Power Grid Integration of Renewable Energy and Fossil Fuel Generation Resources

Stephen Roe, Center for Climate Strategies

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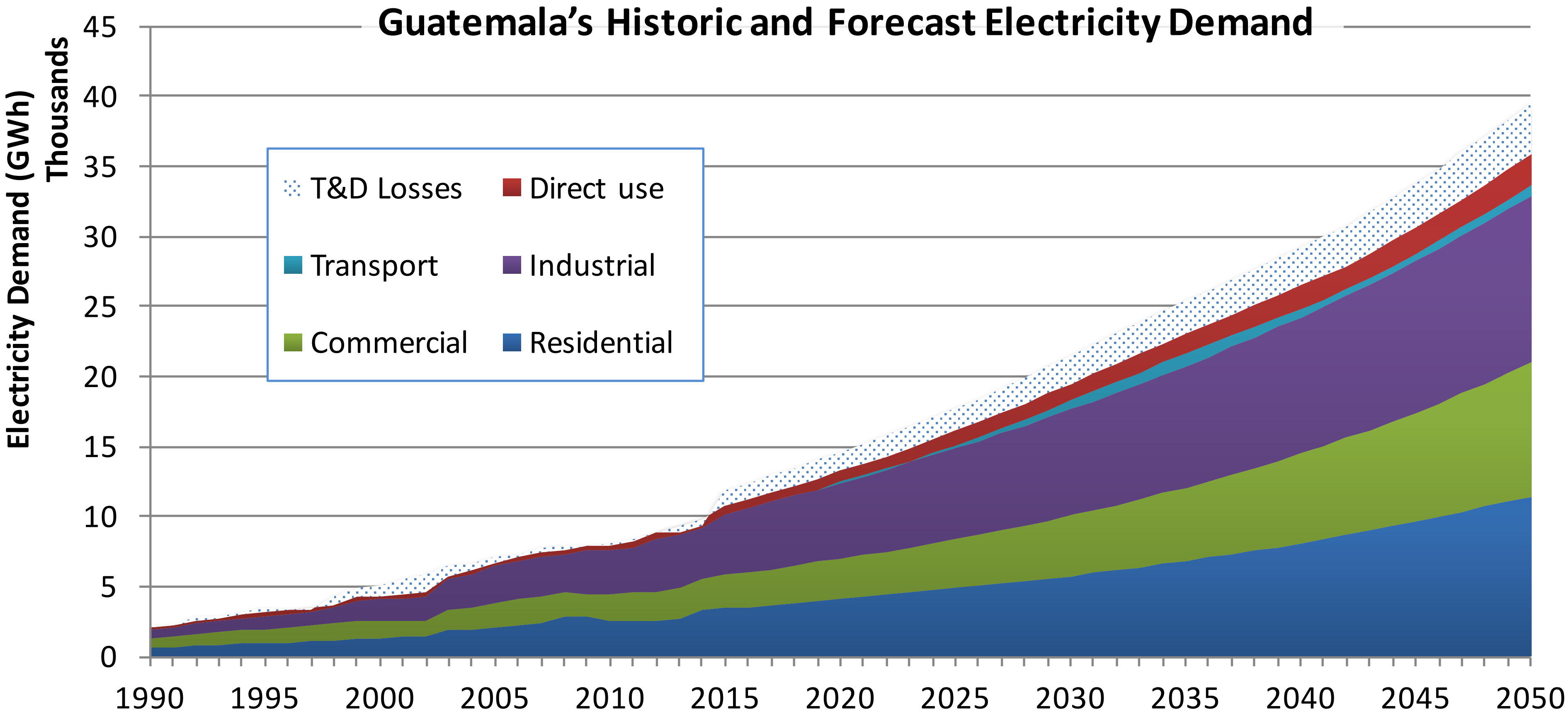
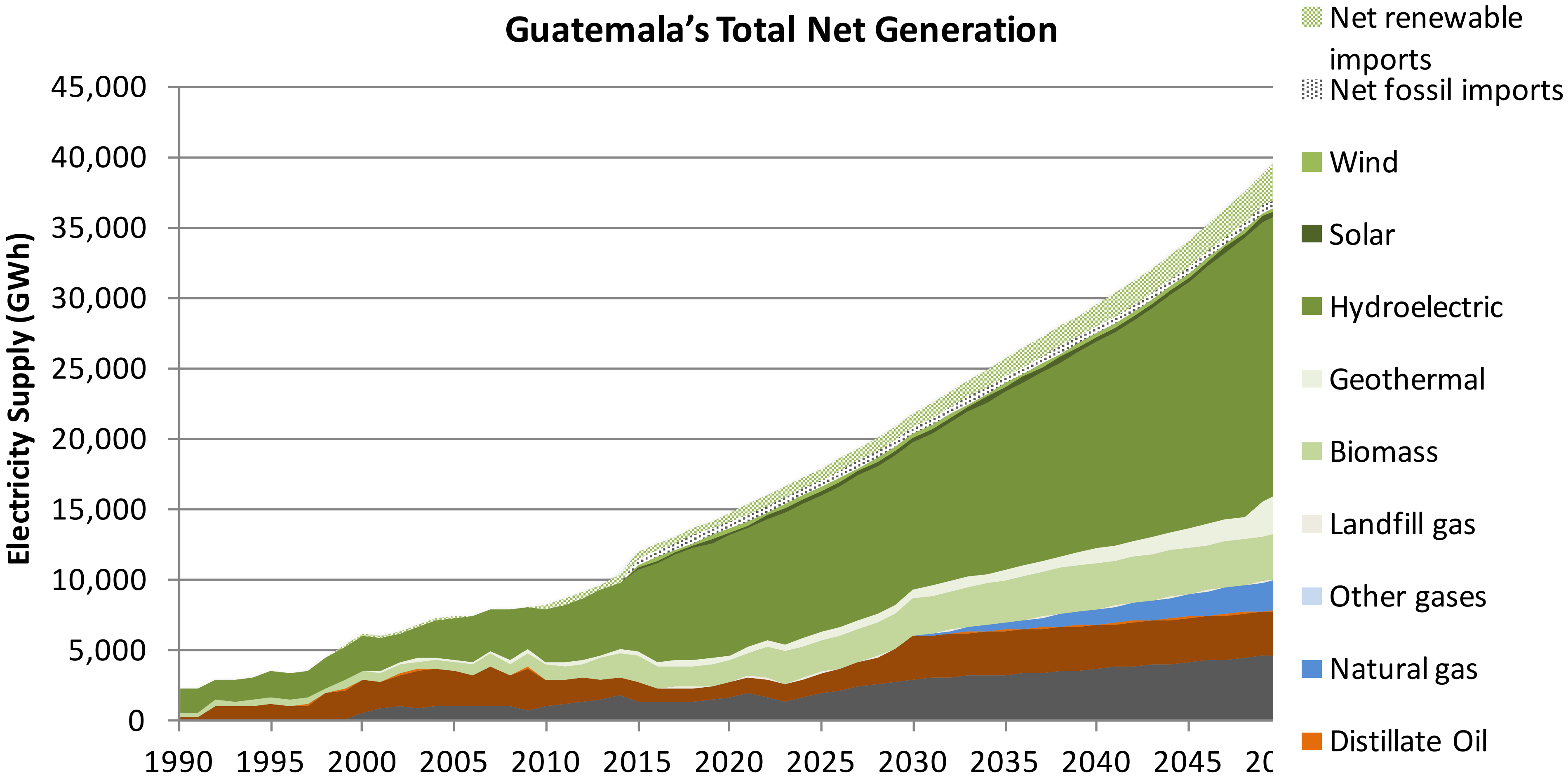
Long-Term Power Sector Planning:

Balancing of Supply and Demand



Source: CCS Guatemala Low Emissions Development Baseline Report: http://www.climatestrategies.us/library/library/view/1221.

