Thoughts on Emerging Energy Technology Systems

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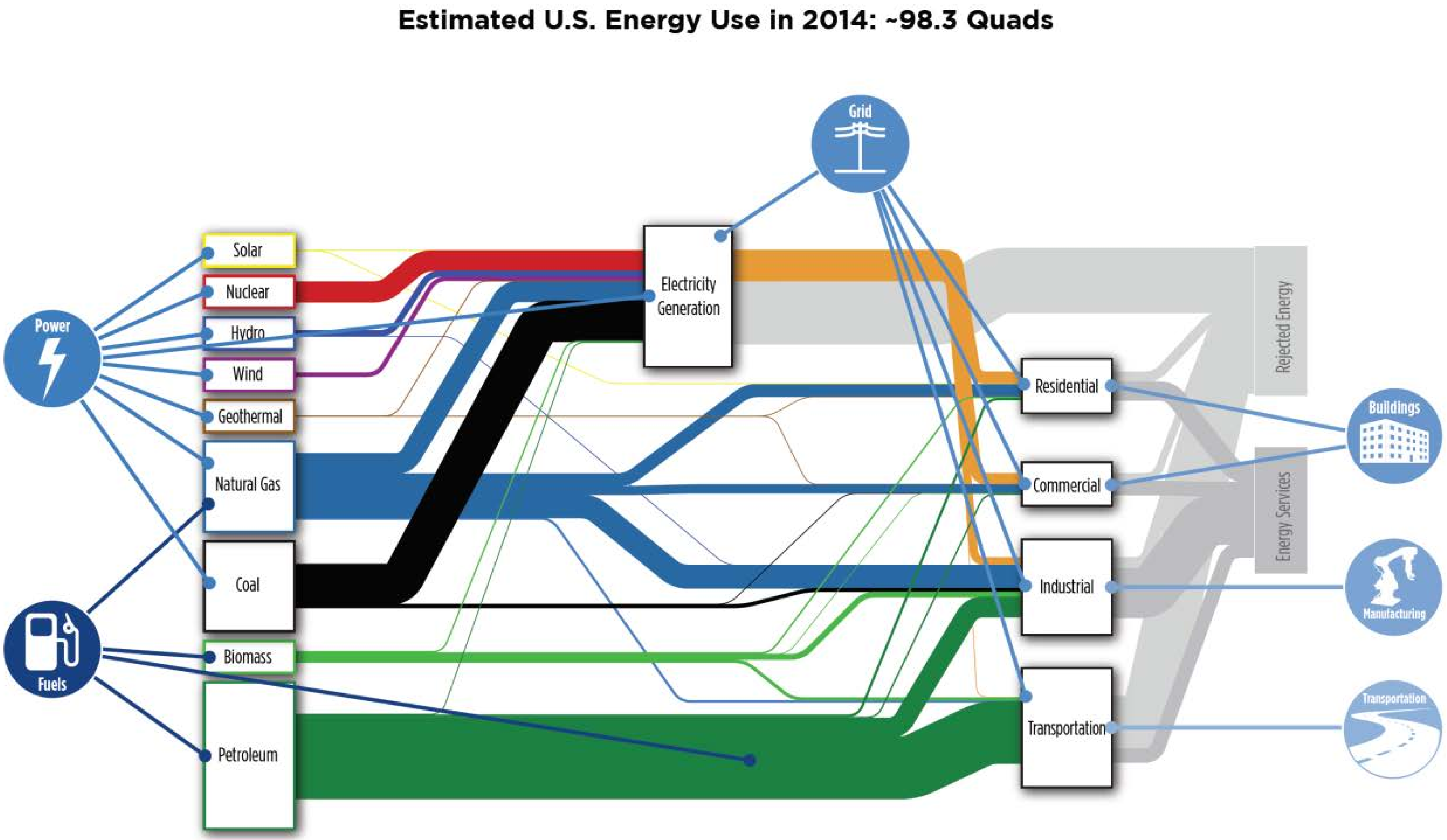
Figure ES.1 Sankey Diagram of the U.S. Energy System Depicting Major Areas of Coverage by the Technical QTR Chapters 3–8



Energy Sectors and Systems

Key issues:

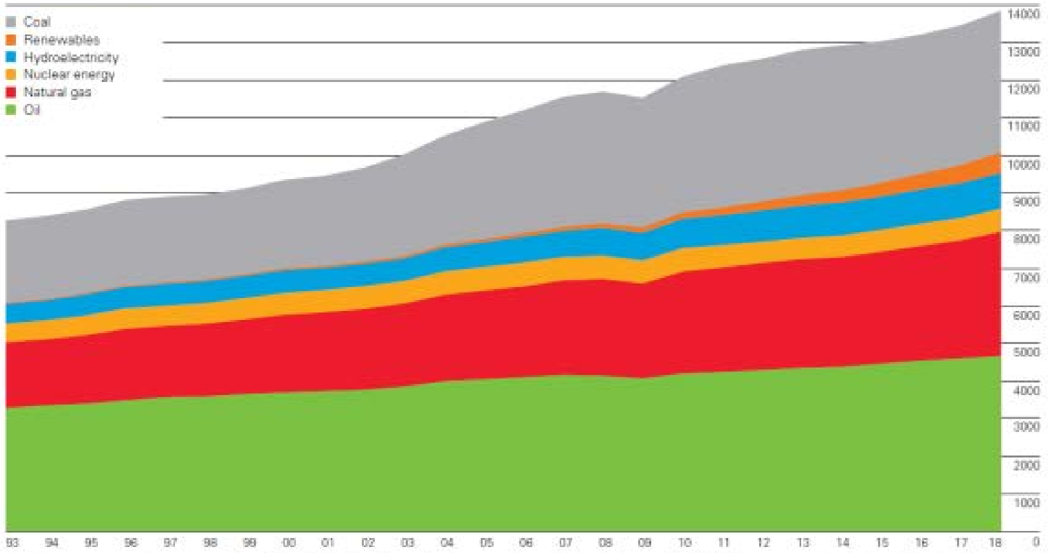
Three layers of increasing integration and complexity:

- Number, variability, and communication of devices connected to the electric grid
- Cross-talk between sectors of the energy system (e.g., fuels/electricity, electricity/buildings)
- Coupling of energy systems to non-energy systems (e.g., Internet, water)

- **Information and communications** technologies are driving the interconnection of energy systems.
- Integration can **improve system cost and efficiency** by optimizing the utilization of assets and resources.
- Integration can also **increase vulnerabilities** and the **risks** of unintended consequences and cascading failure. (Who knows our Grid BEST???)

