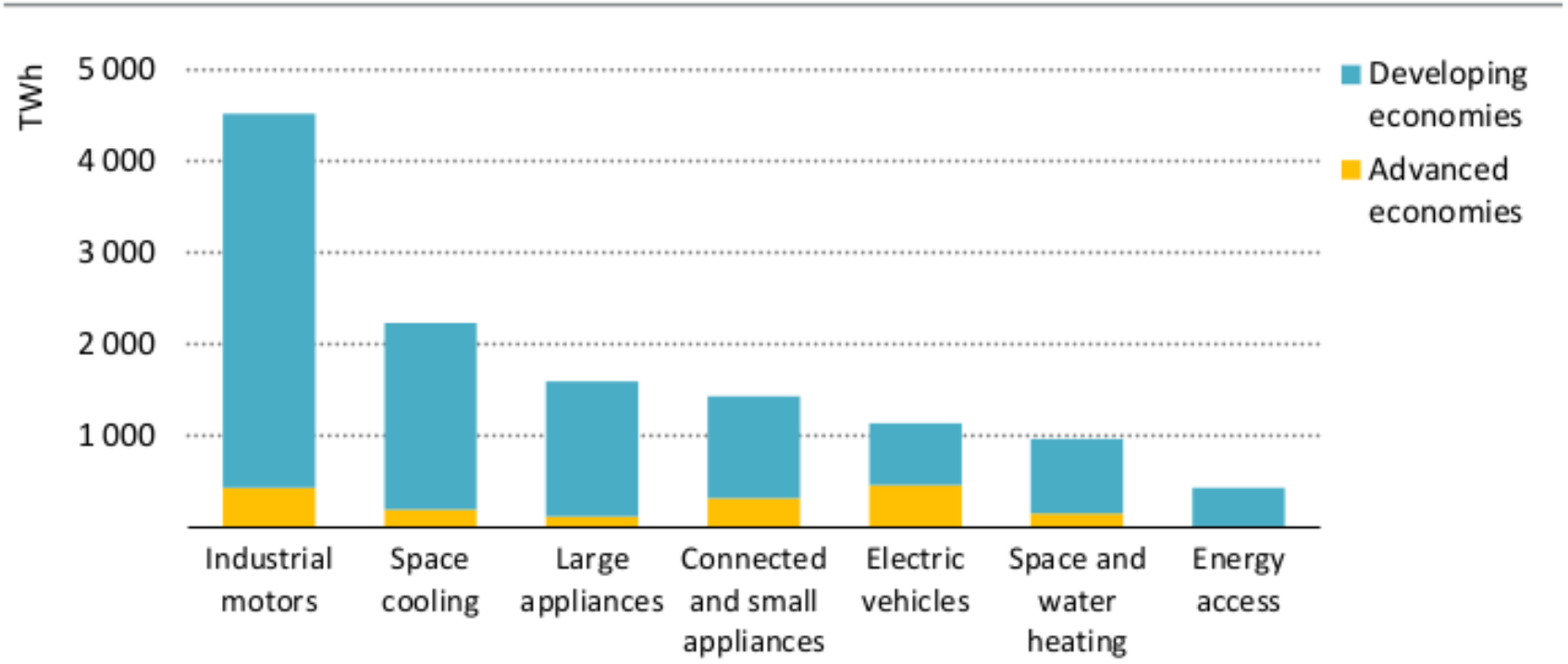
Note: TWh = terawatt-hours; TFC = total final consumption.

Additional demand in China



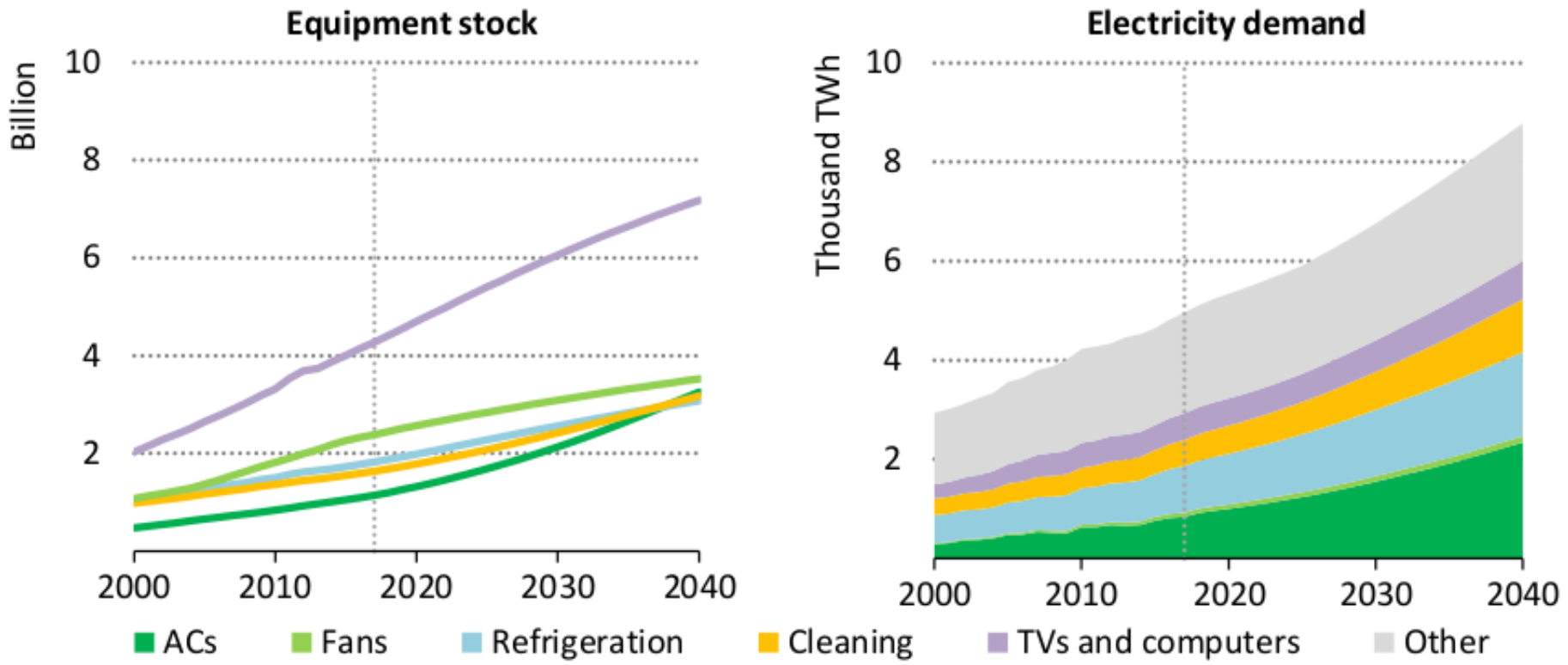
Electricity demand grows for all end-uses in China, with industrial motors driving the increase

Demand growth by end use(2040)



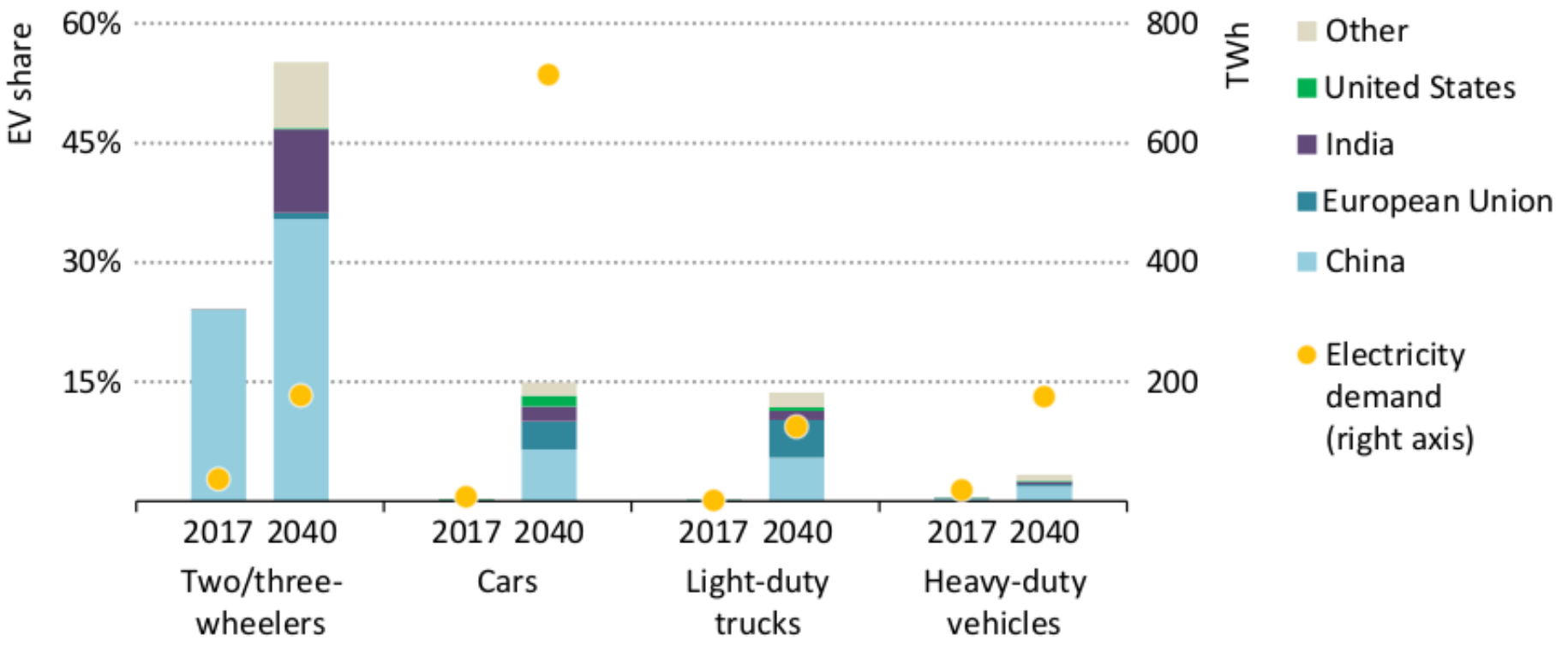
Industrial motors account for a third of the world's appetite for increased electricity while providing electricity access to an additional 680 million people accounts for only 3%

Equipment stock and demand



Rapid growth in the global stock of air conditioners and household appliances accounts for 65% of the increase in electricity demand in buildings

EVs



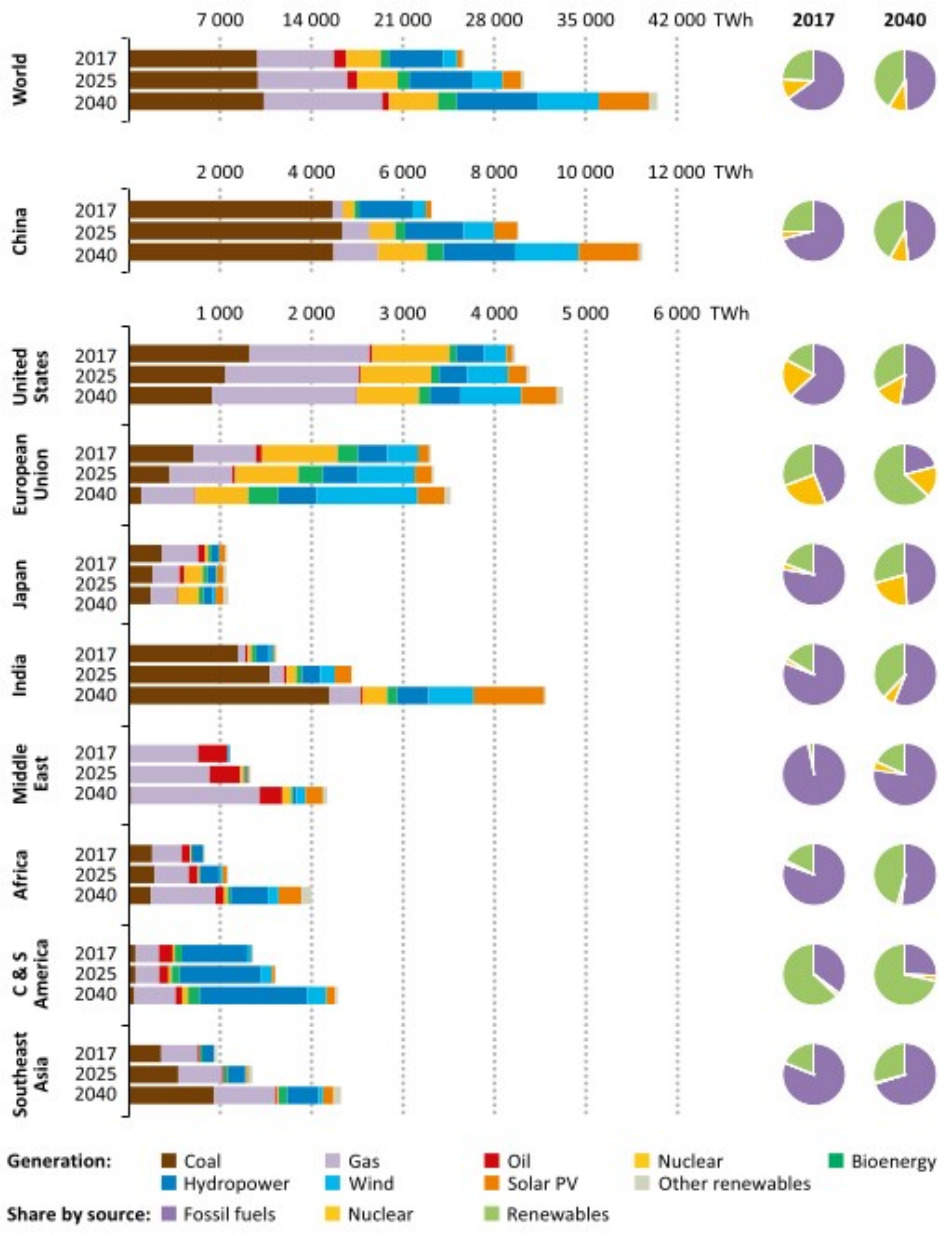
Whereas two/three-wheelers are the most electrified mode, the biggest incremental electricity demand comes from cars, with China in the lead