Long-Term Power Sector Planning:
Balancing of Supply and Demand



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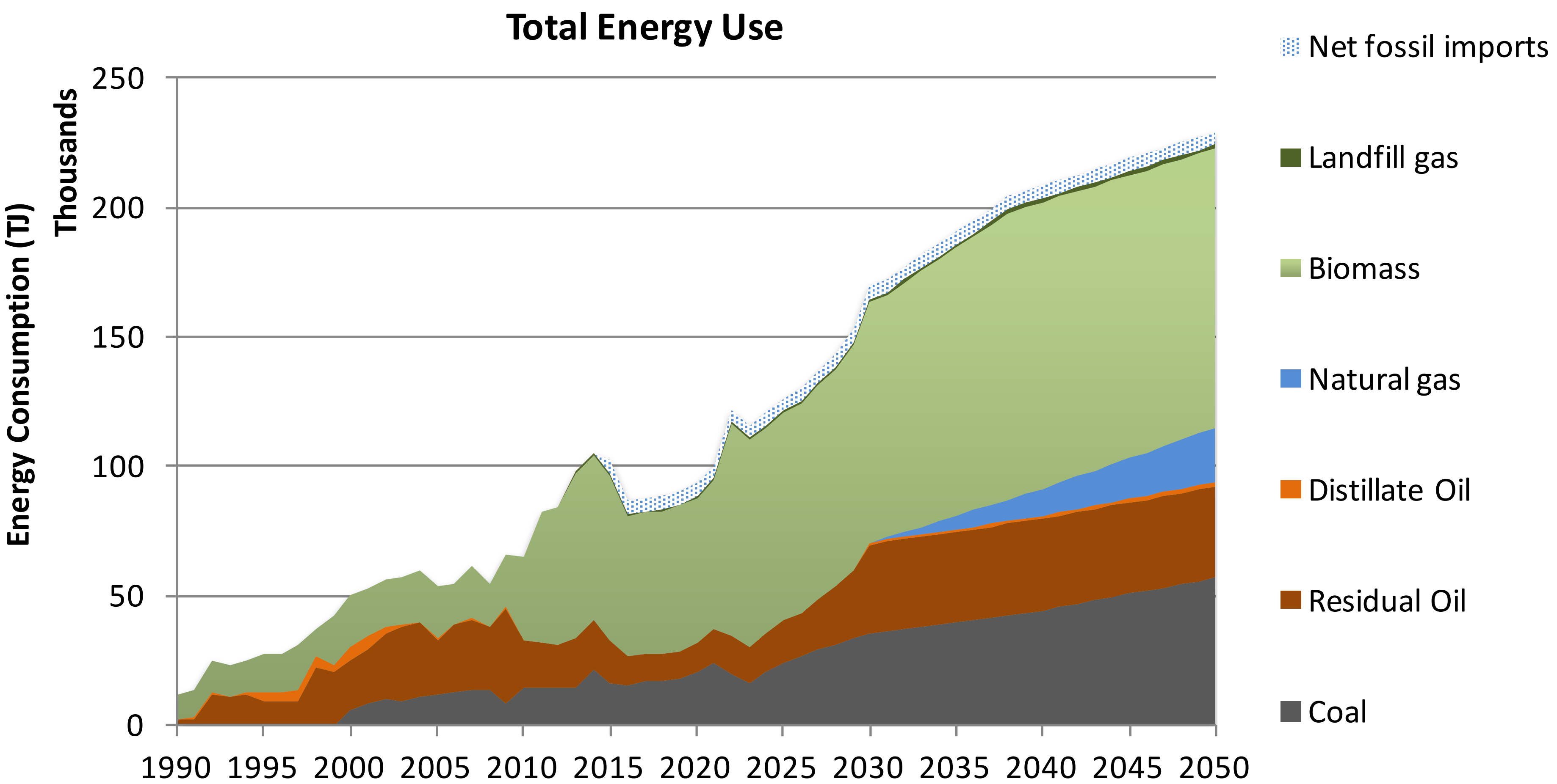
Source: CCS Guatemala Low Emissions Development Baseline Report: http://www.climatestrategies.us/library/library/view/1221.

Long-Term Power Sector Planning:
Resulting Energy Consumption



Source: CCS Guatemala Low Emissions Development Baseline Report: http://www.climatestrategies.us/library/library/view/1221.

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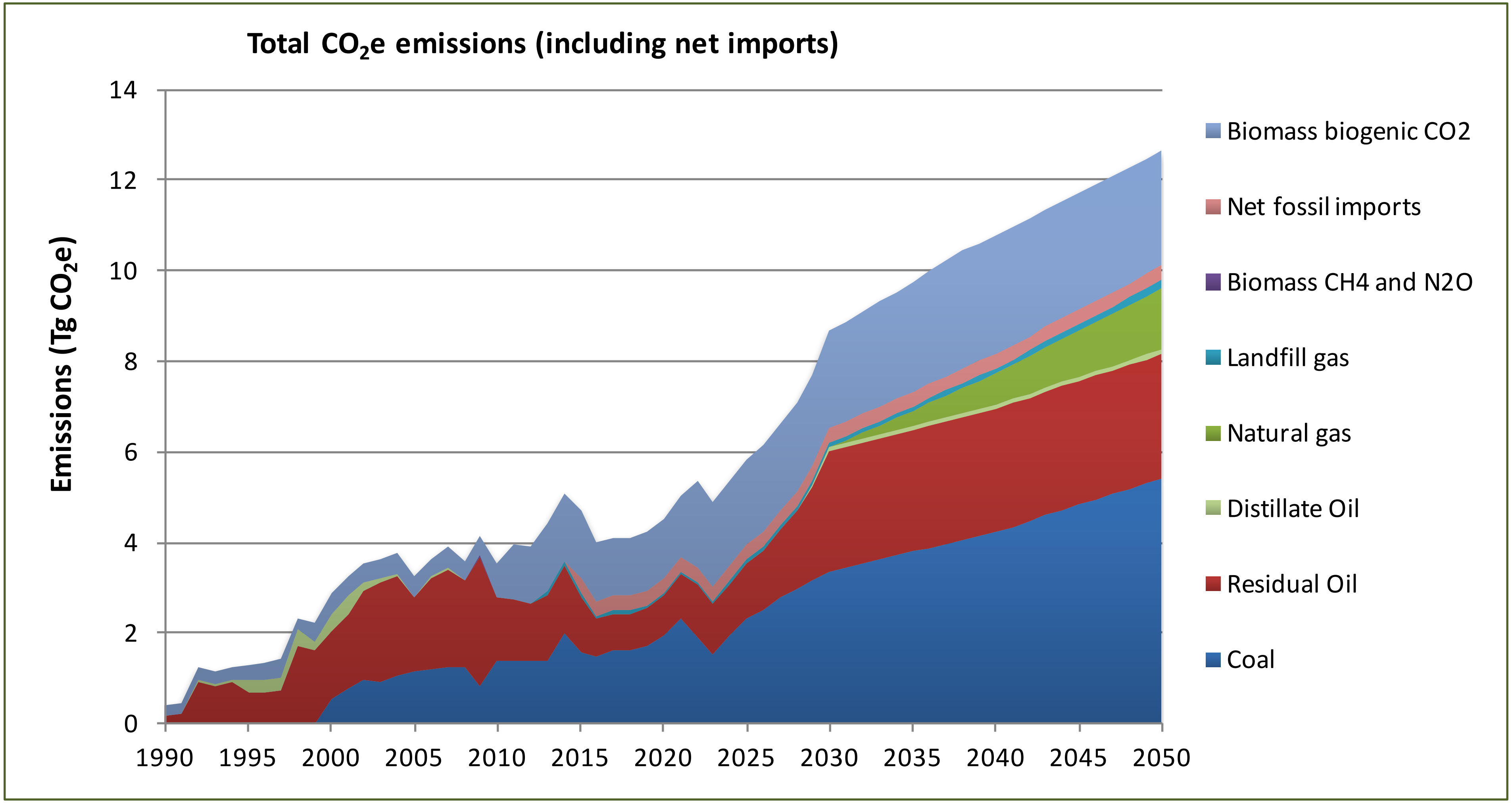
Long-Term Power Sector Planning:
Resulting GHG Emissions



Source: CCS Guatemala Low Emissions Development Baseline Report: http://www.climatestrategies.us/library/library/view/1221.