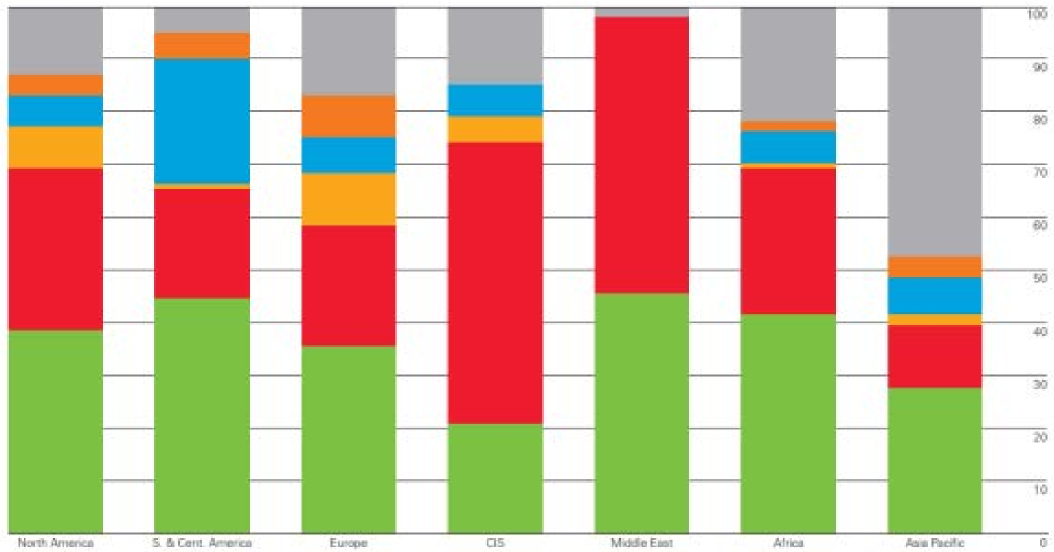
Global Energy Growth Patterns

World consumption
Million tonnes oil equivalent



Global energy consumption increased by 2.9% in 2018. Growth was the strongest since 2010 and almost double the 10-year average. The demand for all fuels increased but growth was particularly strong in the case of gas (168 mtoe, accounting for 43% of the global increase) and renewables (71 mtoe, 18% of the global increase). In the OECD, energy demand increased by 82 mtoe on the back of strong gas demand growth (70 mtoe). In the non-OECD, energy demand growth (308 mtoe) was more evenly distributed with gas (98 mtoe), coal (85 mtoe) and oil (47 mtoe) accounting for most of the growth.

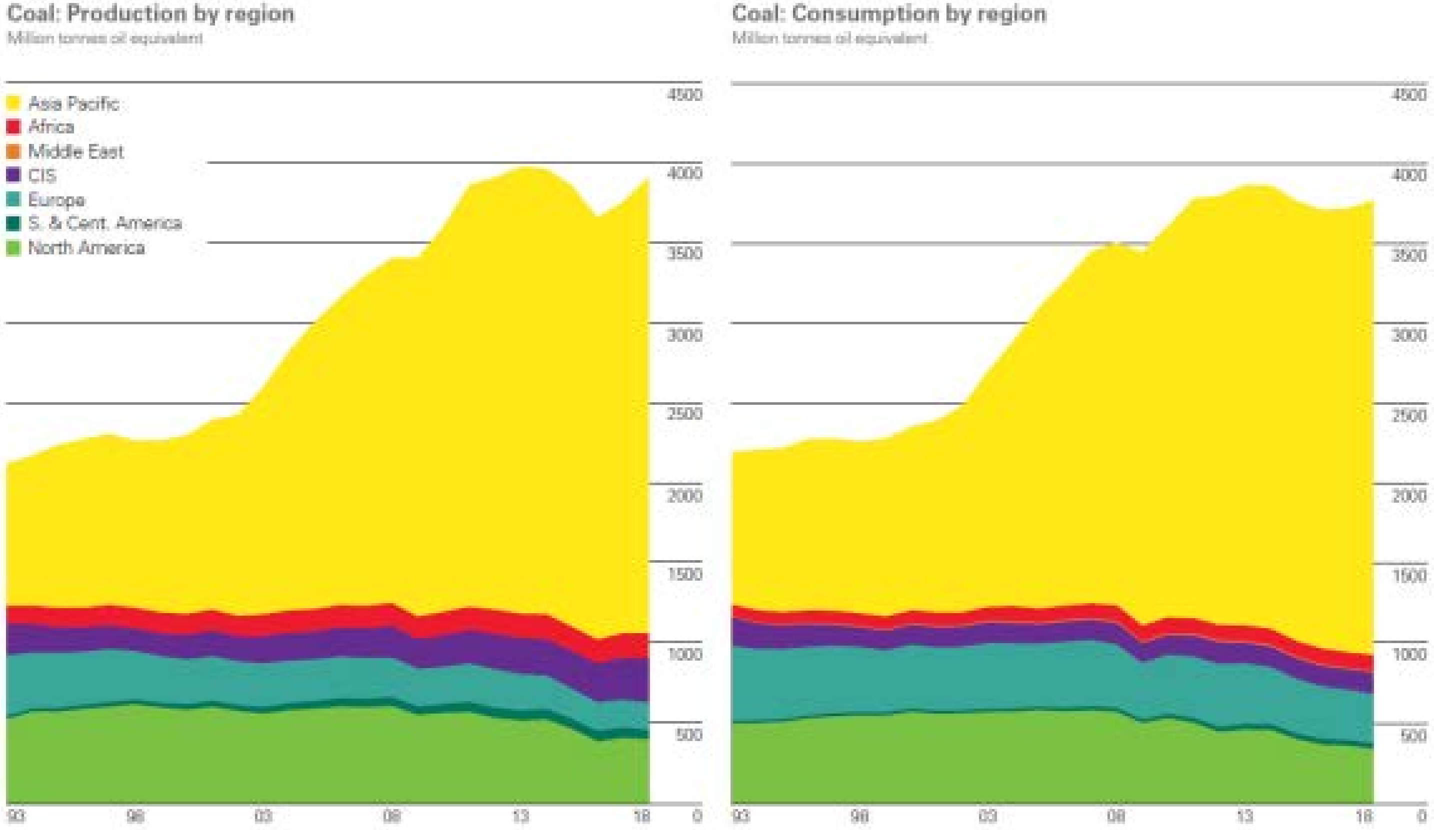
Regional consumption by fuel 2018
Percentage



Oil remains the dominant fuel in Africa, Europe and the Americas, while natural gas dominates in CIS and the Middle East, accounting for more than half of the energy mix in both regions. Coal is the dominant fuel in the Asia Pacific region. In 2018 coal's share of primary energy fell to its lowest level in our data series in North America and Europe.

BP Statistical Review of World Energy 2019

Global Coal Production and Use



Global coal production increased by 4.3% in 2018, significantly above the 10-year average of 1.3%. Production growth was concentrated in Asia Pacific (163 mtoe) with China accounting for half of global growth and Indonesian production up by 51 mtoe. Coal consumption increased by 1.4% in 2018, the fastest growth since 2013. Growth was again driven by Asia Pacific (71 Mtoe), and particularly by India (36 Mtoe). This region now accounts for over three quarters of global consumption, while 10 years ago it represented two thirds.