Avg 20 kWh~ 100km

TR, cars~148 Billion km ~ 29 TWh

WEO 2018

Electricity Supply



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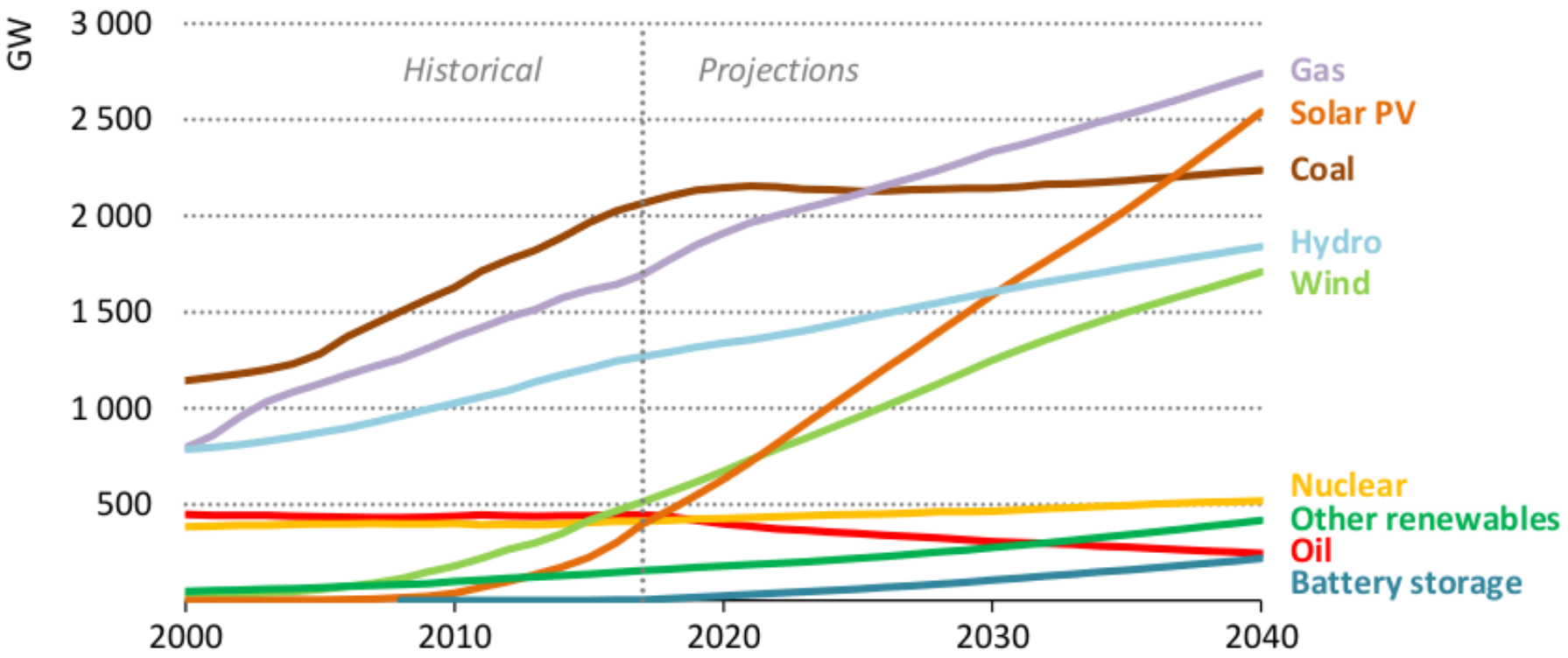
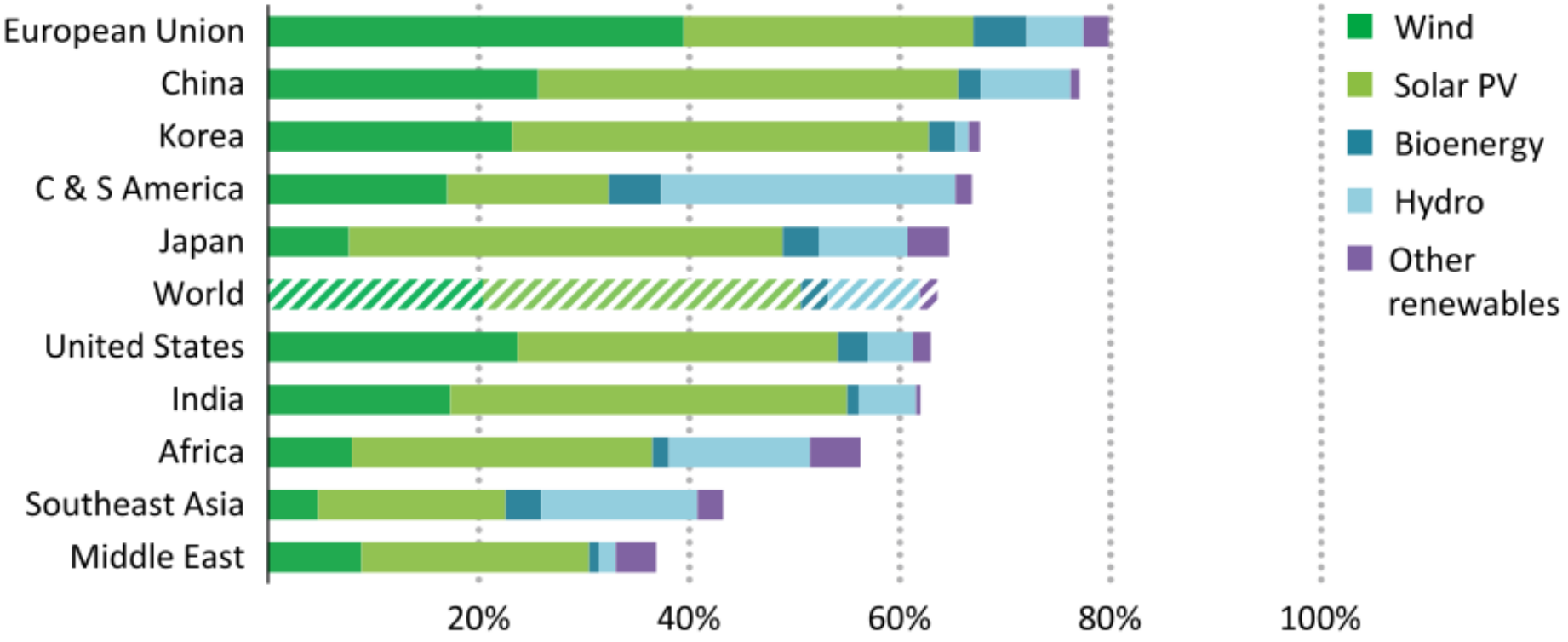
Power Generation Capacity



With more than 180 GW under construction, coal fuels the most capacity until the mid-2020s when natural gas overtakes it, and renewables are on the rise

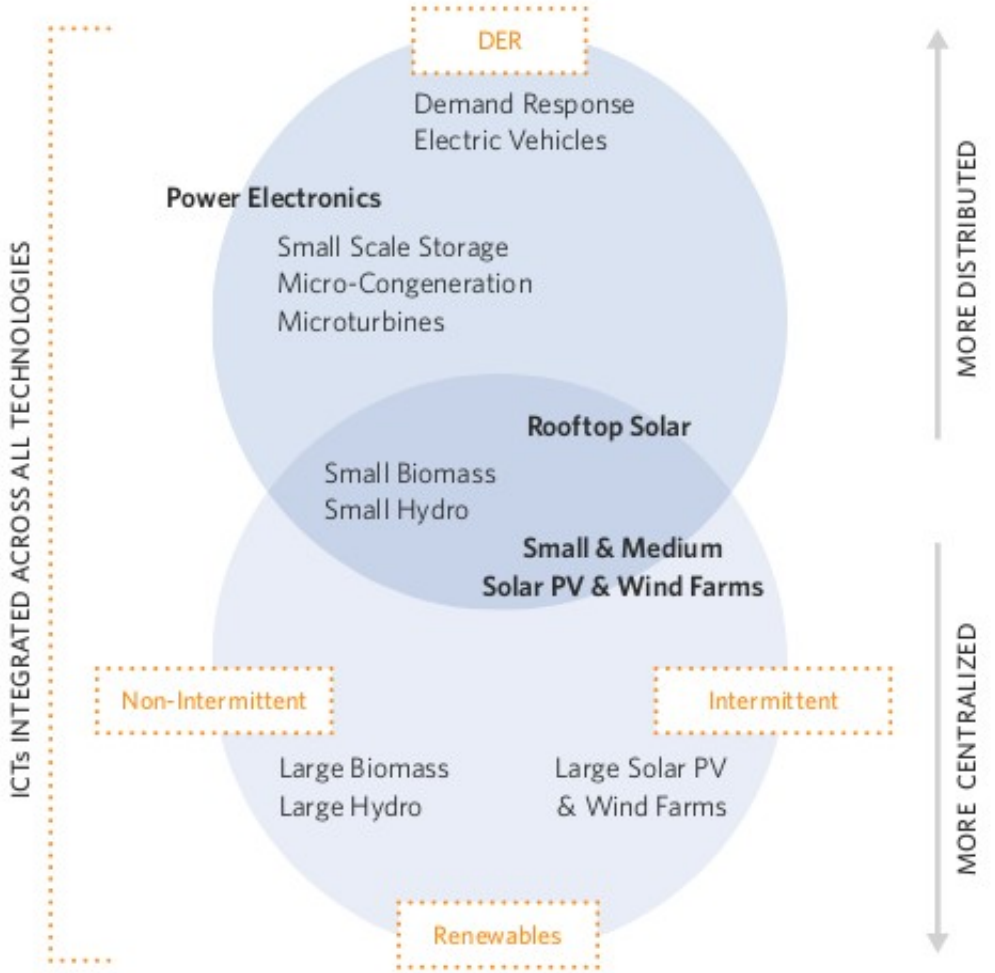
Share of renewables



Renewables dominate capacity additions in most regions of the world, propelled by new solar PV and wind power installations

Note: C & S America = Central and South America.