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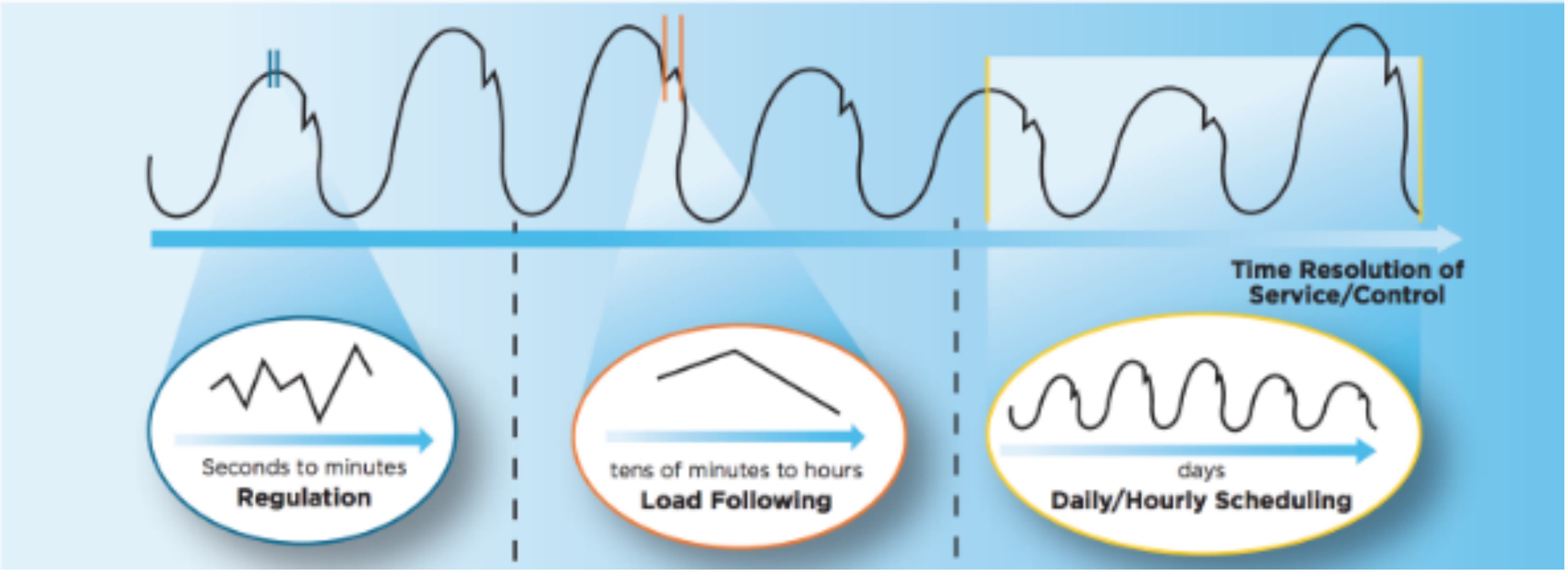
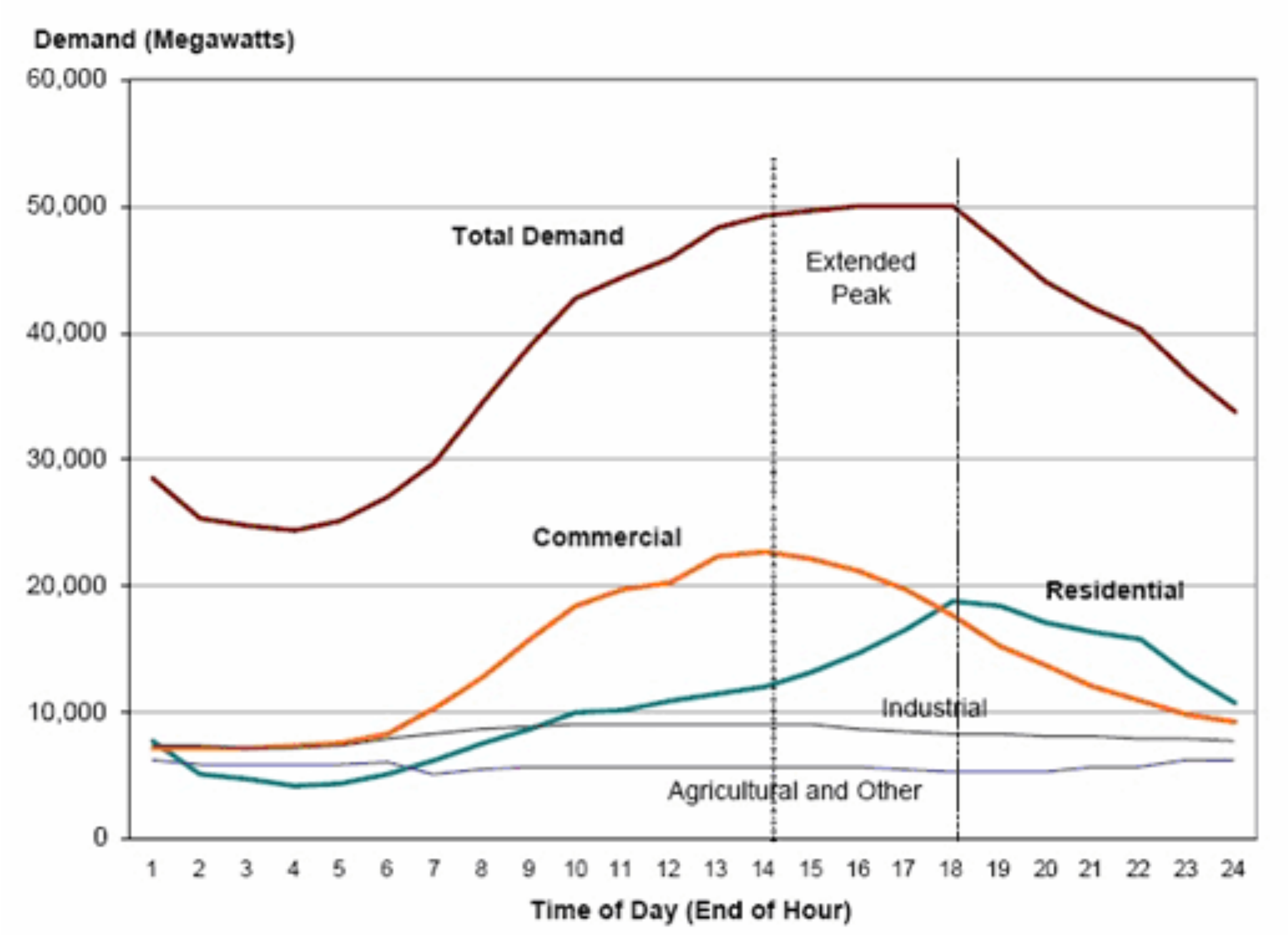
Grid-System Operator:
Balancing of Supply and Demand



Source: Scientific American;
https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/
Primary source: US DOE/EERE; https://www1.eere.energy.gov/solar/pdfs/50060.pdf.