BP Statistical Review of World Energy 2019

Figure 3.3 Evolution of the Electric Power Grid

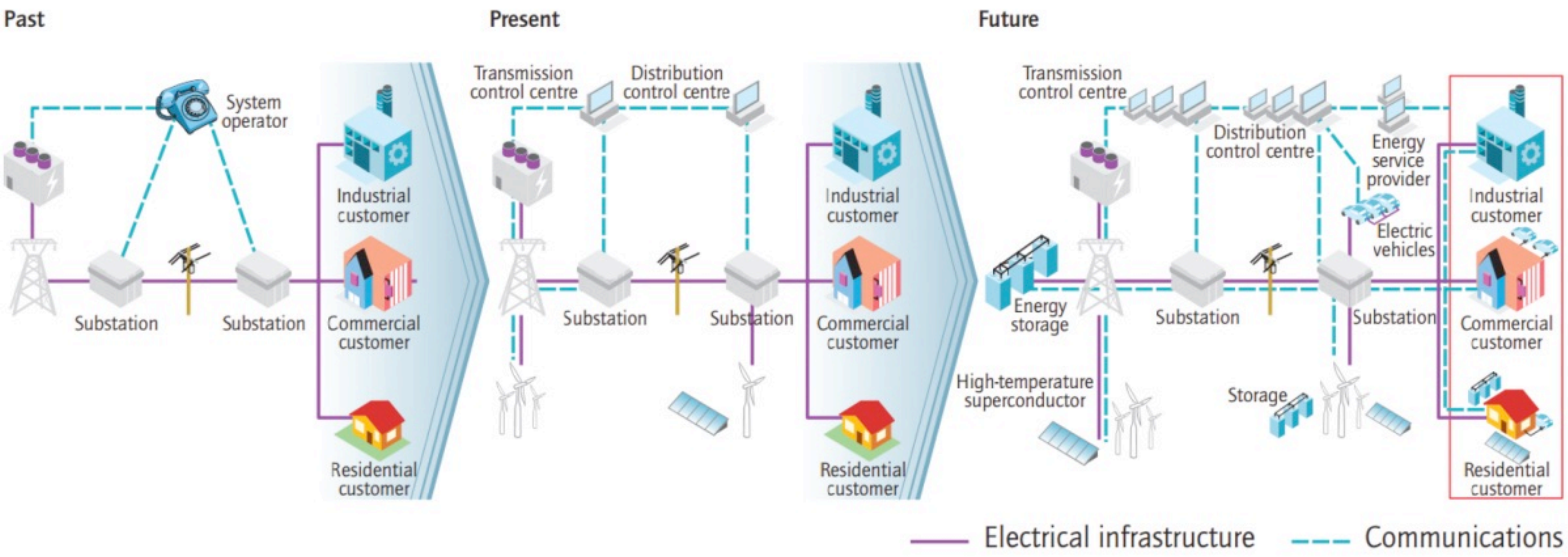


Figure 3.21 Scales of Power Systems Operations and Planning

Credit: Alexandra von Meier, "Challenges to the Integration of Renewable Resources at High System Penetration," California Institute for Energy and Environment (2014). http://uc-ciee.org/all-documents/a/441/113/nested