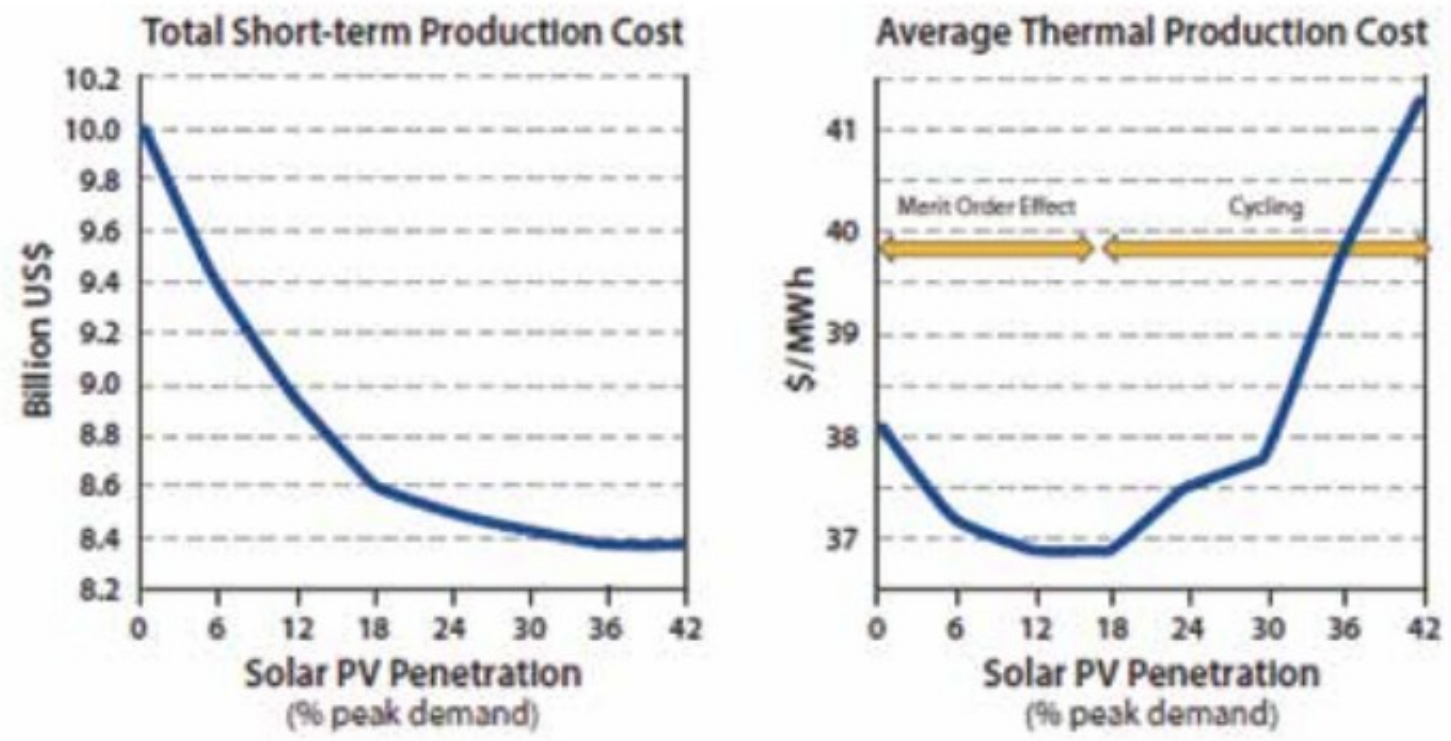
Taxonomy of distributed and renewable resources



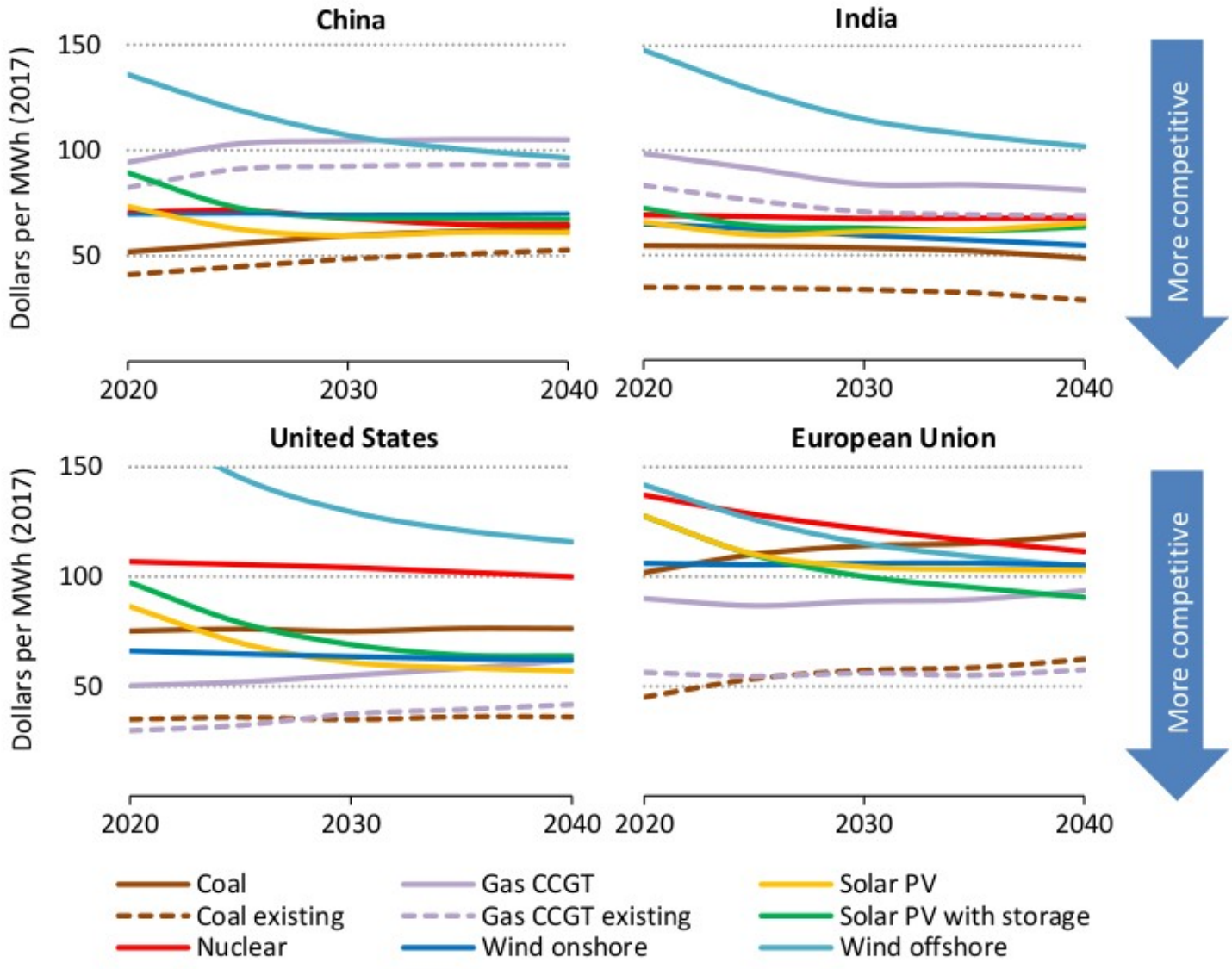
Utility of the Future, MIT

Cost increases with solar penetration

Figure 3.11: Production Costs with Increasing Solar Penetration in ERCOT



Cost of technology



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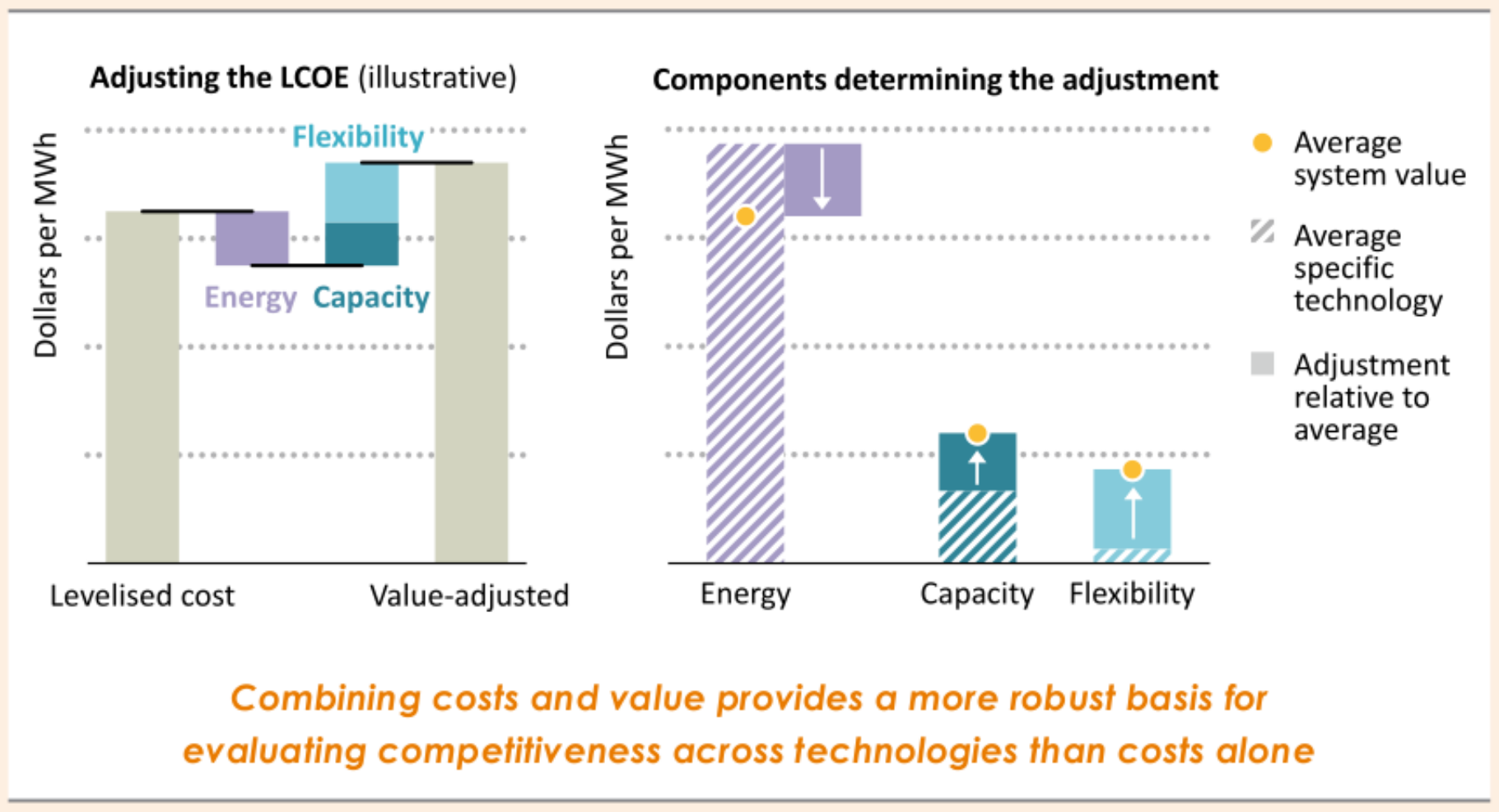
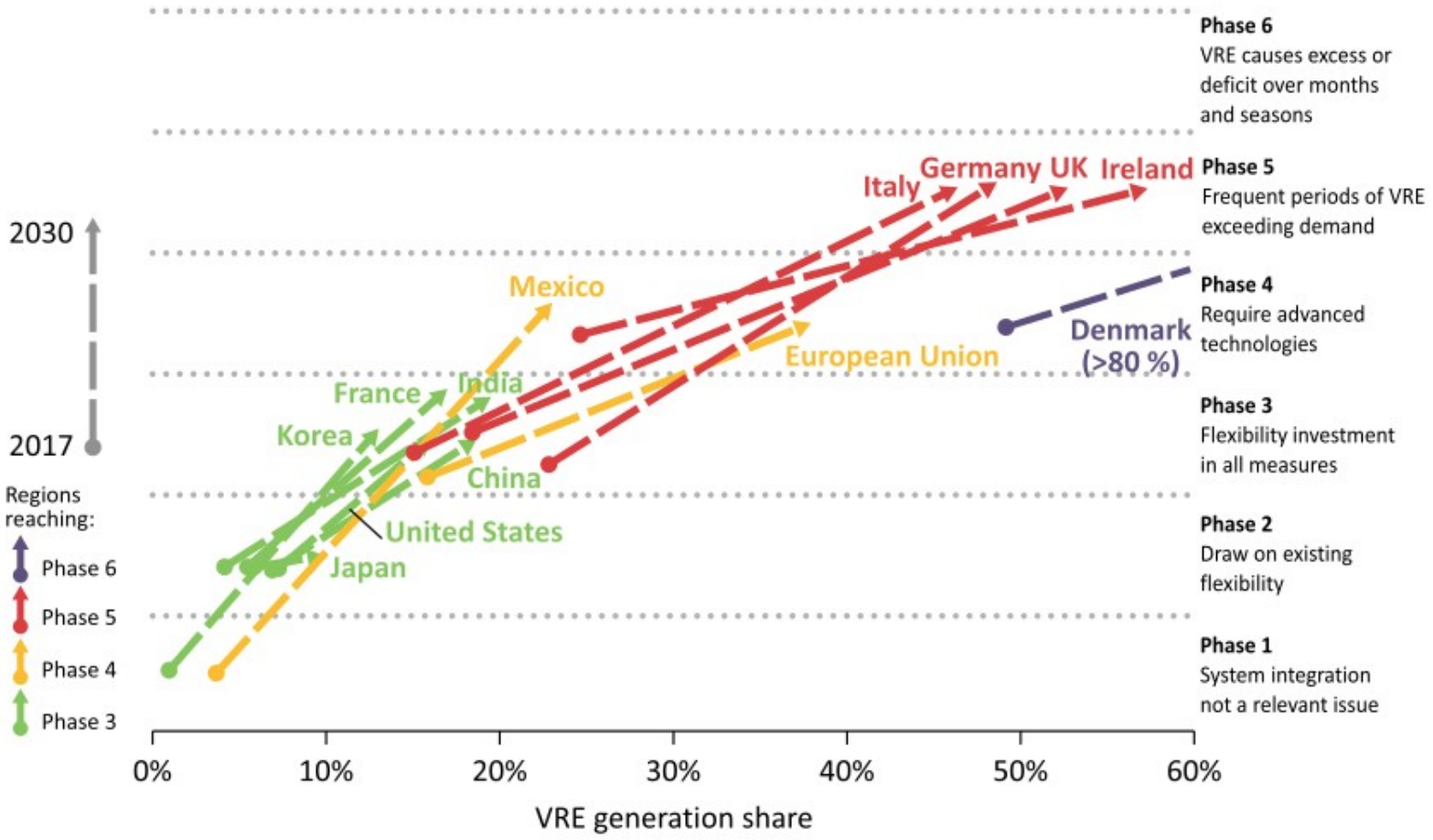
A new term – Value adjusted LCOE