Typical Daily Demand Profile:
California, USA



Source: https://www.quora.com/What-is-the-daily-cycle-of-electricity-use.

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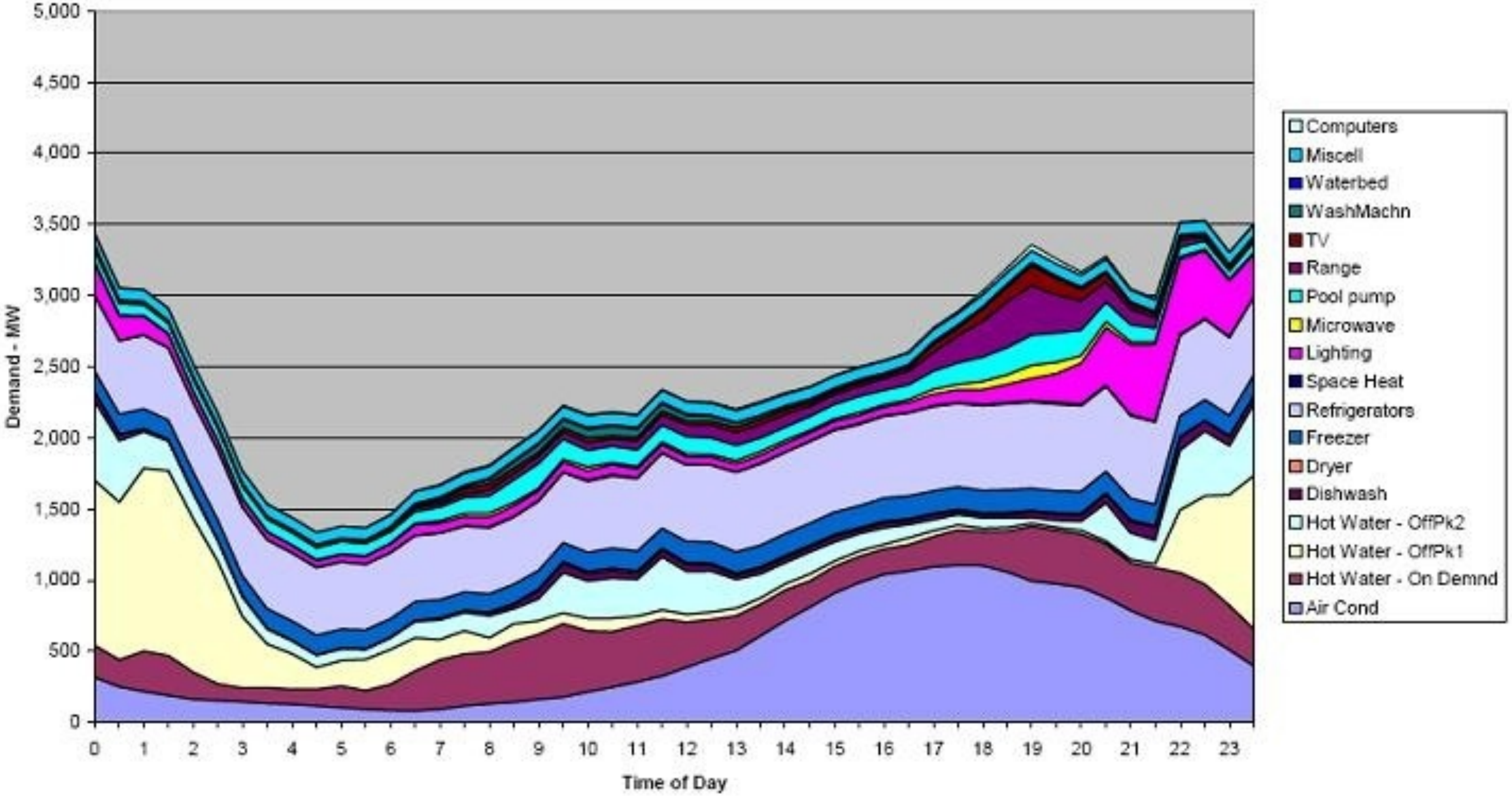
Typical Daily Demand Profile:
Residential Device Level: NSW, Australia



Source: https://www.quora.com/What-is-the-daily-cycle-of-electricity-use.