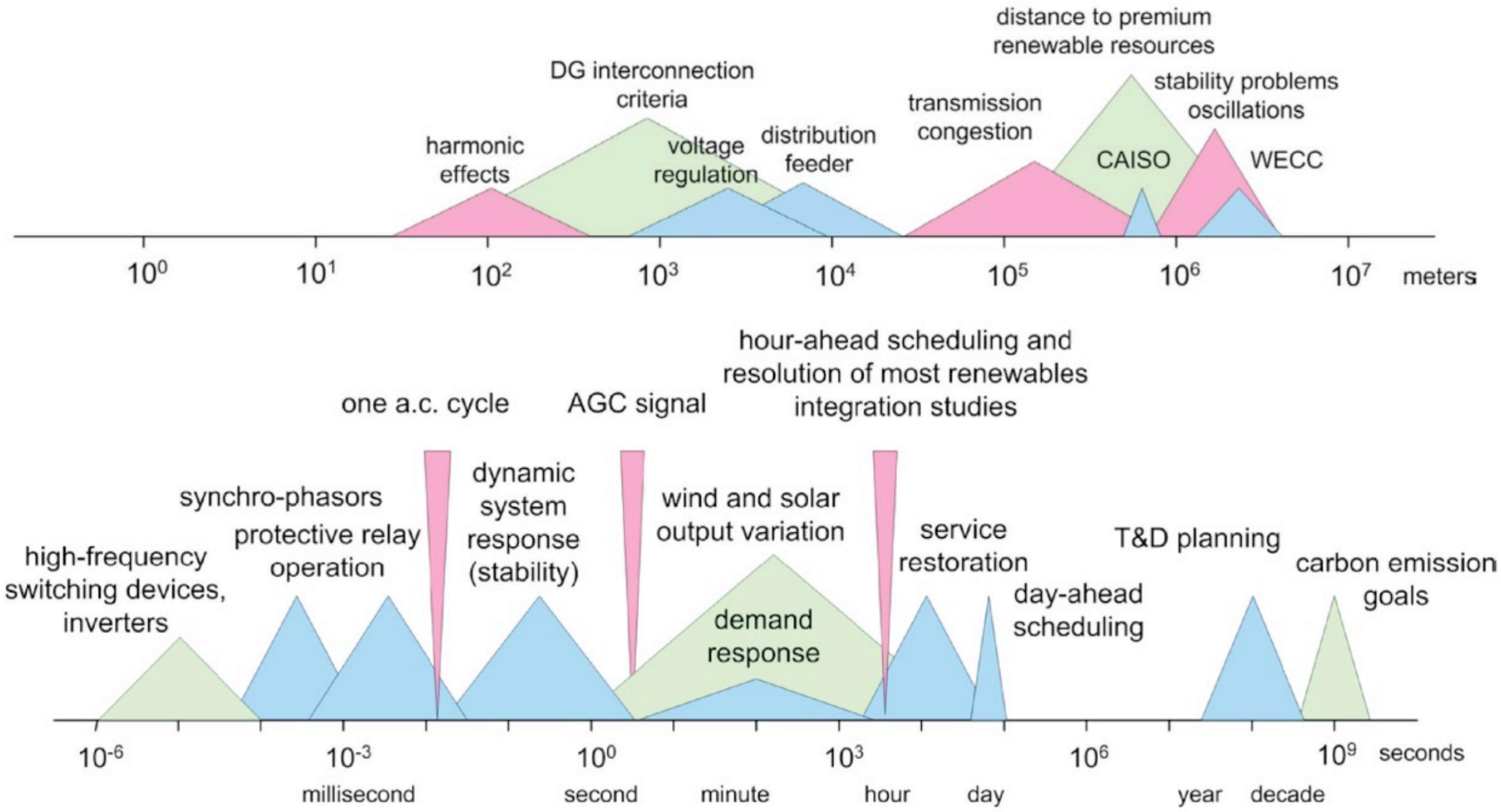


Figure 3.11 Grid Architecture Structure Types

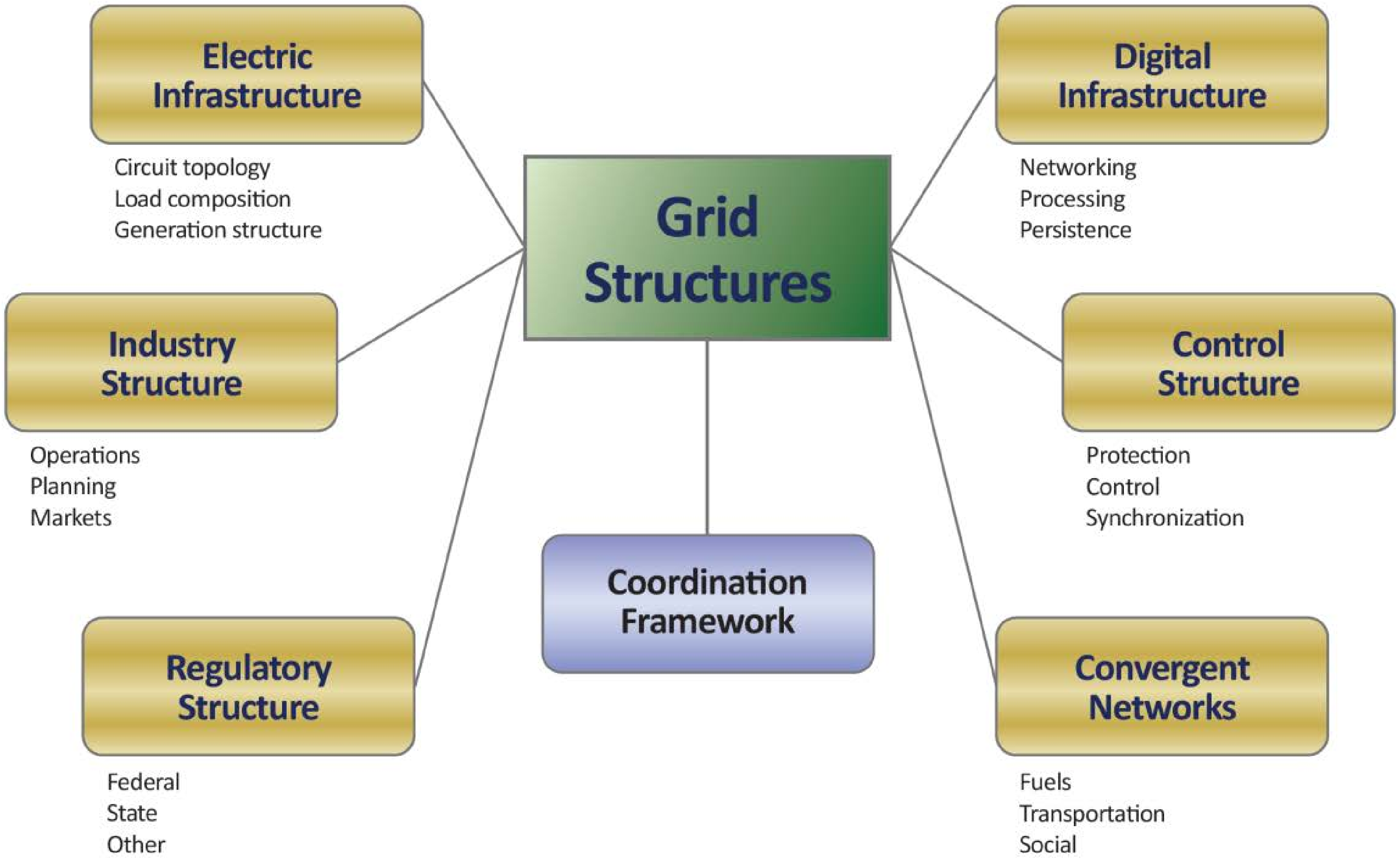


Figure 5.17 Future grid systems and smart building controls can communicate in ways that improve overall system efficiency and reliability.