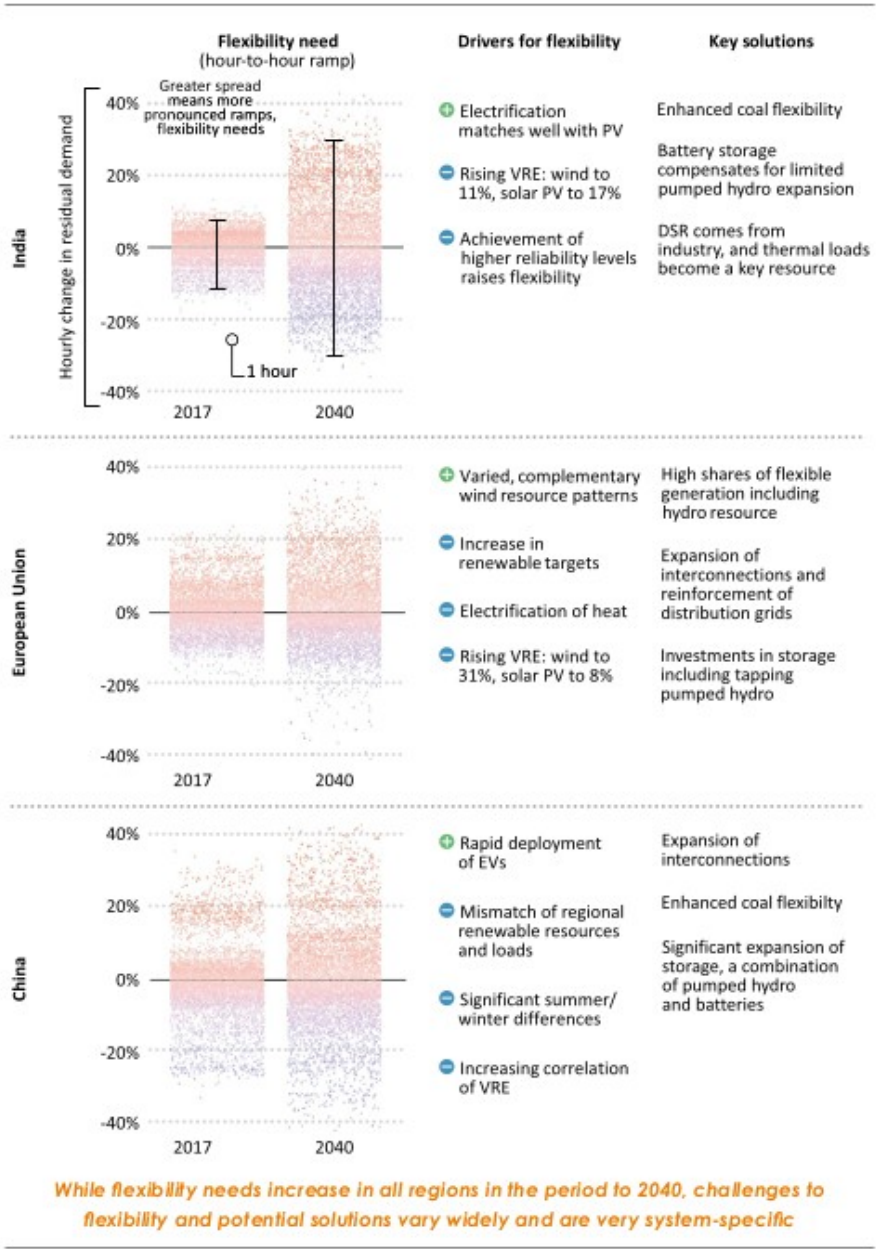


Evolving Flexibility Needs



The size of the power system, flexibility of thermal generation, shape of demand profile, imply different needs for additional flexibility even at the same levels of VRE

Flexibility



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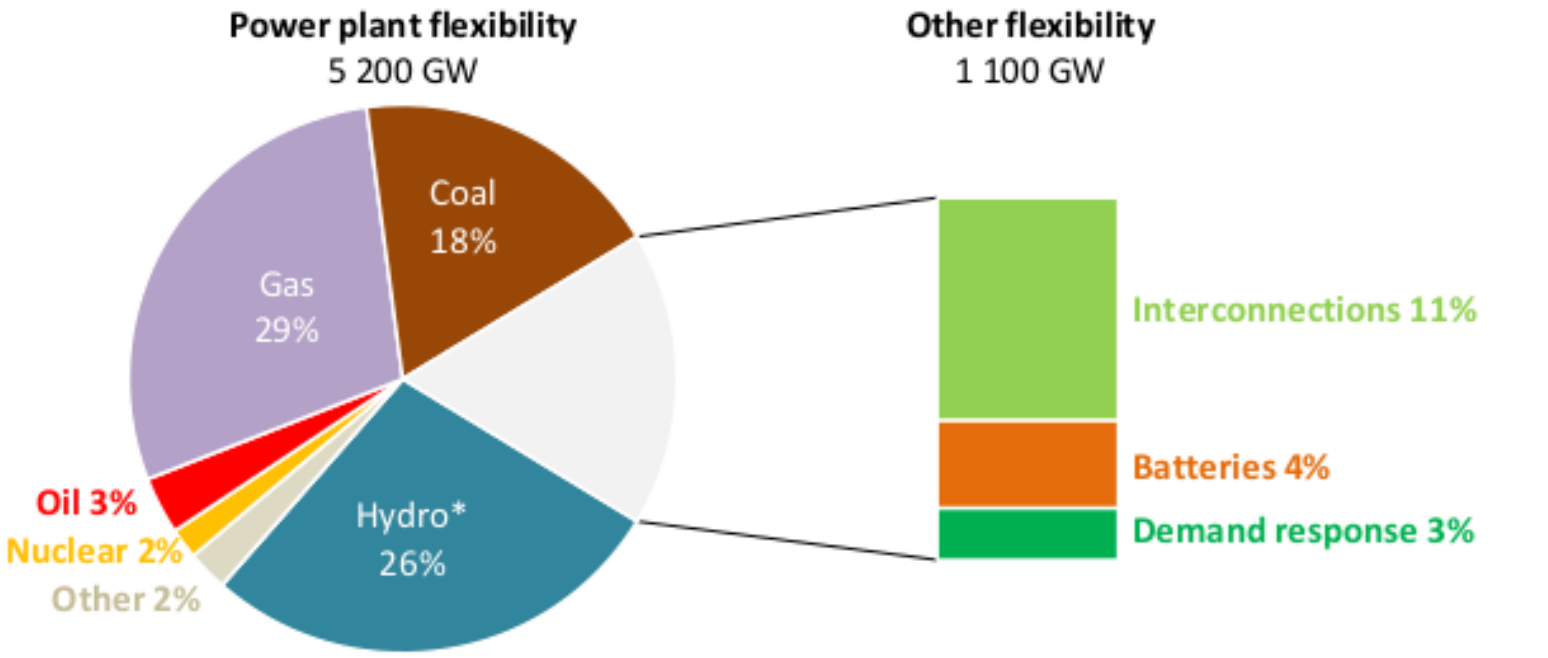
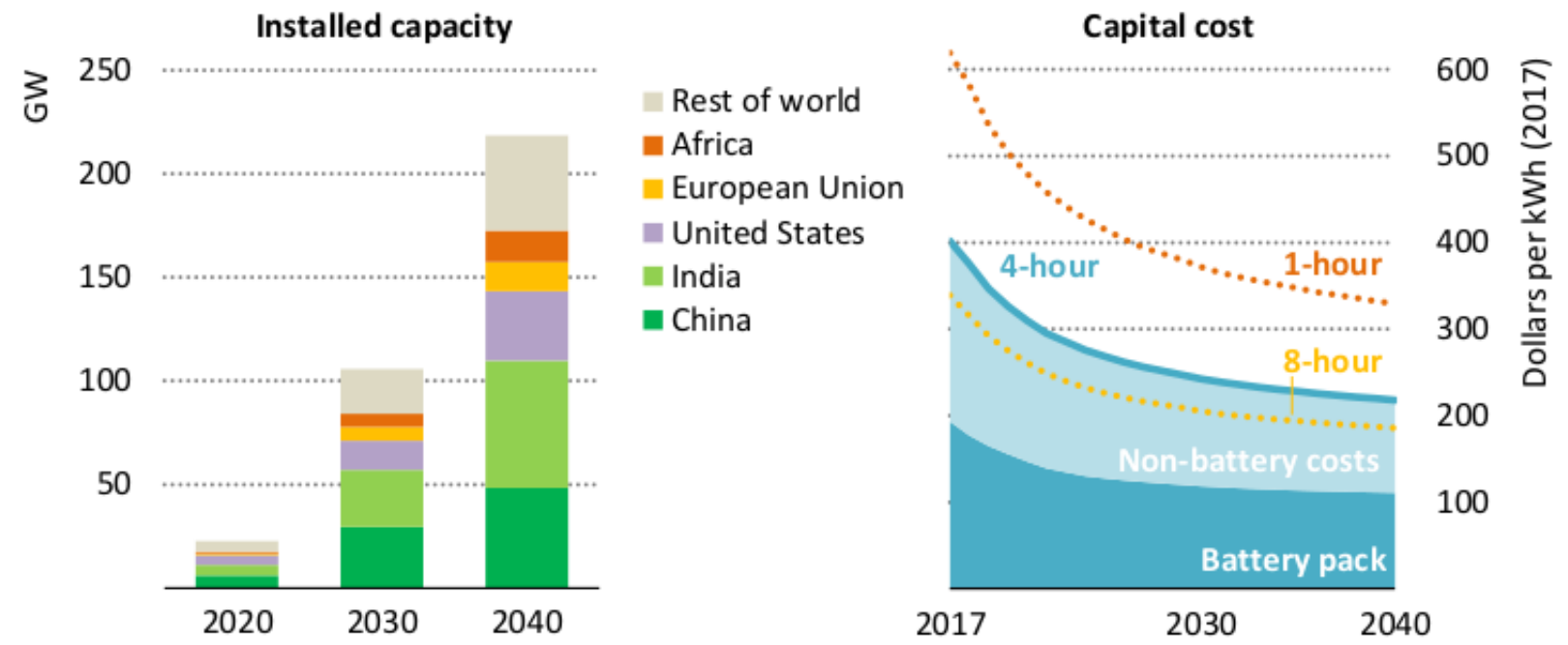
Contributors to flexibility



While power plants remain the cornerstone of flexibility, storage and network investments play an important part in meeting the needs for increasing flexibility

* Includes pumped storage.