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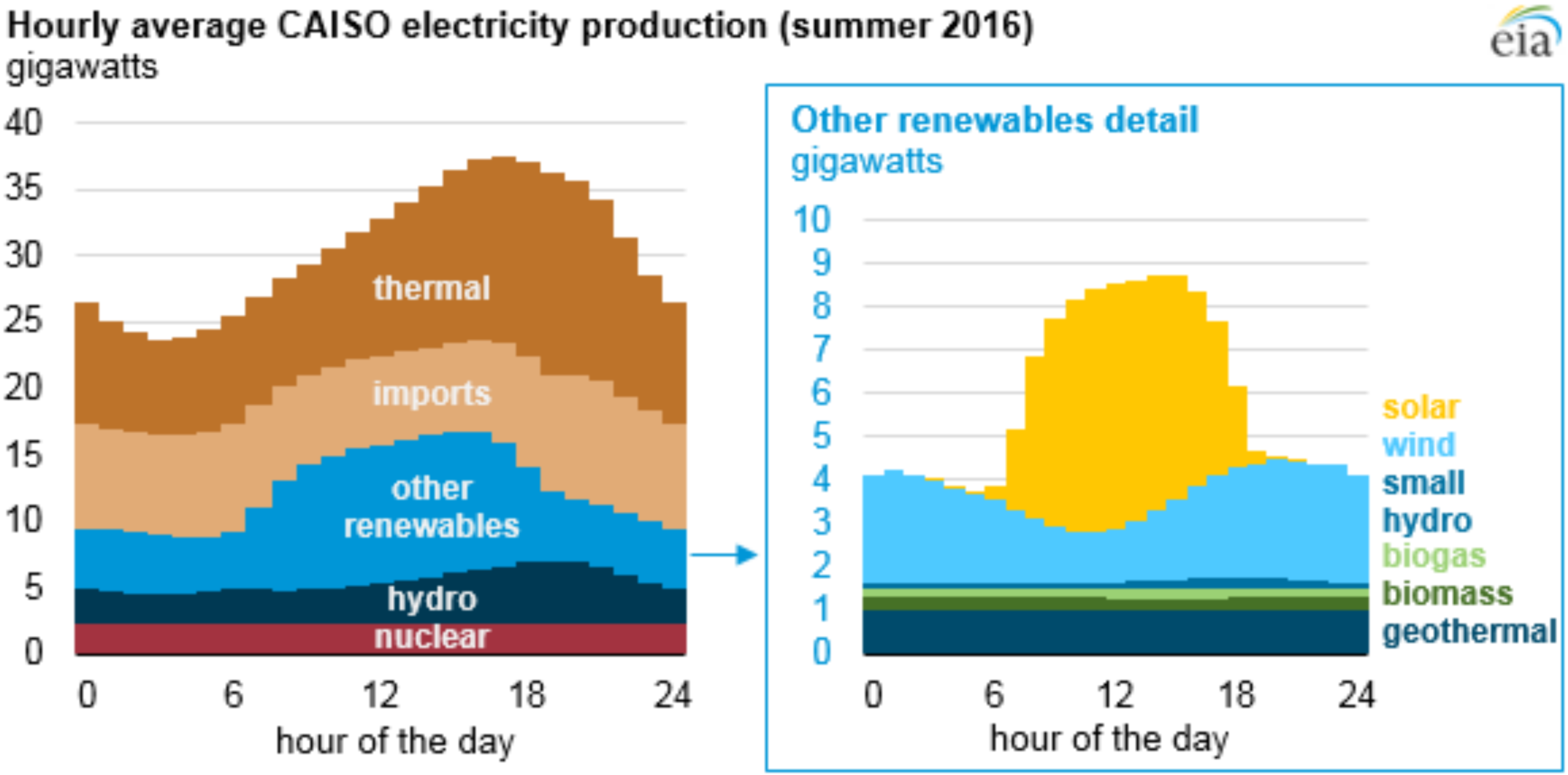
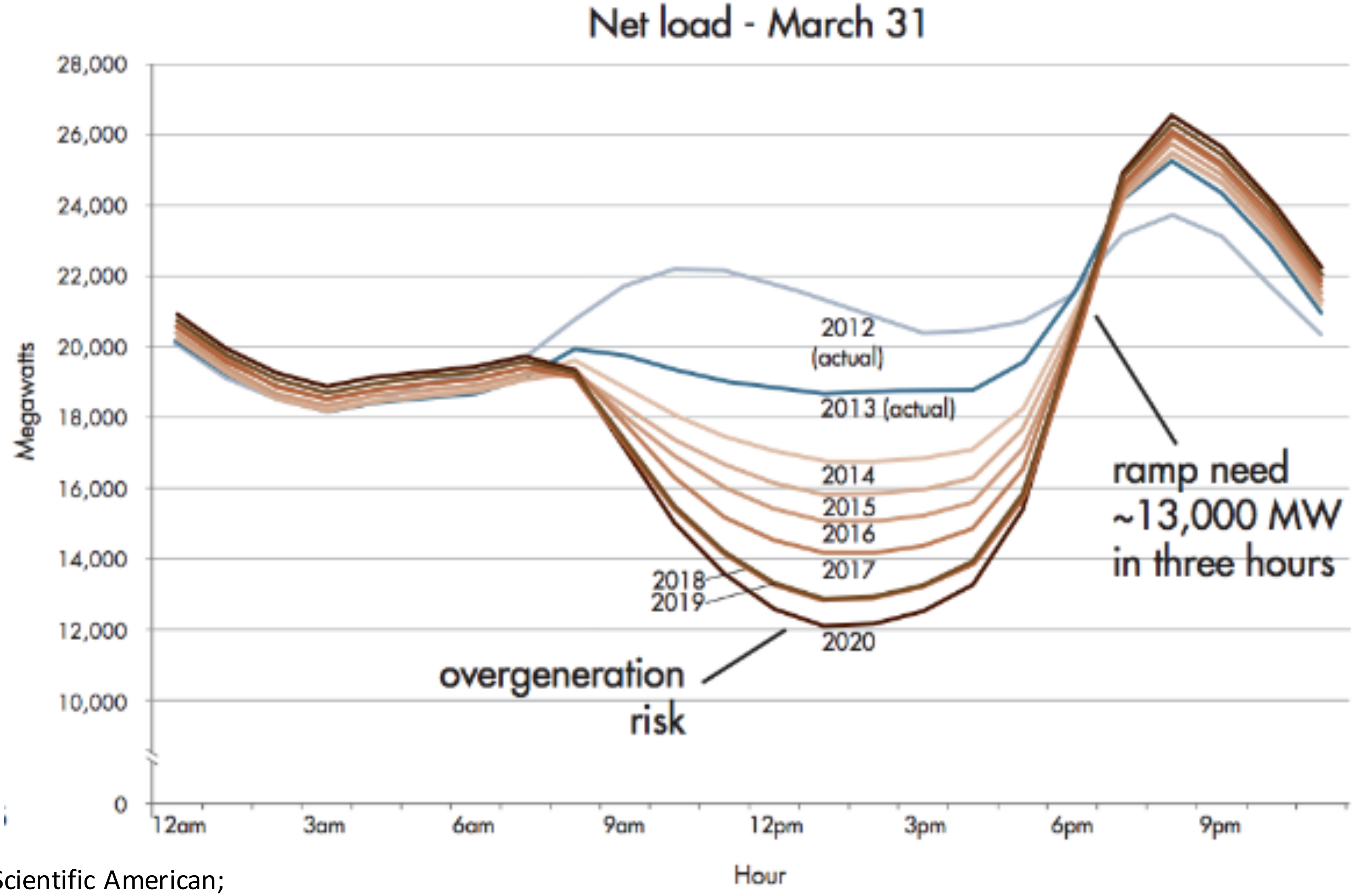
California Daily Generation Profile



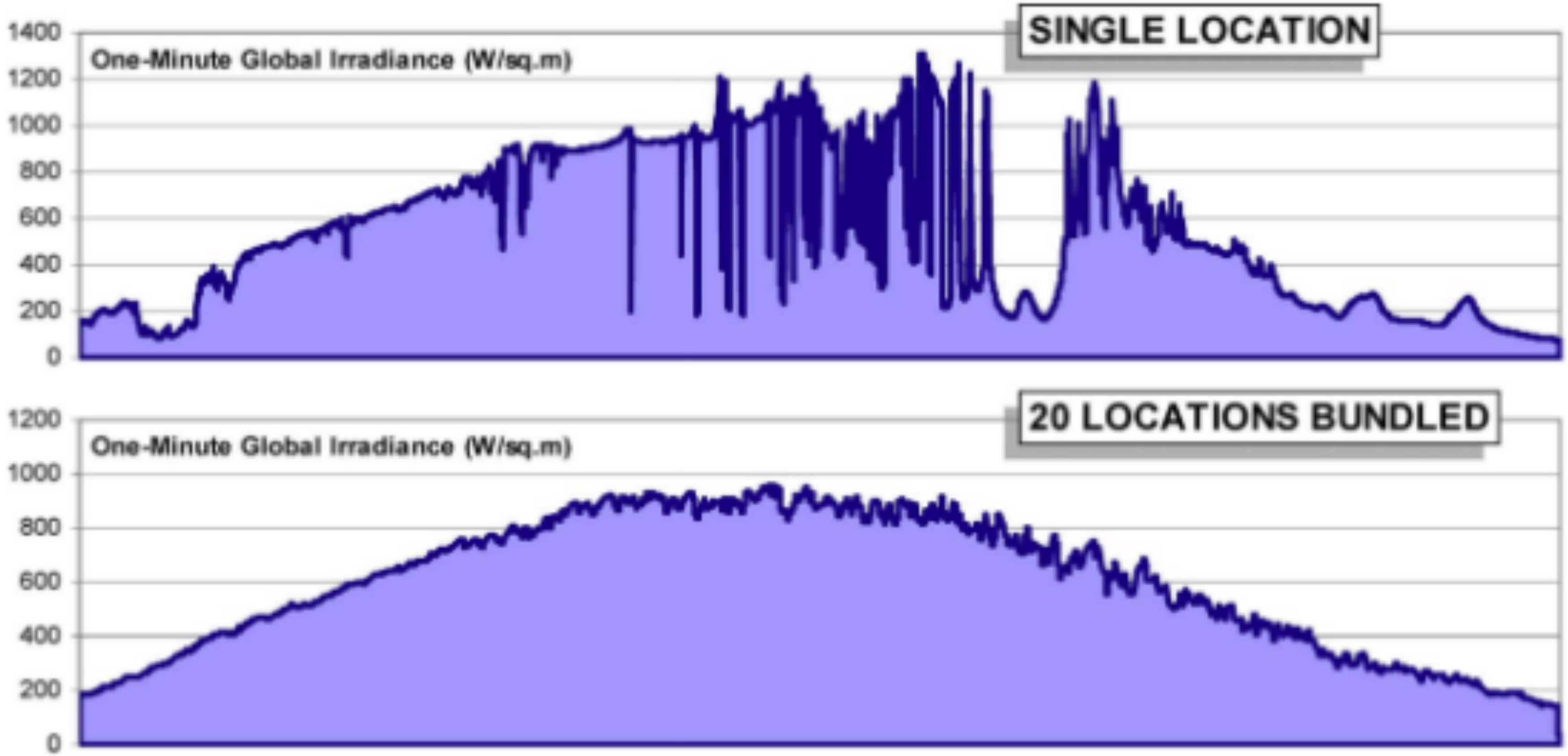
Source: US DOE, Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=27832.