Credit: National Institute of Standards and Technology

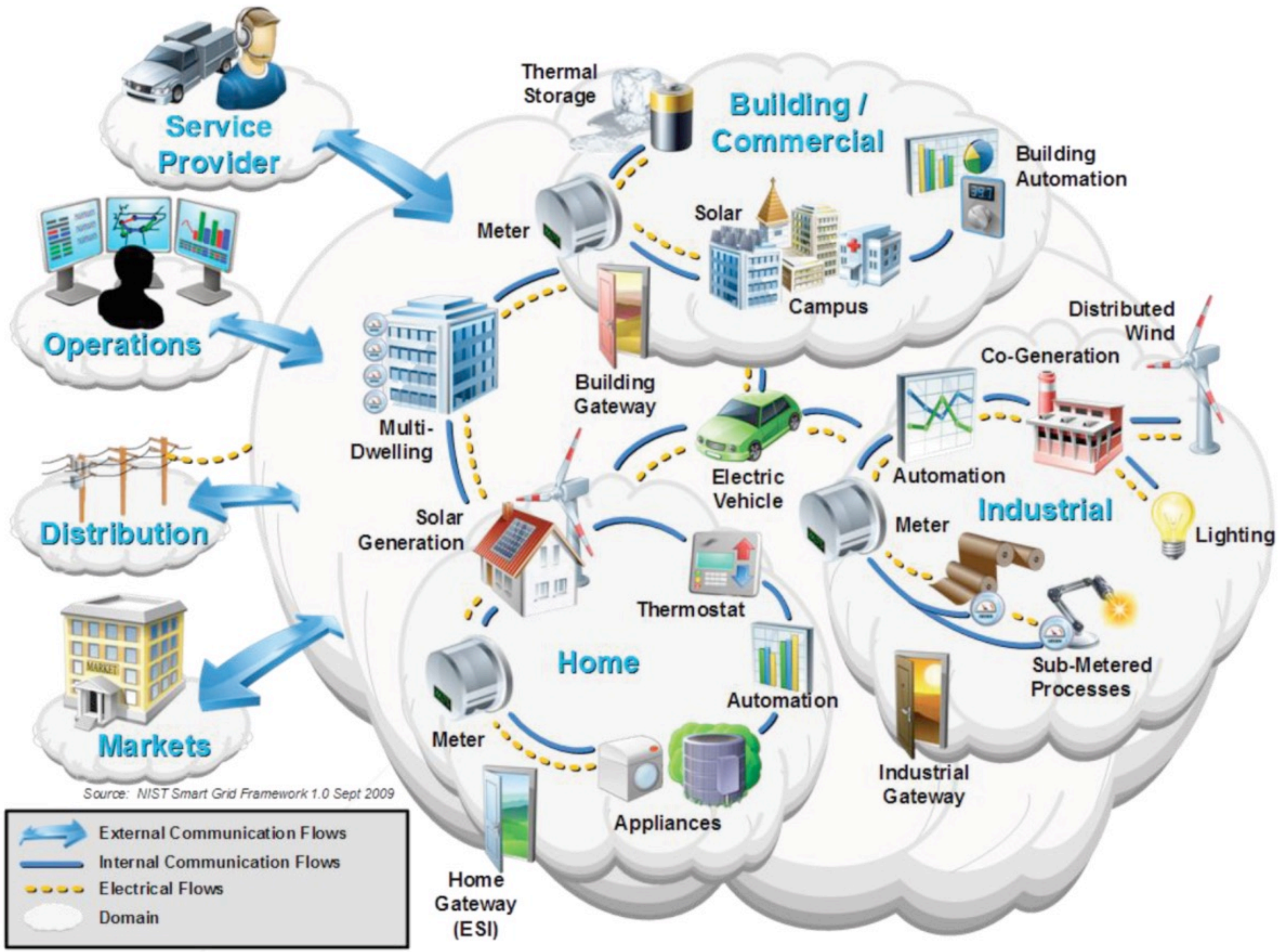


FIG. 5-11

Conceptual Framework for Smart Cities

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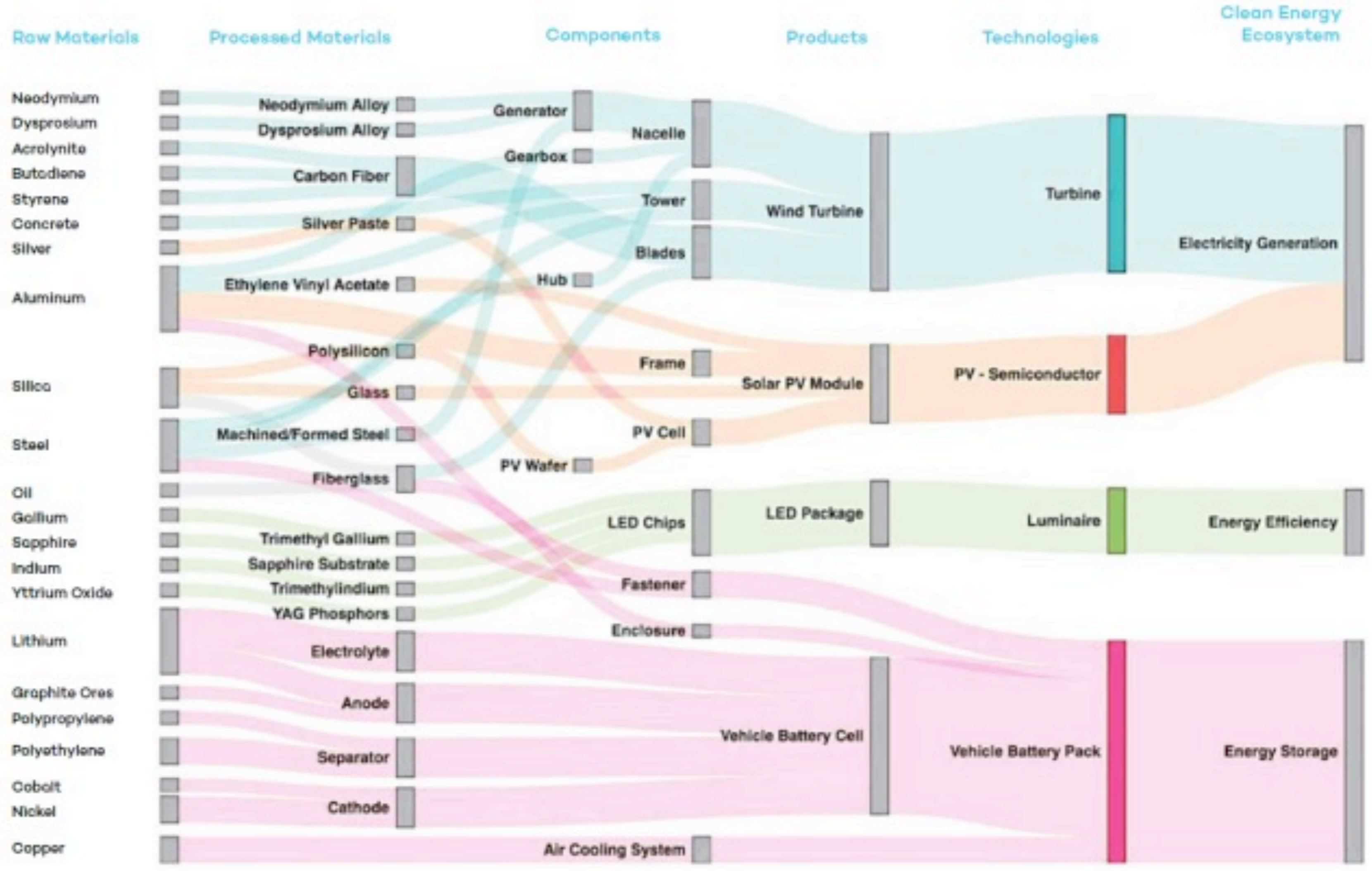
FIG. 3-2

Sankey Diagram of the Clean Energy Technology Supply Chain