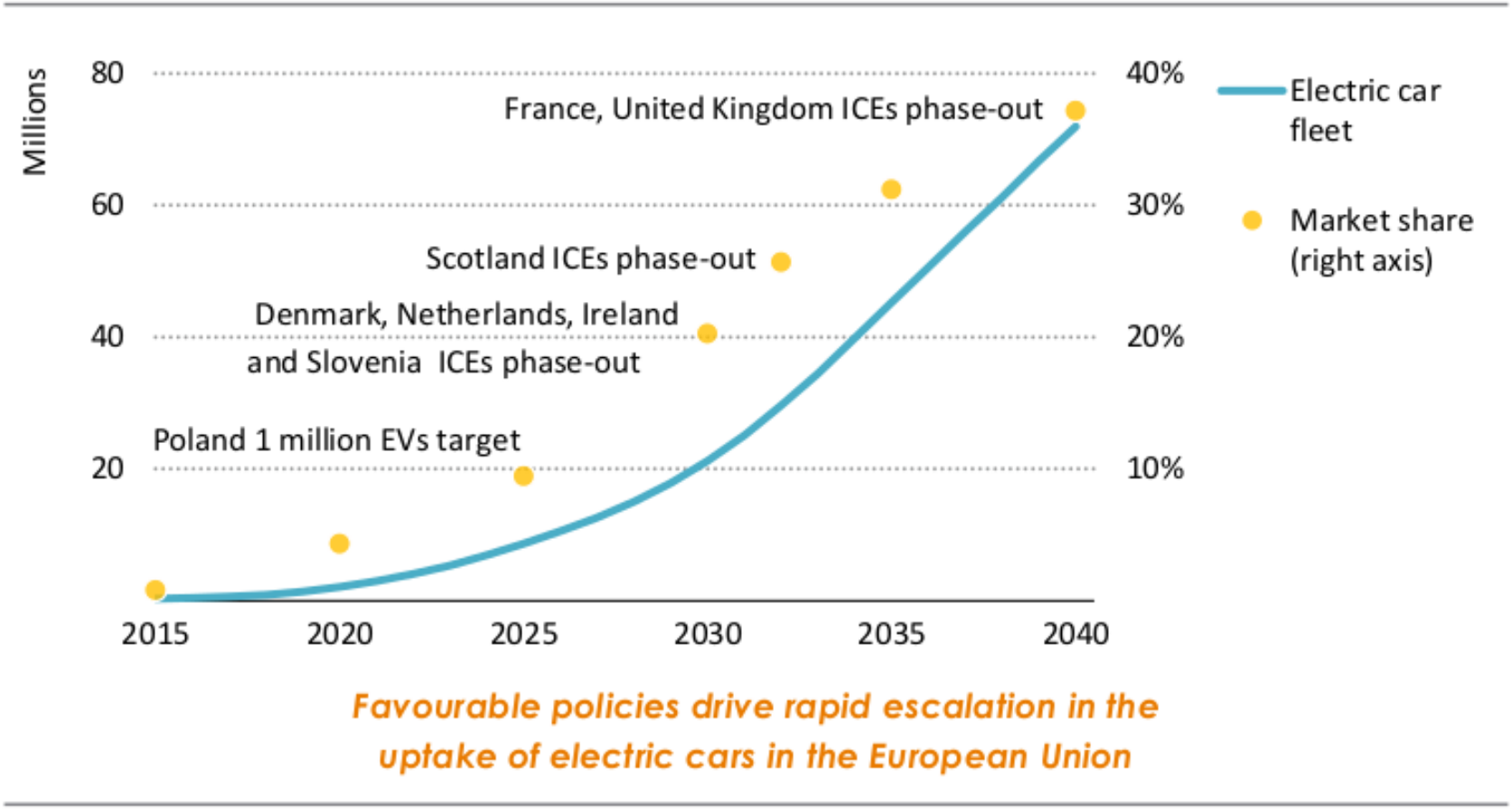
Battery storage systems



Declining costs for battery storage systems underpin utility-scale deployment to reach 220 GW by 2040, most of which is paired with renewables

Note: The figure with cost breakdown (on the right) refers to four-hour battery storage.

Electrification of cars in Europe



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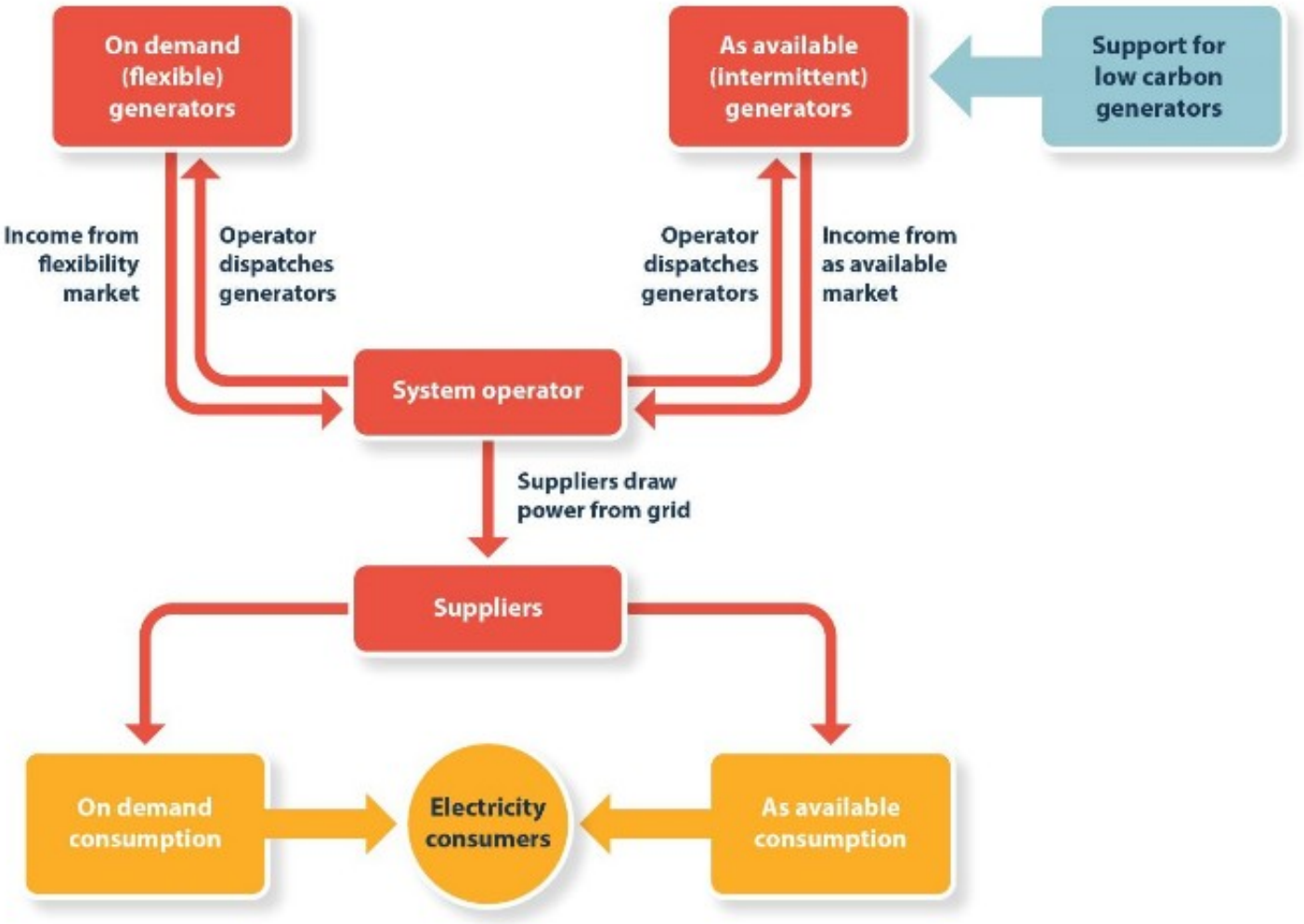
2 sides of Market Design

- Dispatchables
  - Fossil supply
  - Storage-battery
  - Transmission
- Non-dispatchables (now)
  - Demand
  - Distributed generation
  - Renewables

Market Design Question

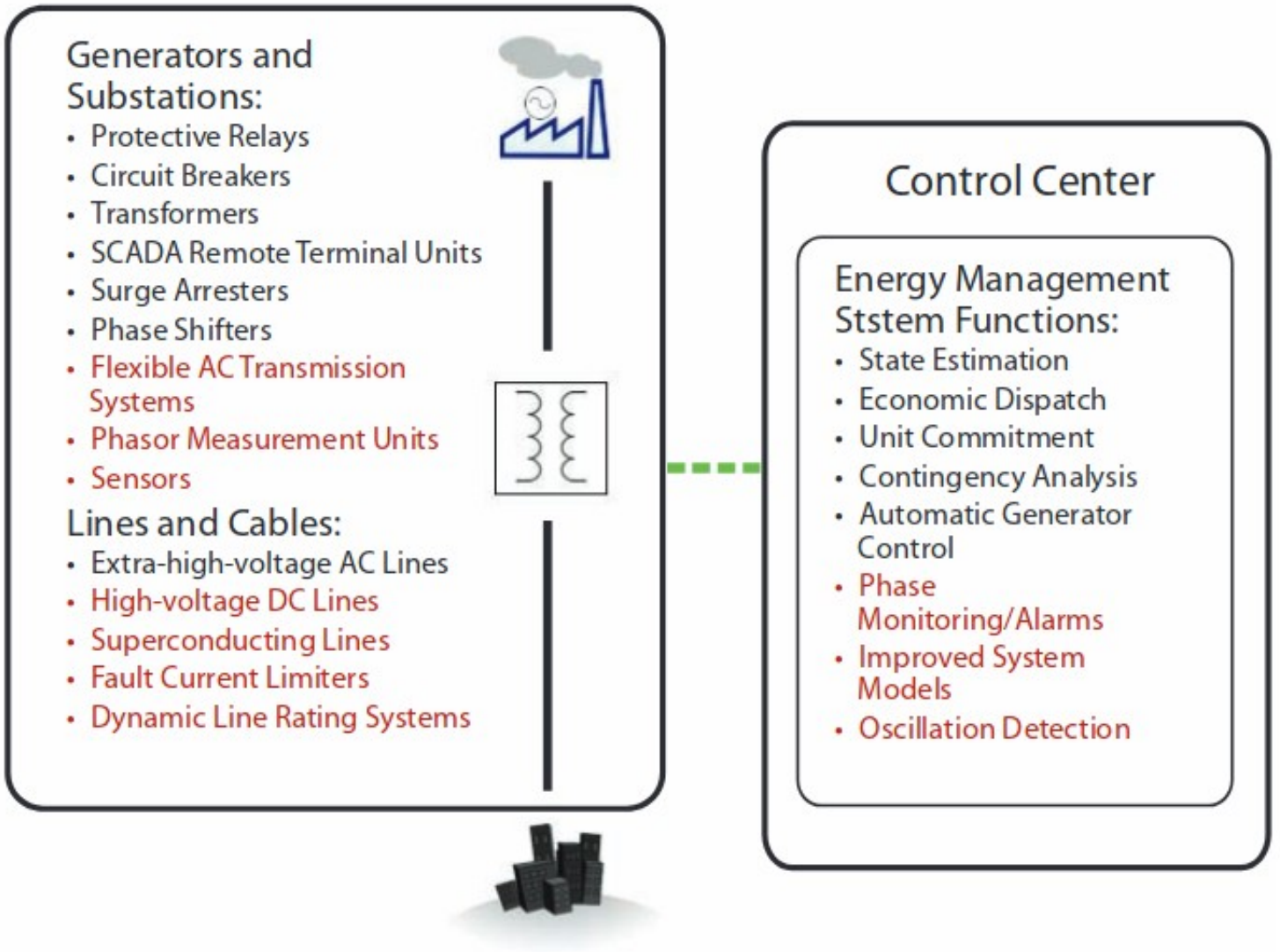
- Decarbonised system
- Distributed system
- Price signal
  - Capacity
  - Flexibility
- Blockchain
- Dist Co as mini TSO