RE Integration Success and Challenges – California's "Duck Curve"



Source: Scientific American;
https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/
Primary source: California Independent System Operator

Reducing RE Variability – Applying the Law of Large Numbers



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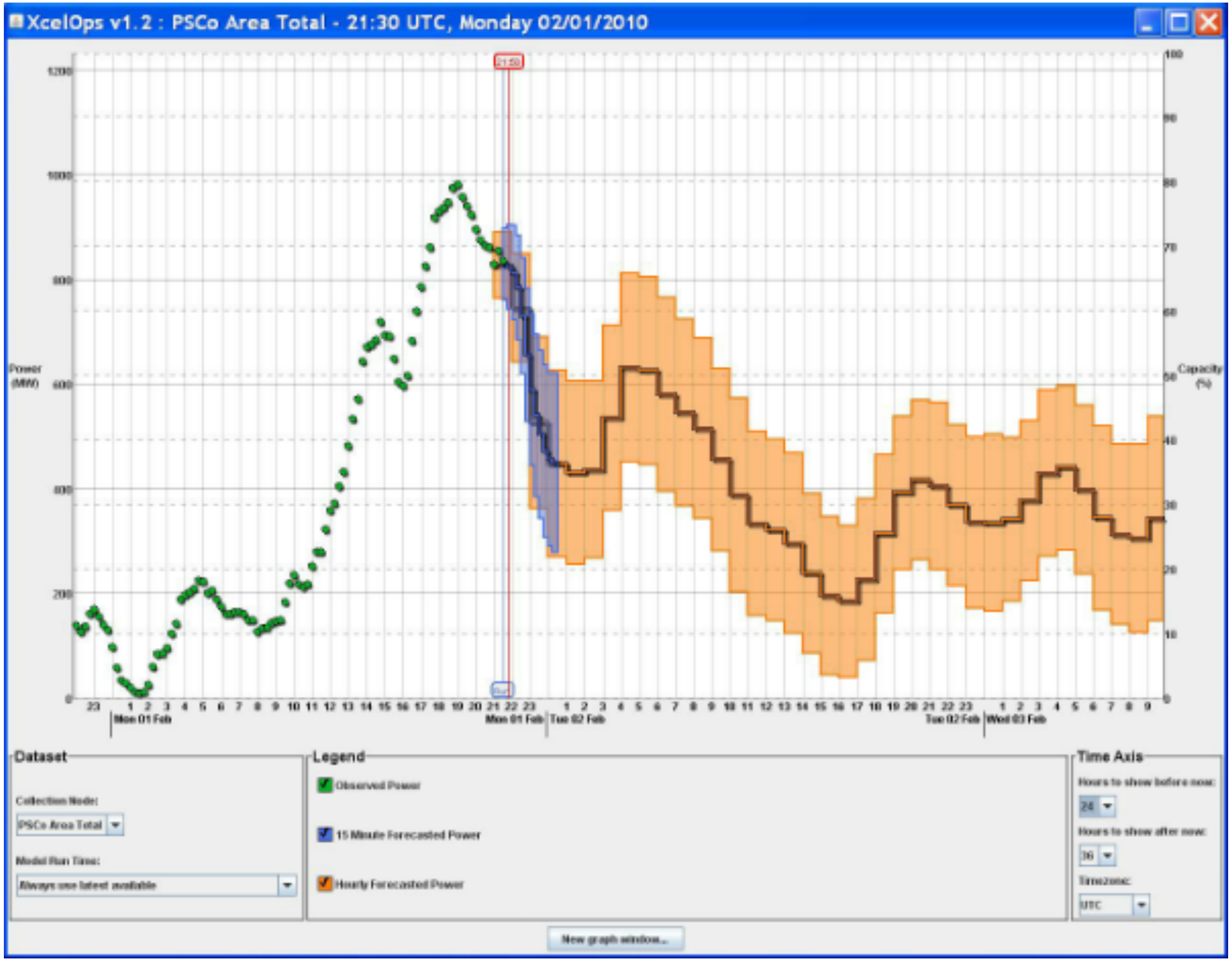
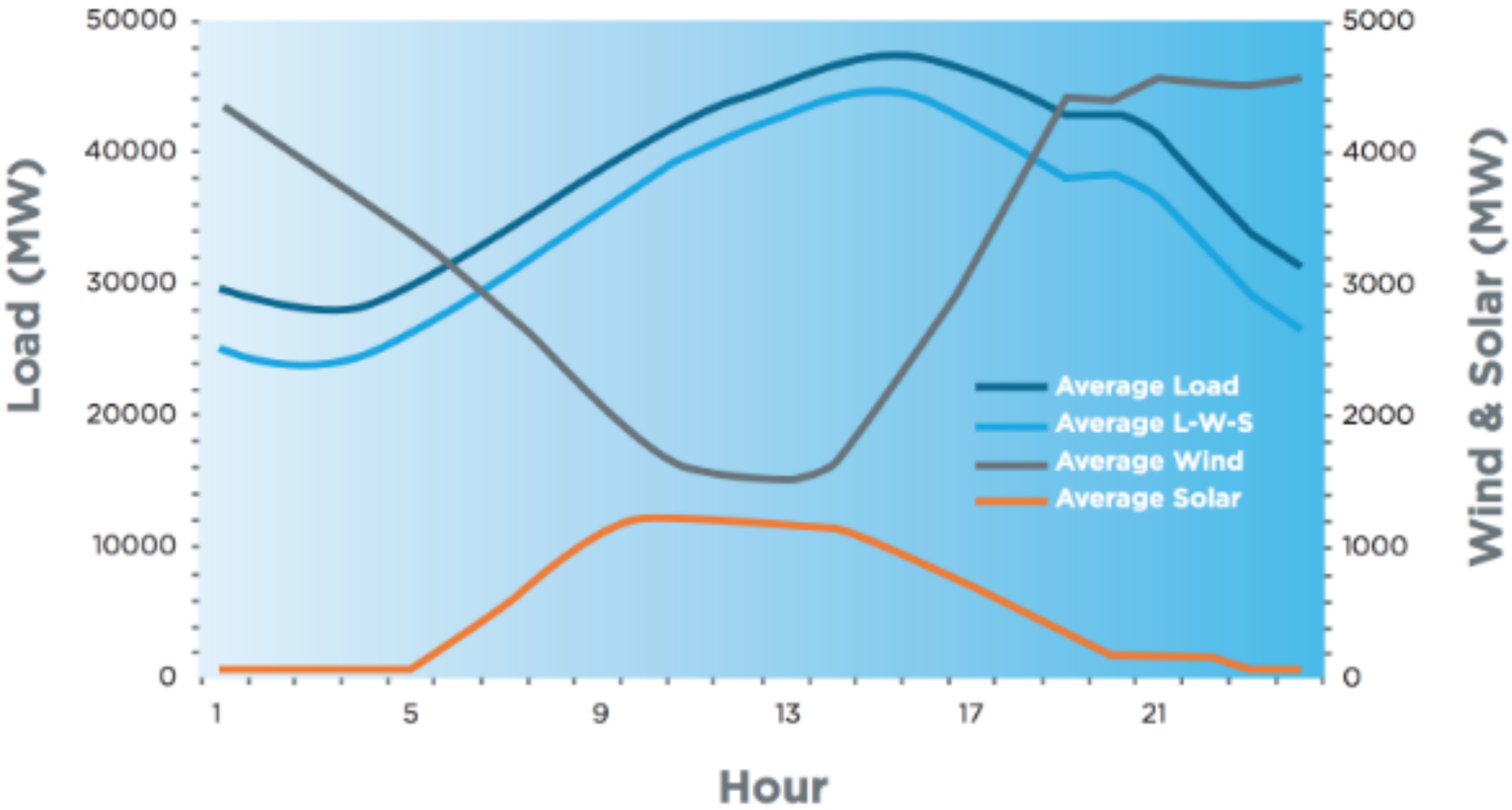
Source: Scientific American;
https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/
Primary source: Perez et al; https://ieeexplore.ieee.org/document/4637912/.