The clean energy technology supply chain is vast and complex, but also includes numerous interconnections between raw materials and technologies.

Source: McCall, 2017. Clean Energy Manufacturing Analysis Center

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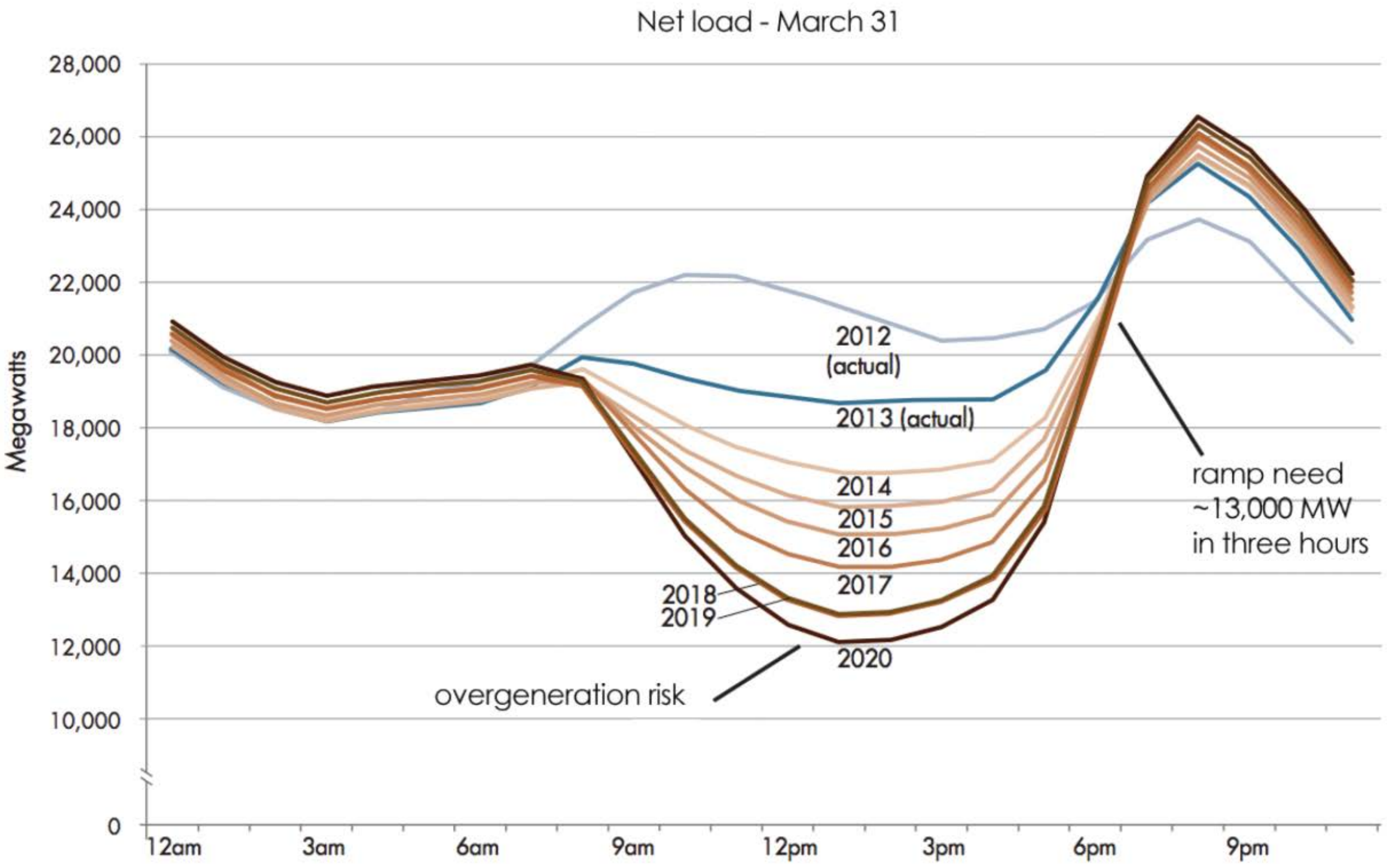
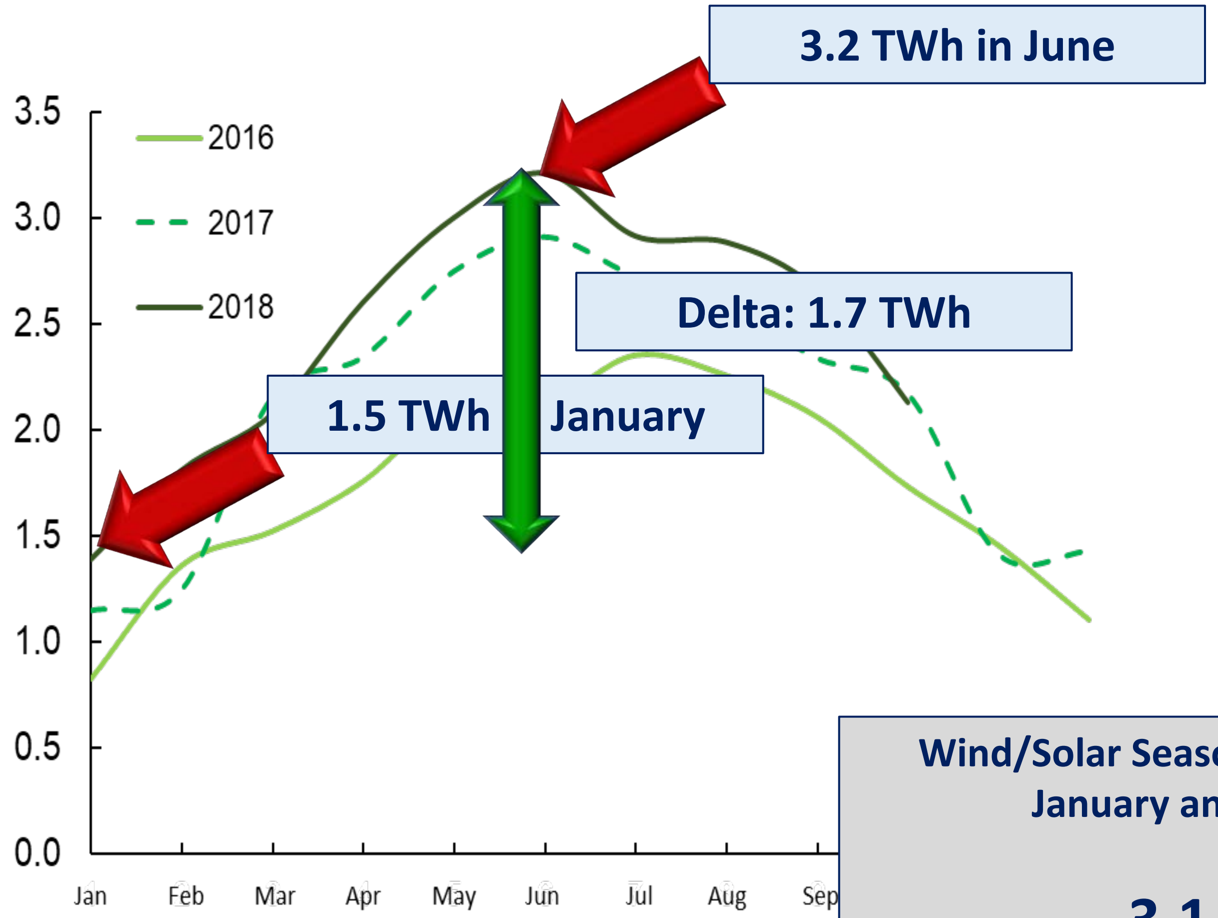
Figure 3.9 California ISO Projected Electricity Supply