Two market design



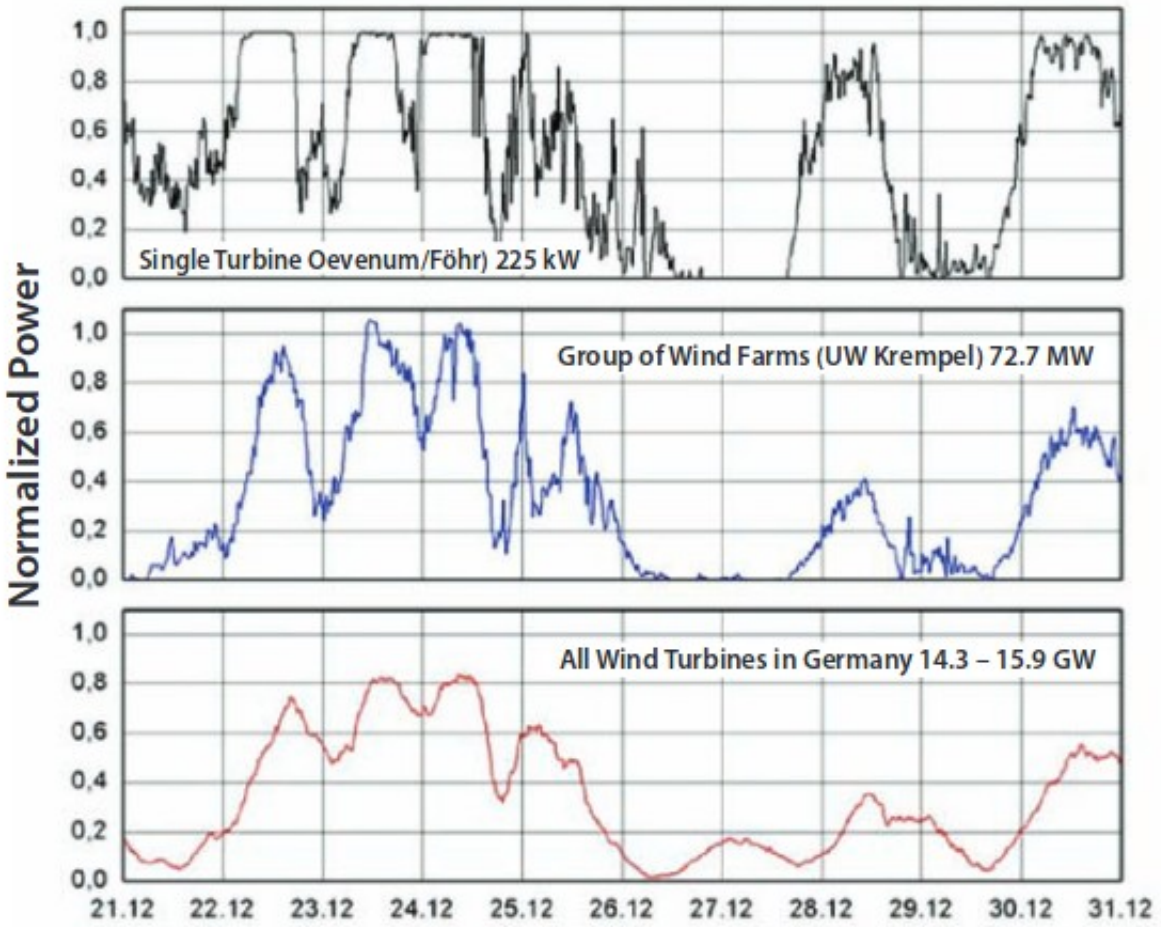
https://www.oxfordenergy.org/publications/decarbonised-electricity-system-future-two-market-approach/

Transmission network tech



Note: Existing technologies and functions are listed in black; new and emerging elements are shown in red.
SCADA = Supervisory control and data acquisition.

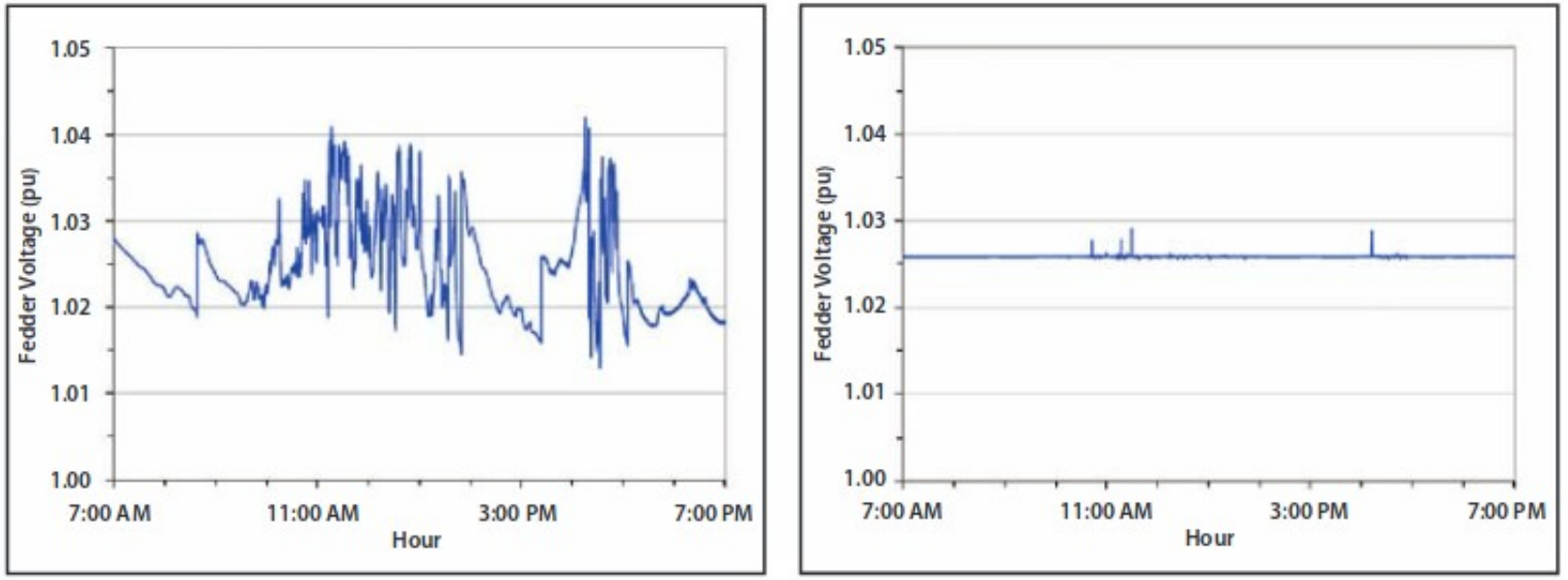
Aggregation-A solution?



Source: Copyright © Fraunhofer IWES, Germany; Institute for Solar Energy Technology, Wind Energy Report Germany 2005 (Kassel, Germany, 2005); H. Holtinnen et al., Design and Operation of Power Systems with Large Amounts of Wind Power: Final Report, Phase One 2006–2008, research note 2493 (Espoo, Finland: VTT, 2009).

Solar - problems&solution

Figure 5.1 Feeder Voltage at the Point of Interconnection of a Solar PV System



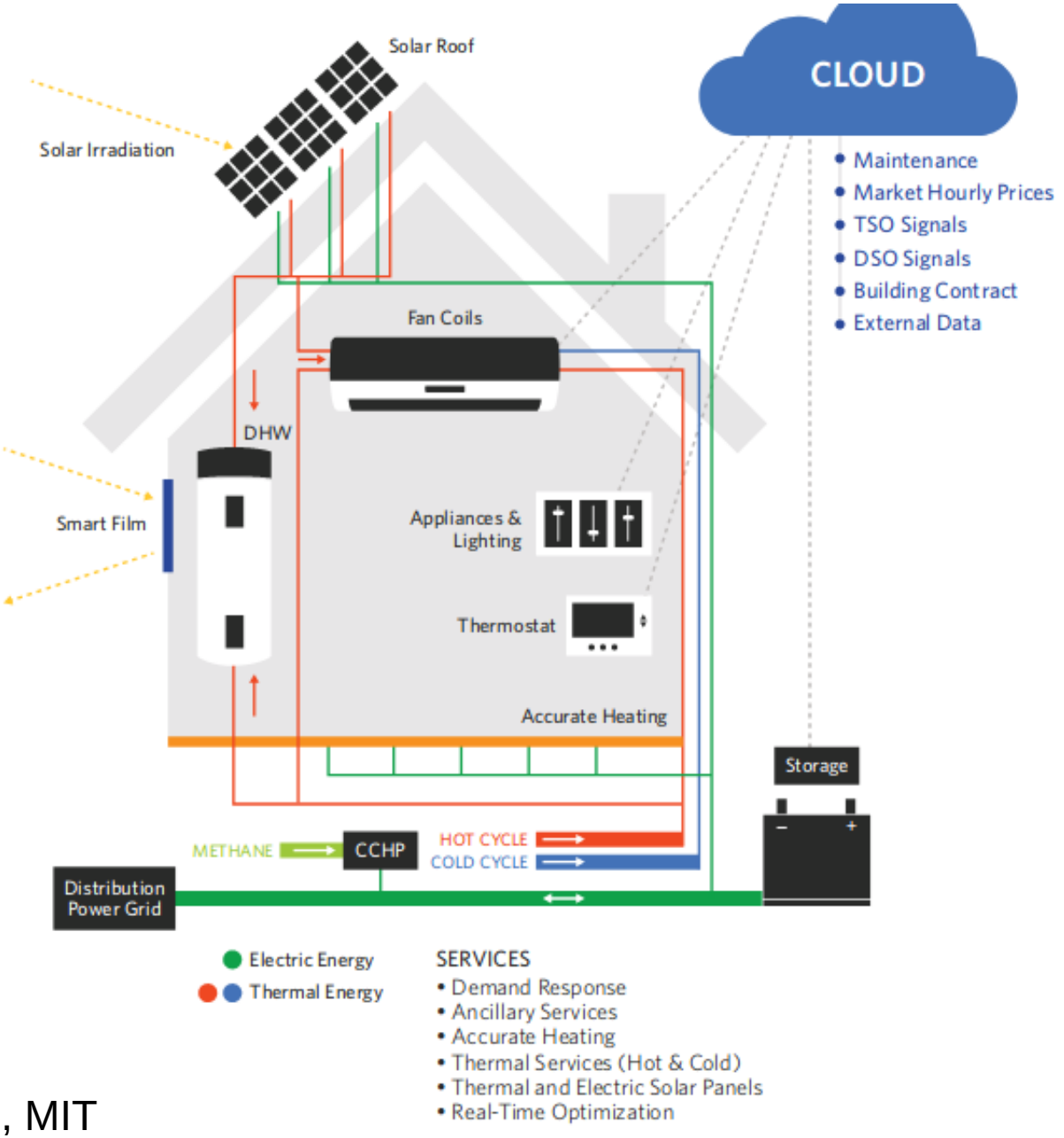
(a) Without Voltage Regulation Capability