Reducing RE Variability – Predictive Modeling



Source: Scientific American; https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/
Primary source: US National Center for Atmospheric Research (NCAR): https://www2.ucar.edu/atmosnews/news/5771/ncar-wind-forecasts-save-millions-dollars-xcel-energy.

Reducing RE Variability – Applying a Mix of RE Sources



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Primary source: DOE/EERE: https://www1.eere.energy.gov/solar/pdfs/50060.pdf.

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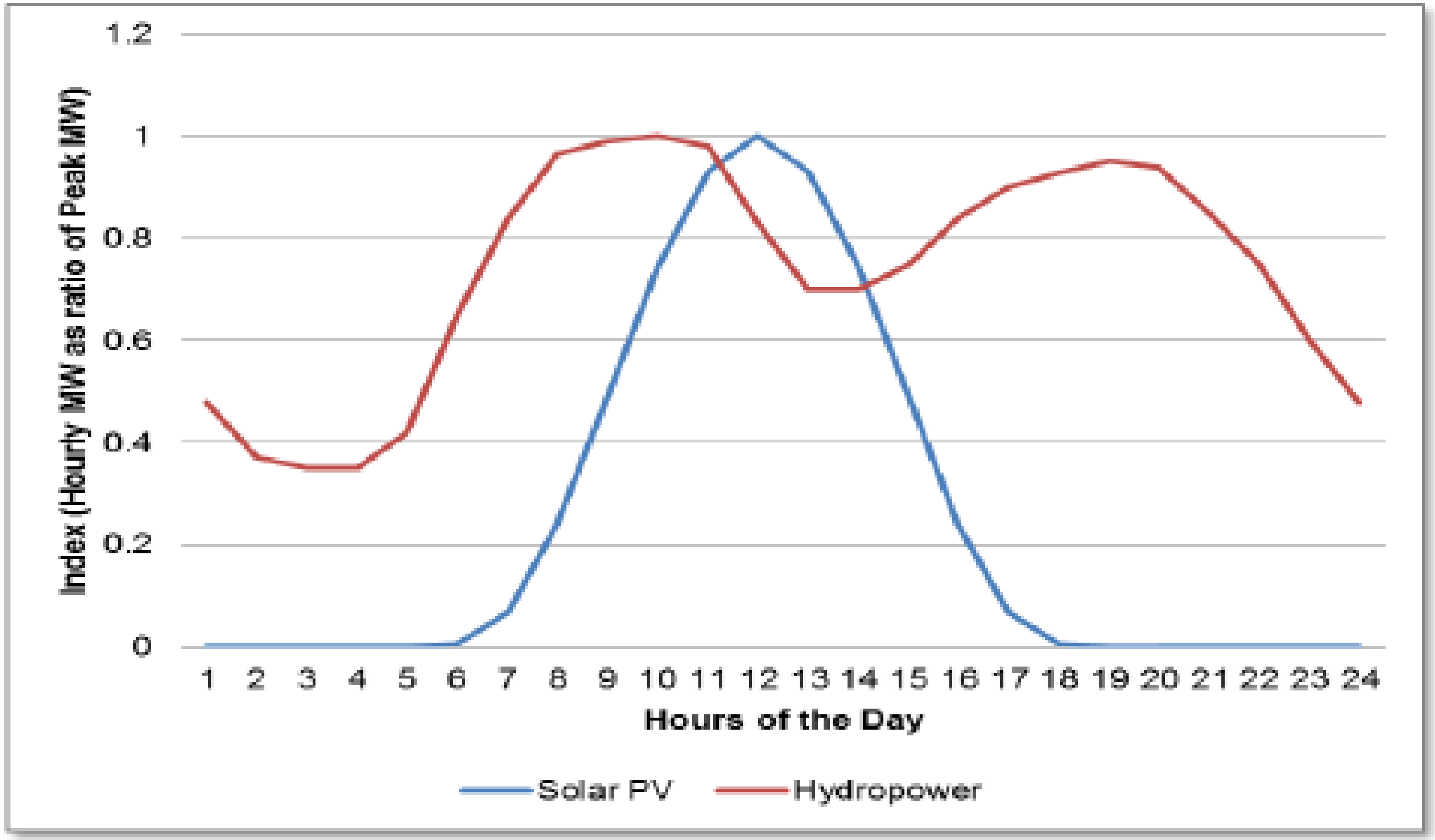
Reducing RE Variability – Applying a Mix of RE Sources