Credit: California Independent System Operator Corporation

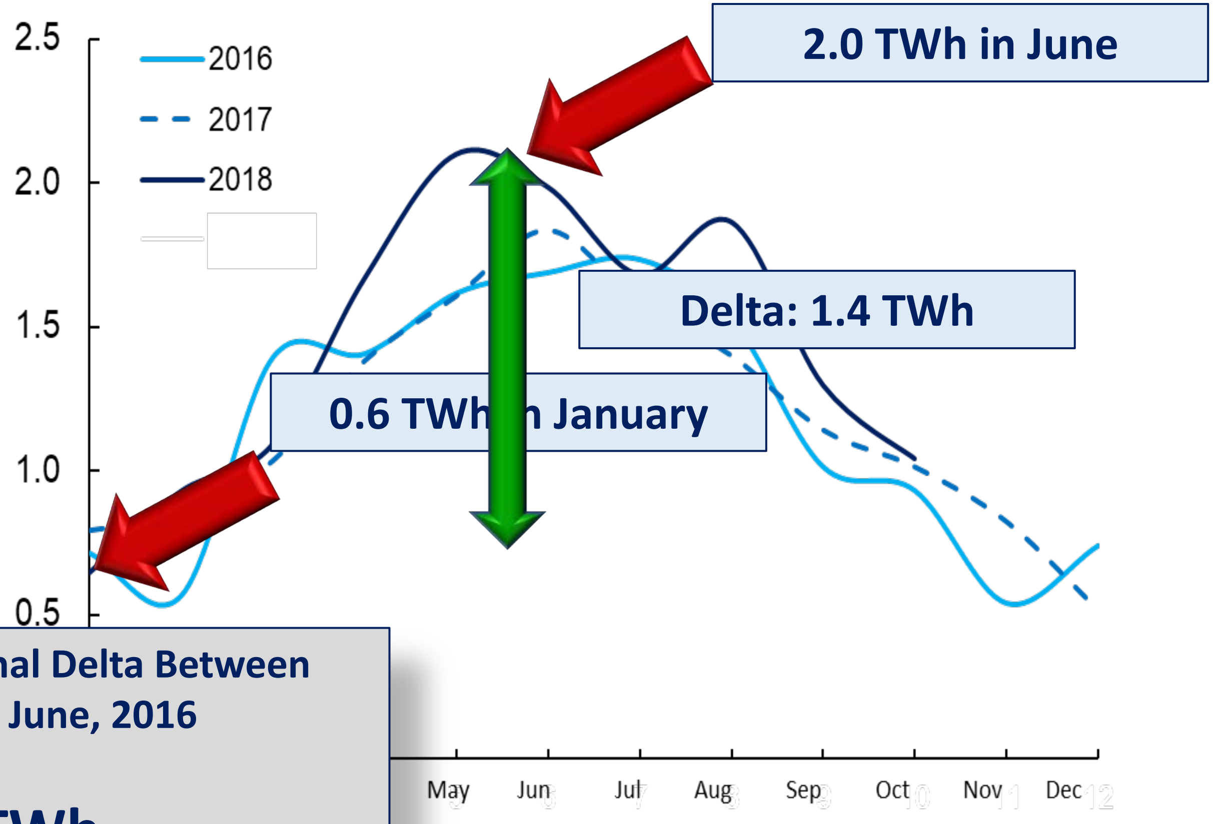


Seasonal Variation in Solar & Wind, Impacts of Drought on Hydro Generation

Metered Solar Generation



Wind Generation



Wind/Solar Seasonal Delta Between January and June, 2016

3.1 TWh

Source: EFI, compiled using data from CAISO

Seasonal Variation in Solar & Wind, Impacts of Drought on Hydro Generation

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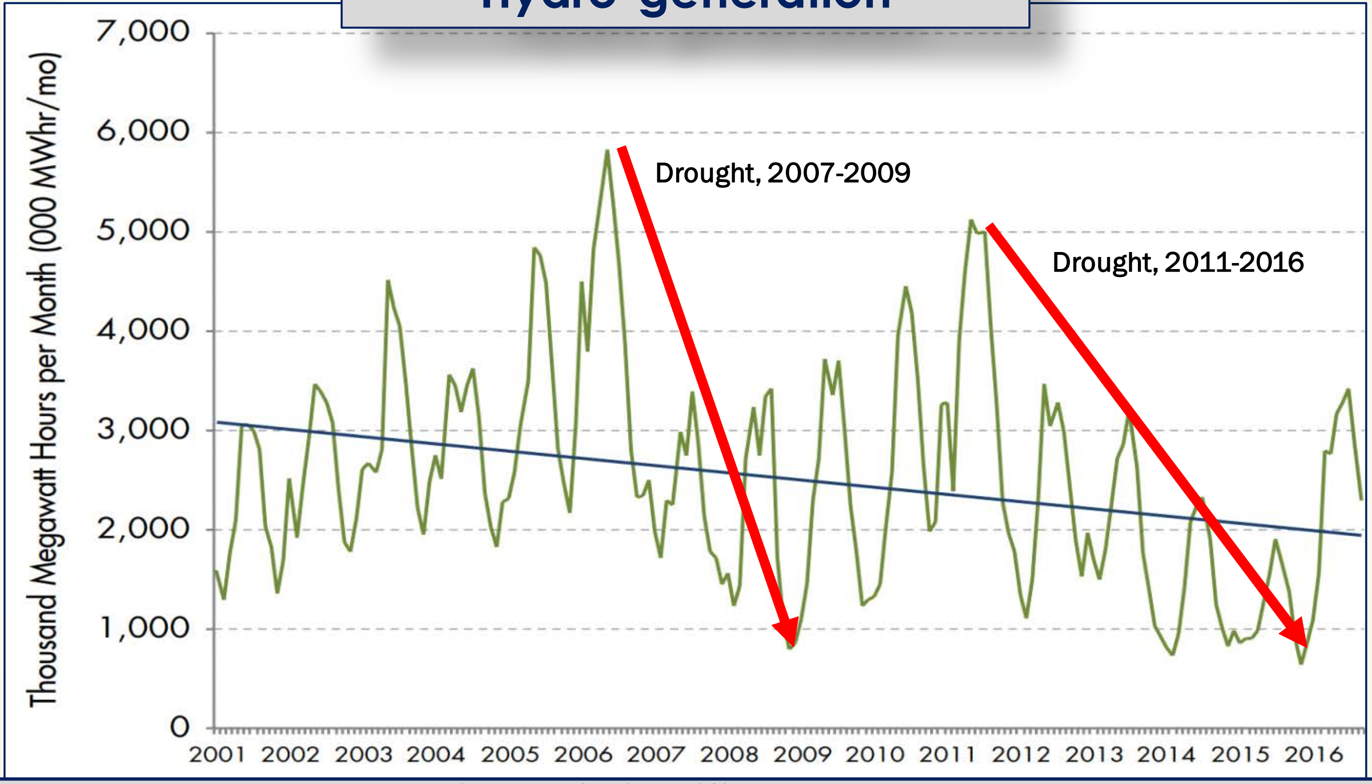
Hydro-generation



…between 2007-2009, a period of significant drought, hydro generation fell to about 13 percent of California's total generation, down from a peak of 18 percent, with monthly hydro production falling from 5,000 MWh/month to less than 1,000. In the most recent and more severe drought, hydro generation was under seven percent of total generation.

Source: Pacific Institute, 2017

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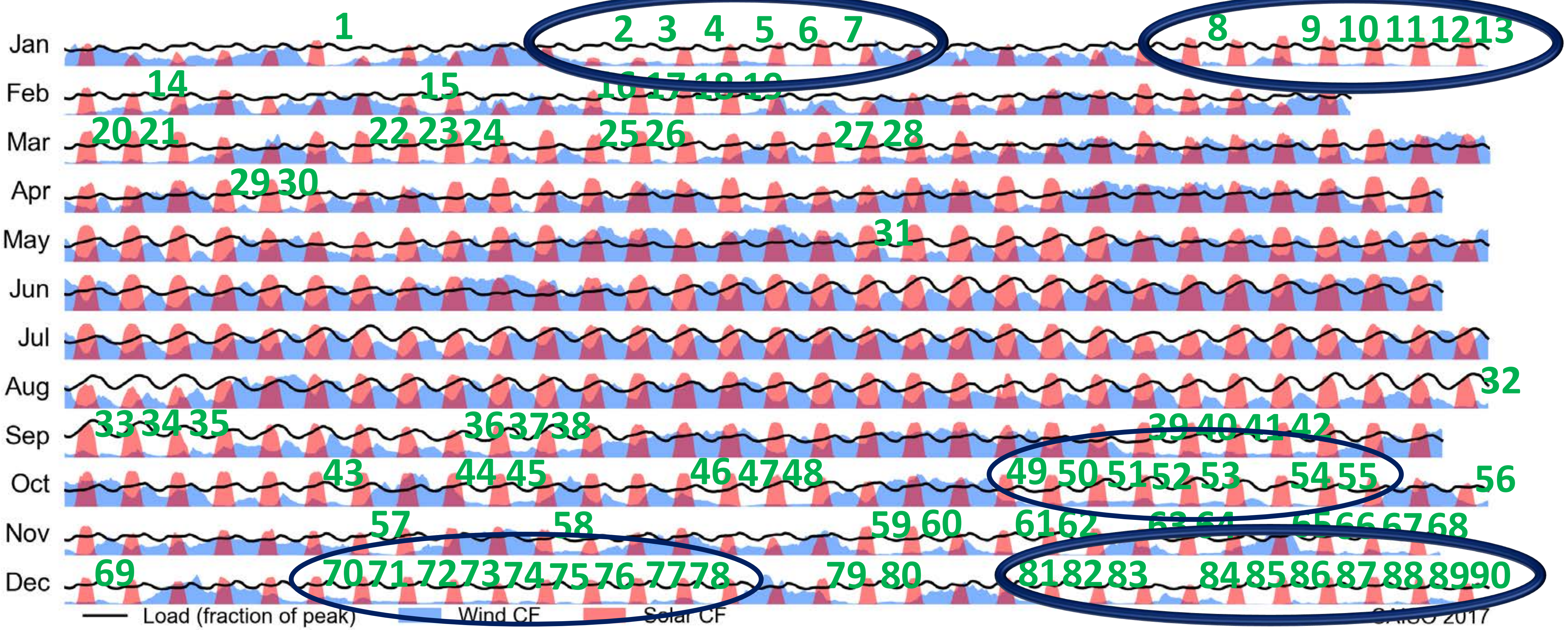
Challenges with Integrating Intermittent Renewables

Over the course of a year large-scale dependence on both wind and solar will result in significant periods requiring very large-scale back-up options



Hourly trends in solar and wind capacity factors in CA for 2017 aligned to normalized variation in hourly load relative to peak daily load