(b) With Voltage Regulation Capability

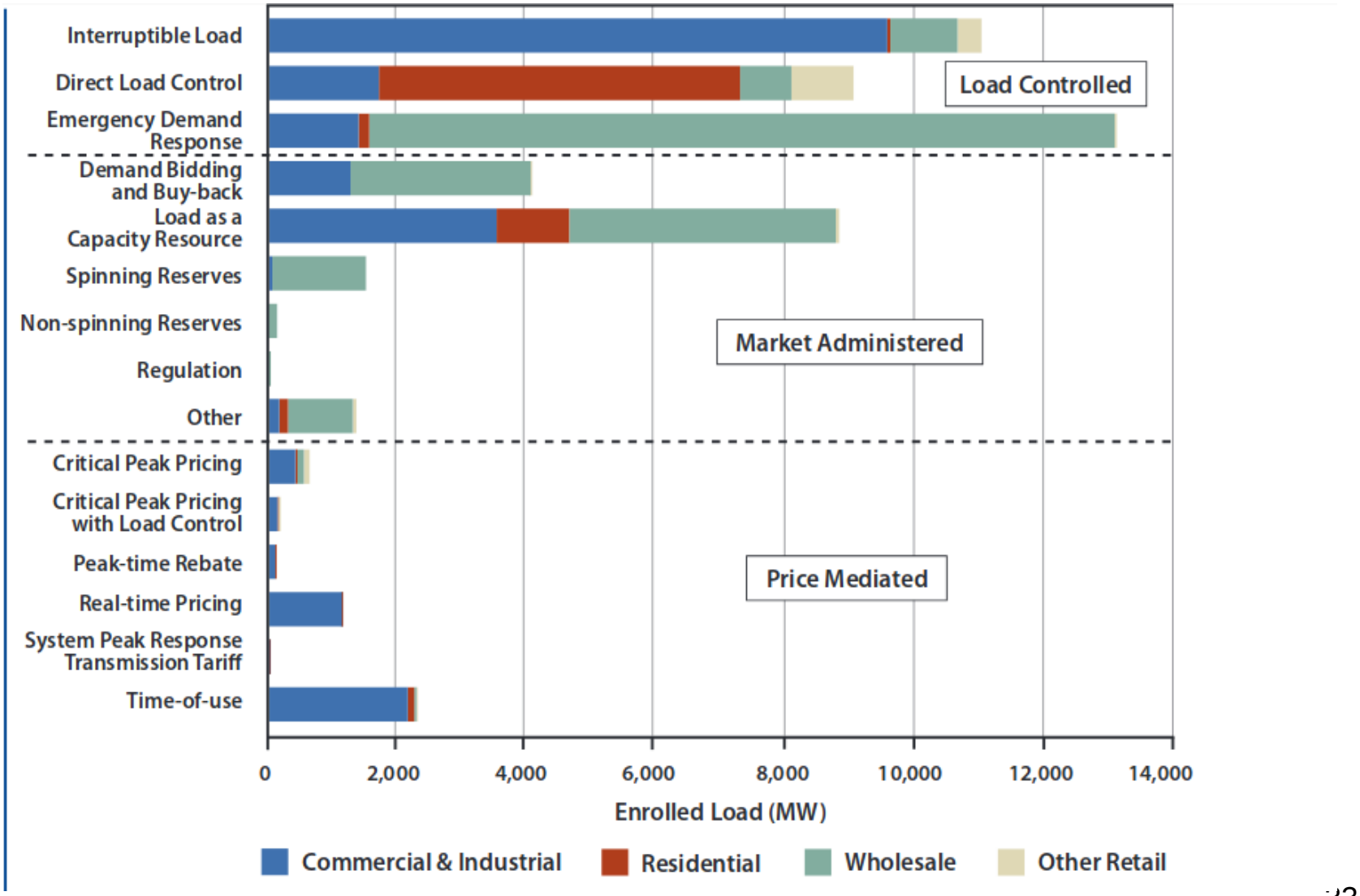
Note: The voltage scales on these plots are in a normalized measure called per-unit (pu). The normalizing constant is the nominal voltage of the line, 13.8 kV in this case. The line is operating at approximately 1.026 pu, which is 14.2 kV.

Source: © 2010 IEEE. Reprinted, with permission, from R. A. Walling and K. Clark, "Grid Support Functions Implemented in Utility-Scale PV Systems," paper presented at the Transmission and Distribution Conference and Exposition, 2010 IEEE Power & Energy Society, New Orleans, LA, April 19–22, 2010.

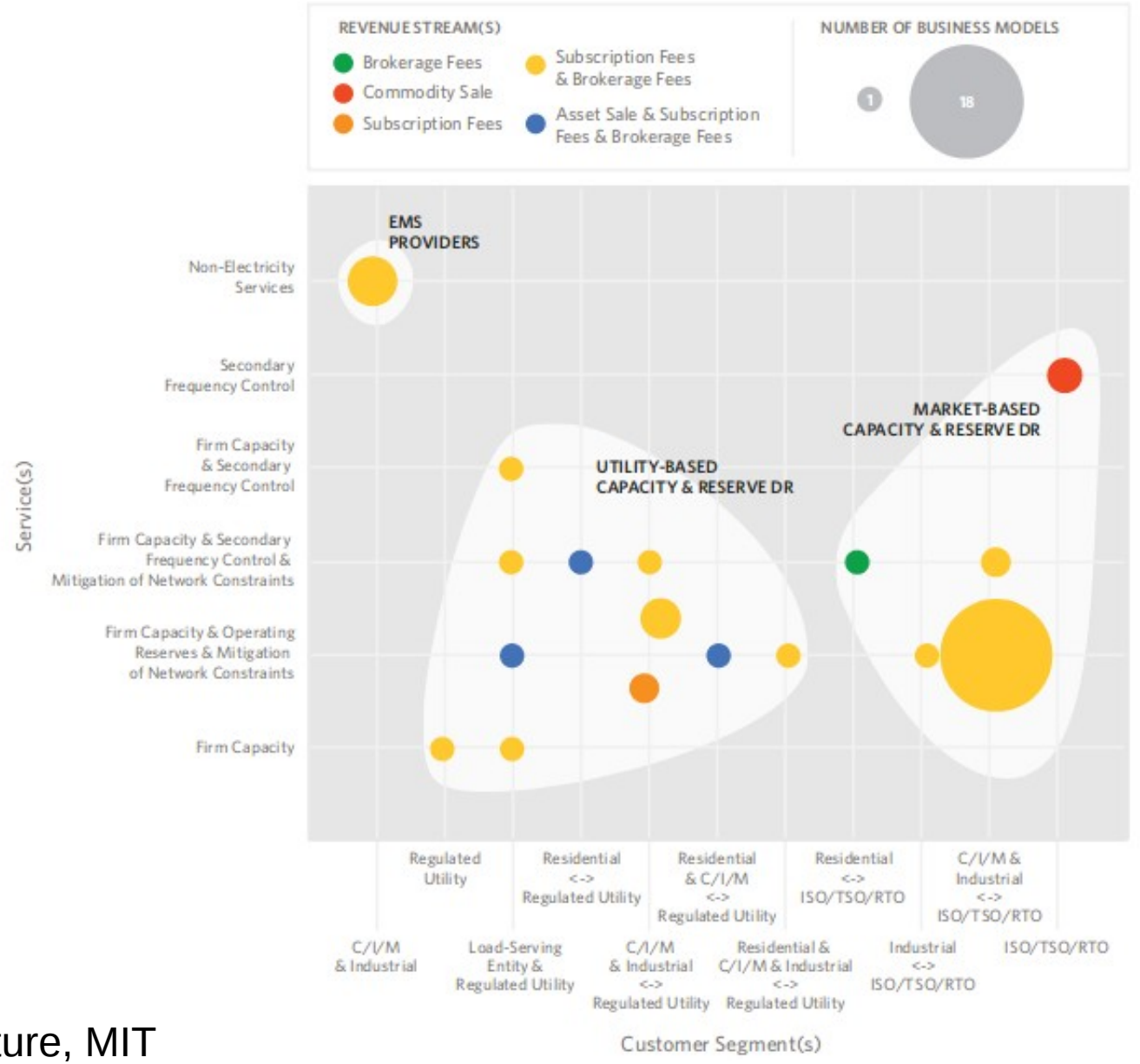
Smart Home concept



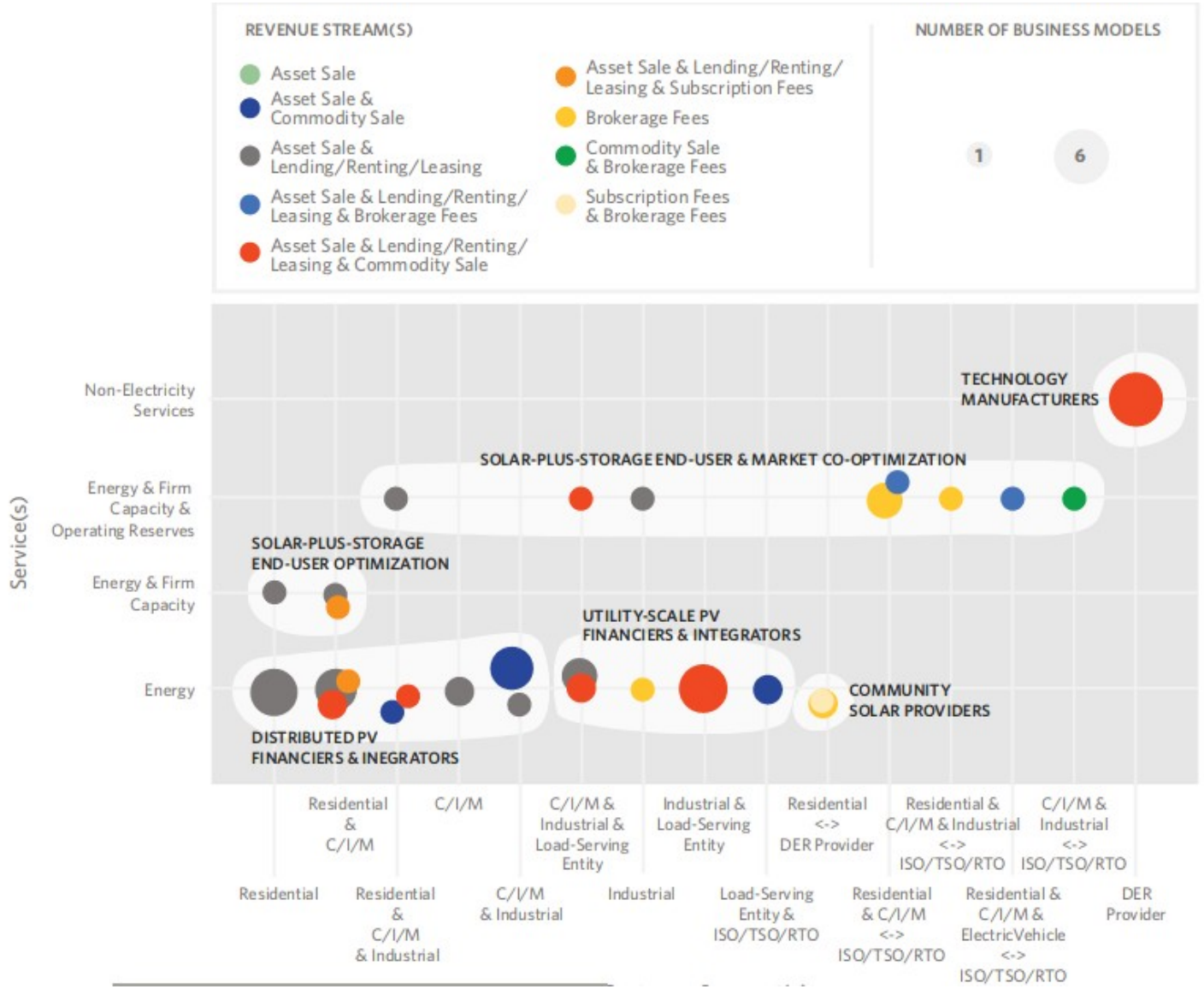
Types of Demand Response



Demand Response and Energy Management System Business Models



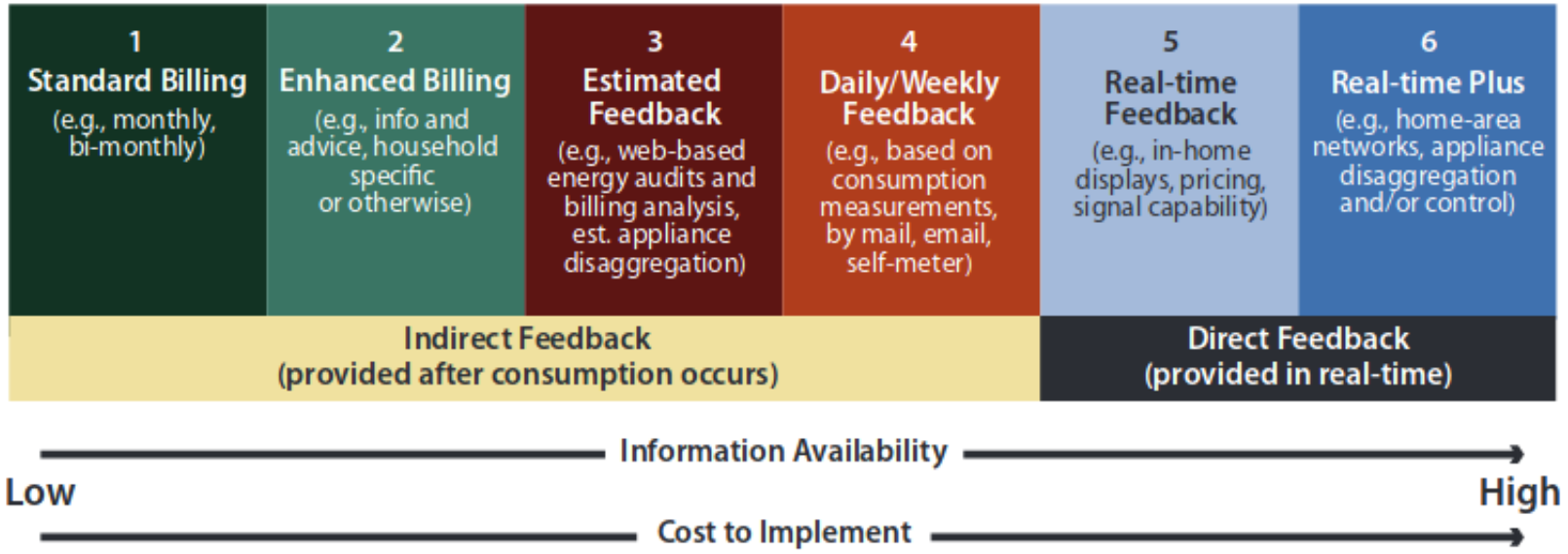
Solar & storage biz models



Utility of the Future, MIT

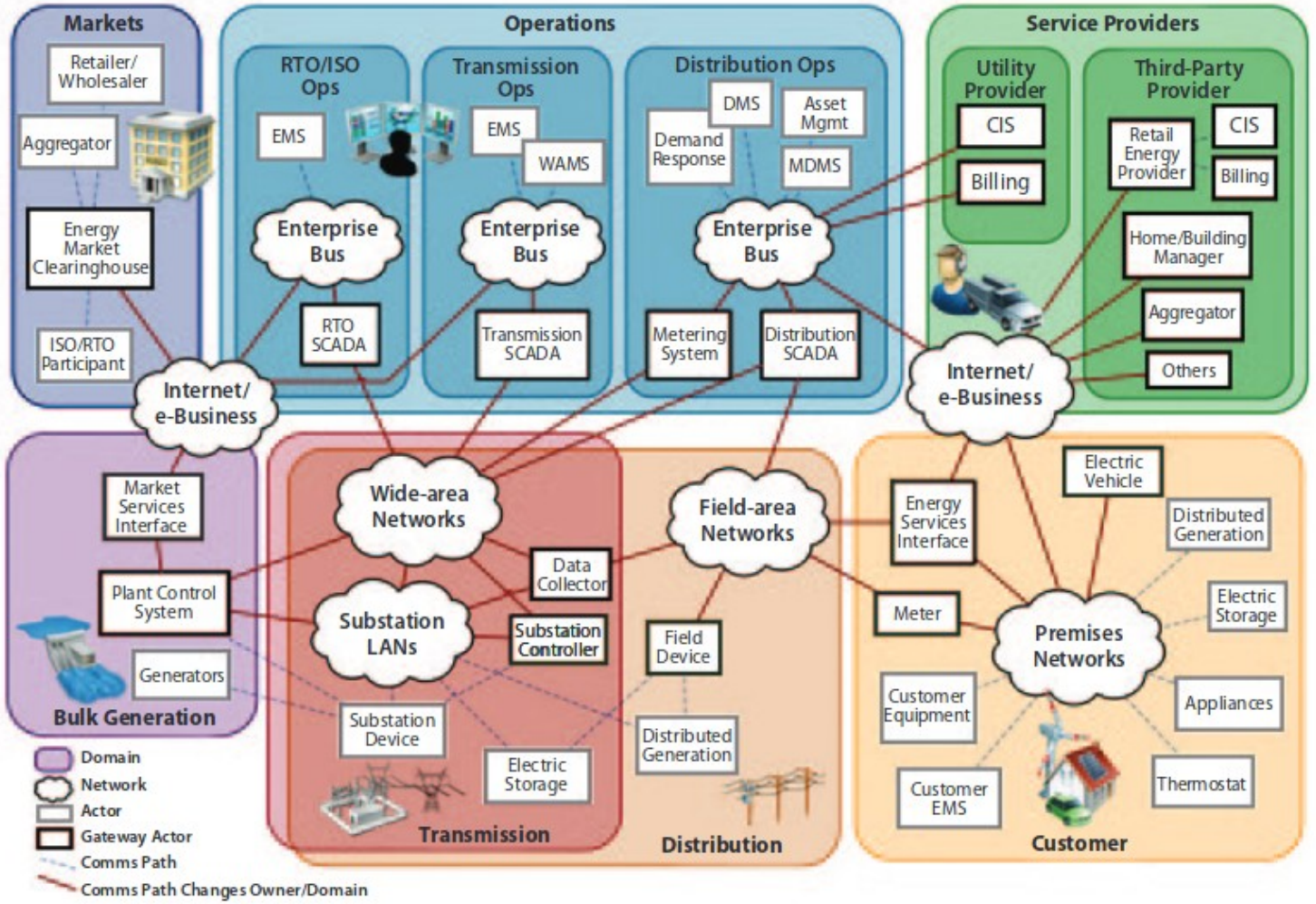
Do you want real time feedback

Figure 7.2 Informational Feedback Continuum



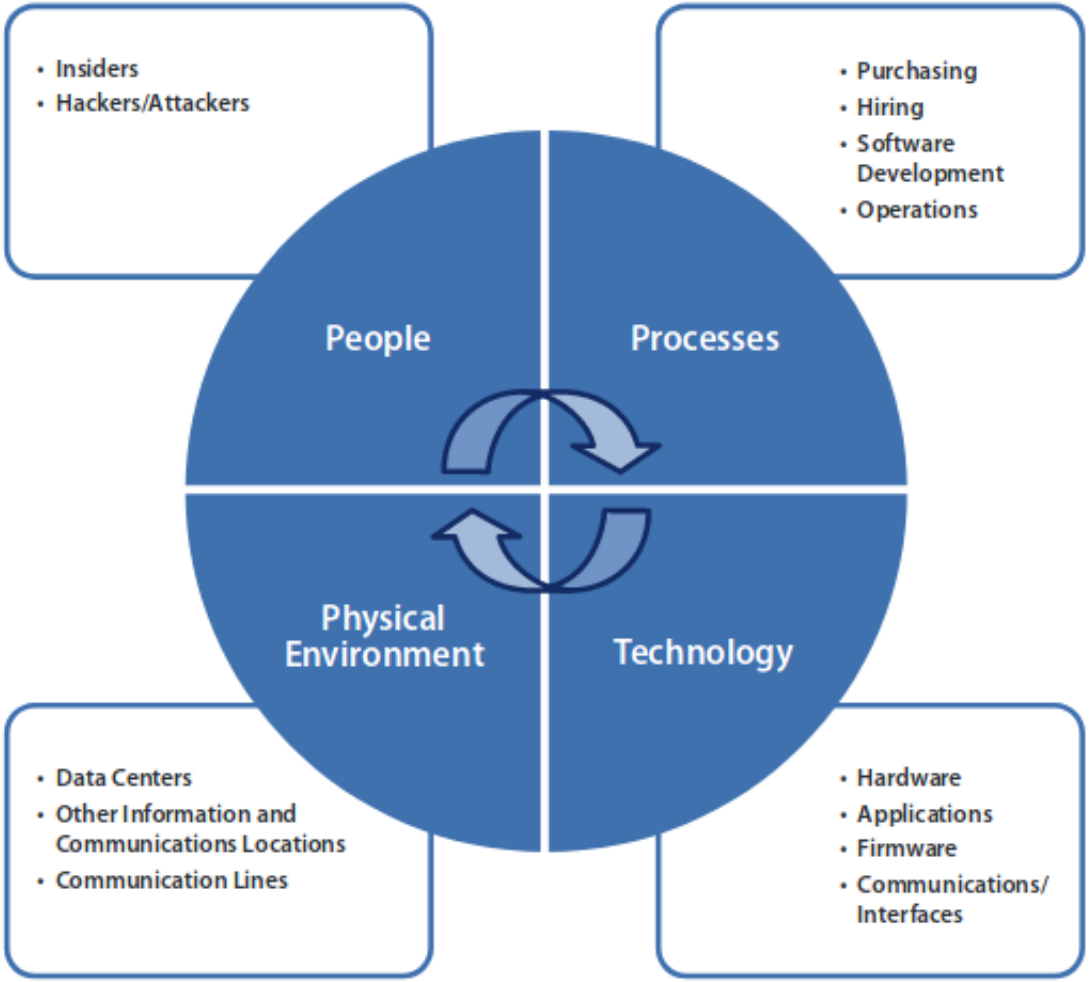
Source: Electric Power Research Institute, *Residential Electricity Use Feedback: A Research Synthesis and Economic Framework* (Palo Alto, CA, 2009).

Communication flows

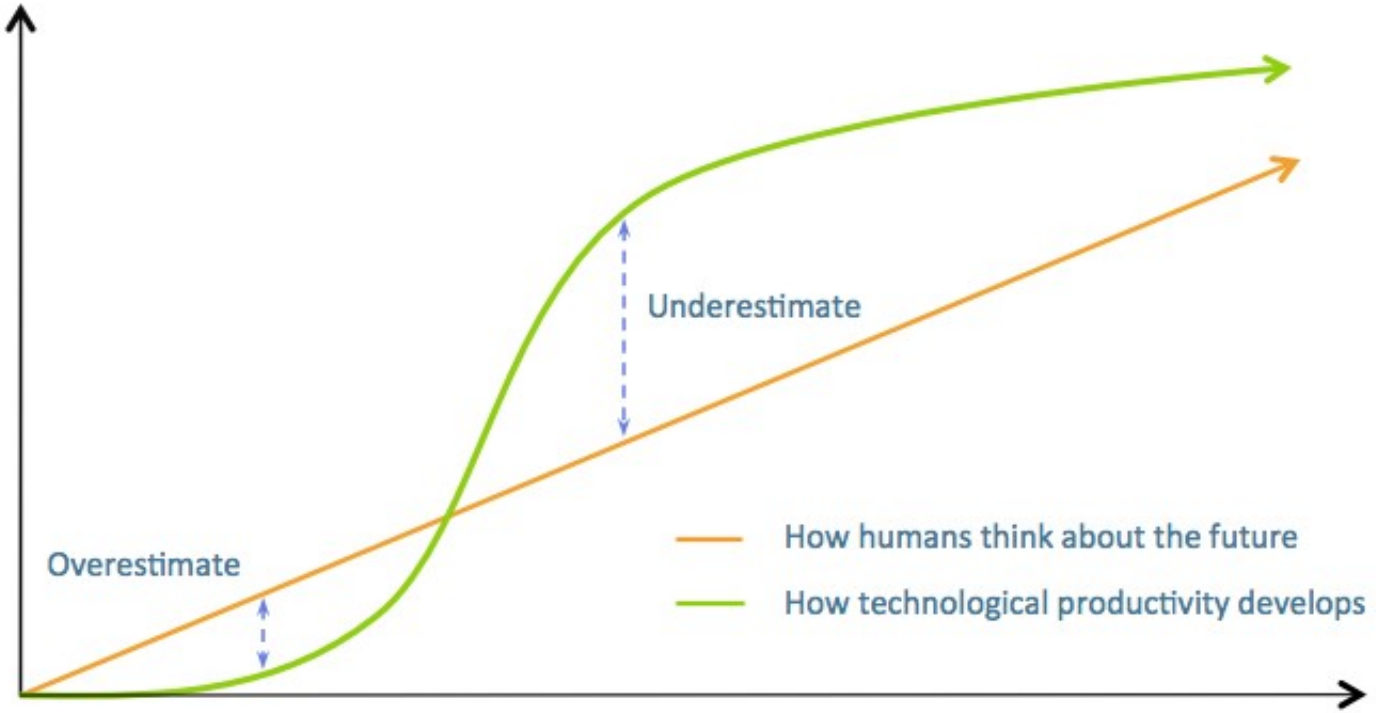


Source: National Institute for Standards and Technology, *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0*, special publication 1108 (Washington, DC: U.S. Department of Commerce, 2010), 35, http://www.nist.gov/public_

Cybersecurity vulnerabilities



A few words



http://www.rocrastination.com/thoughts/2014/8/28/why-we-overestimate-the-short-term-and-underestimate-the-lon.html

Conclusion

- Electric system is bound by physical laws
  - Kirchhoff law will be relevant, Faraday etc.
- Economic systems are affected by each other
  - Distributed internet services (Remember Napster!)
- Regulation is heavily impacted by technology
  - More solar more flexibility regulation
- In assessing the future
  - Observe the hype and ask "what can go wrong"
  - Listen but not follow nay sayers, ask "why not"?
  - Reality falls in between opposite views. "what are the boundaries of my reality"

Questions