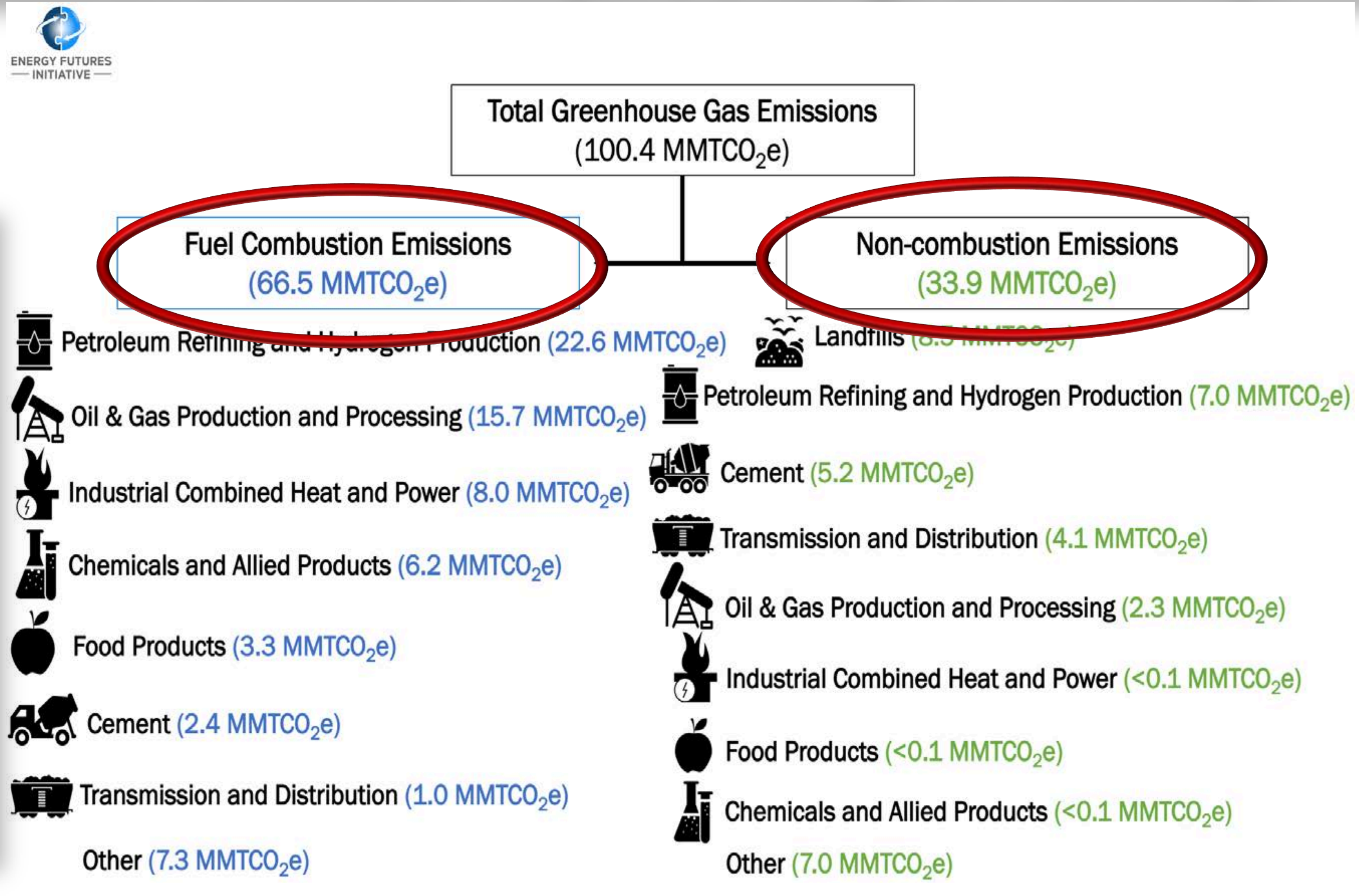
Source: CAISO data, EFI analysis

Manufacturing: Difficult to DeCarbonize

A California example

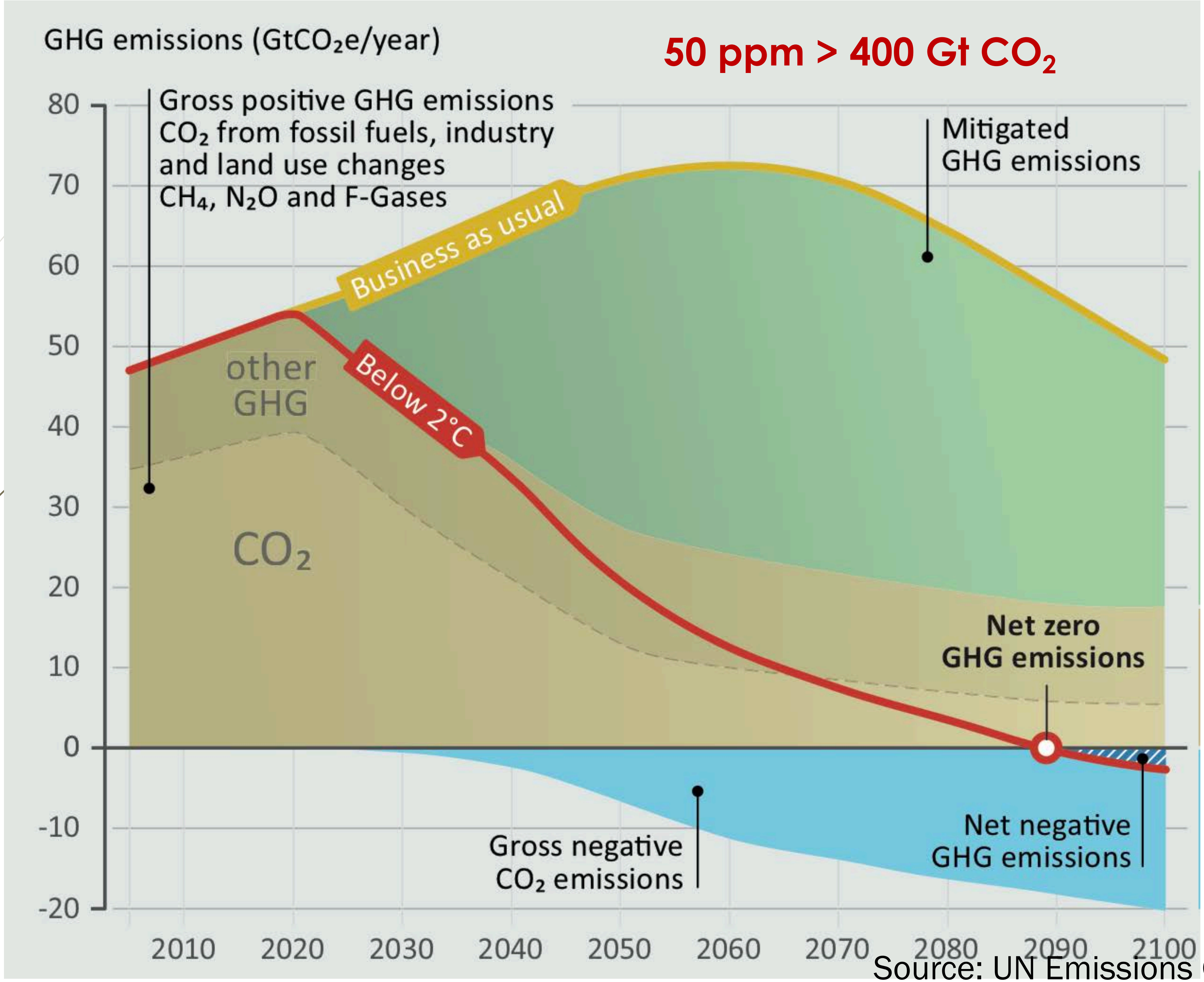
Industry: Multiple Subsectors, Combustion and Non-Combustion Emissions Require a Range of Pathways

There is a large technical potential for GHG emissions reductions across a range of mitigation options that can help decarbonize the Industry sector. Given the complexity and heterogeneous nature of many industrial processes, however, an effective decarbonization strategy will necessitate tailored solutions that account for the unique challenges and opportunities in each subsector.



Carbon Dioxide Removal

Unfunded Liability



Source: UN Emissions Gap Report, 2017

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Multiple CDR Pathways

CAPTURE SOURCES

Dilute

Atmosphere

Oceans

CAPTURE METHOD

Natural

Forestry & land management
Crops & soil management
Coastal ecosystems (blue carbon)

Technologically-enhanced Natural Processes

Carbon mineralization
Advanced crop cultivars
Ocean fertilization
Ocean alkalinity enhancement

Technological

Direct air capture
Direct ocean capture
Bioenergy with CCS (BECCS)

CONVERSION & DISPOSITION

Utilization

Efficient or intensive EOR
Products
Terrestrial (e.g., biochar)

Disposal

Geologic
Oceans
Terrestrial (e.g., deeper roots)

Recycling/Displacement

Liquid or gaseous fuels

Working Draft—Not for Citation or Distribution

Things That Must Change

- Climate must **transcend politics/ borders**
- Humanity must manage **“nuclear” power**
- Humanity must manage **Hydrogen at scale**
- “A **better vs** a **draconian** world future”
- Proponents must **acknowledge shortcomings** and issues of technologies – whole truth
- **Efficiencies** can obviate power requirements – **value**
- **Liability? Justice?**
- ????!!!!!!

Thank You