Figure III-9: Solar Power & Hydropower Balancing Potential



Source: Myanmar Energy Master Plan

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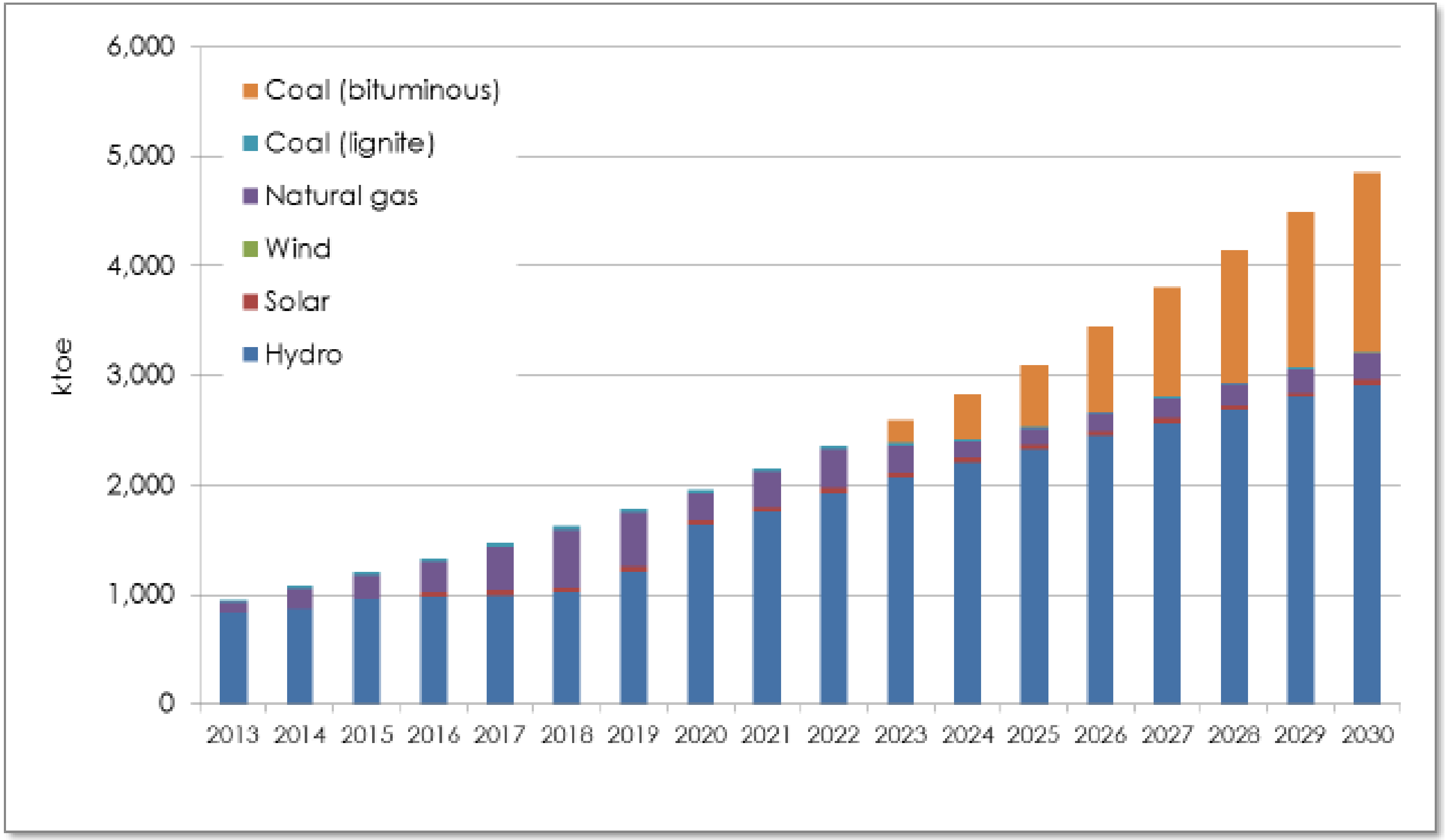
Maximizing Generation Flexibility:
Is this true for Myanmar Case 2 – Optimal Fuel Use?

Figure IV-18: OPTIMAL Long-Term Fuel Mix – Case 2 (Balanced Hydro / Coal / Solar PV)



Source: Myanmar Energy Master Plan

Storage: Role of Utility-Scale Battery Systems

- Dispatchable capacity: for example, Tesla's Solar PV and Battery Project in Kauai, Hawaii
- Grid resilience: near instantaneous response to load fluctuations on the grid:

129 MWh and 400 MWh projects in southern Australia,

More are underway or planned

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Source: https://inhabitat.com.

More on Storage

- Emerging battery types (for example, flow batteries) are expected to bring costs down from current lithium-based batteries.
- "Virtual power plants": Large numbers of distributed RE systems could be tasked with providing resiliency (voltage support) to local grids
- In theory, could replace the need for gas or diesel "peaker plants"
- Other forms of storage: pumped hydro; hydrogen; etc.
- Demand Management: shifts in demand to consume electricity when it is abundant

Considerations for RE Integration Planning & Implementation

- The electricity "system" is not limited to the current and future electrical "grid" and its associated generation resources –
  - Depending on level of service needs, distributed renewables or micro-grids avoid the costs of inter-connection with the grid
- When inter-connected with the grid, distributed RE can support:
  - reliability (voltage regulation)
  - quality (reduced line losses)
  - market expansion (new supply sources)

Recommendations for RE Integration Planning & Implementation

- Develop and apply electricity system models capable of:
  - geographic specificity: electricity load-balancing region level, if possible
  - temporal specificity: seasonal and diurnal supply and demand profiles
  - ability to compare costs and impacts of a baseline electricity system to alternative systems with different RE sources, RE penetration levels, and demand assumptions

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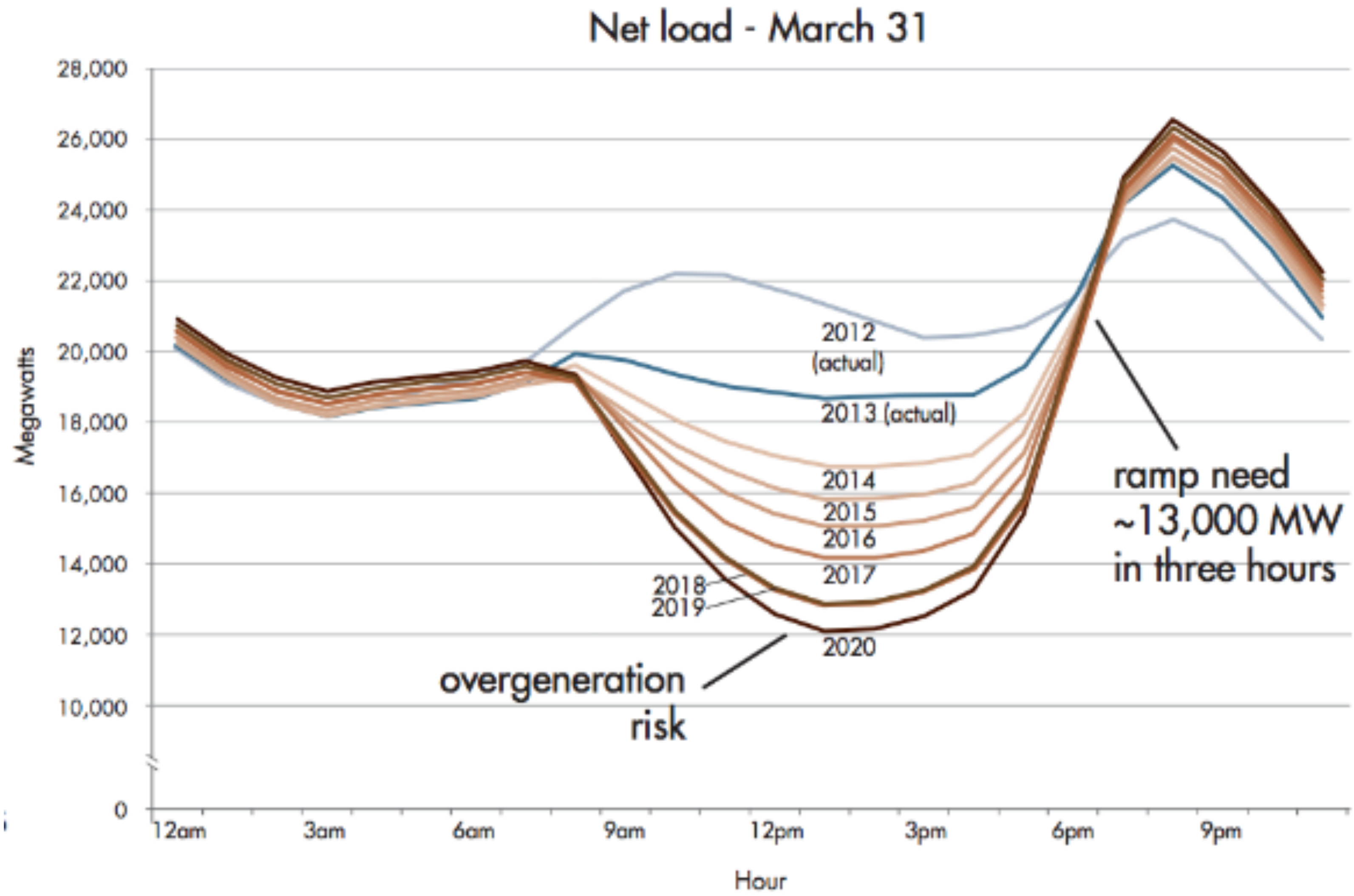
Recommendations for RE Integration:

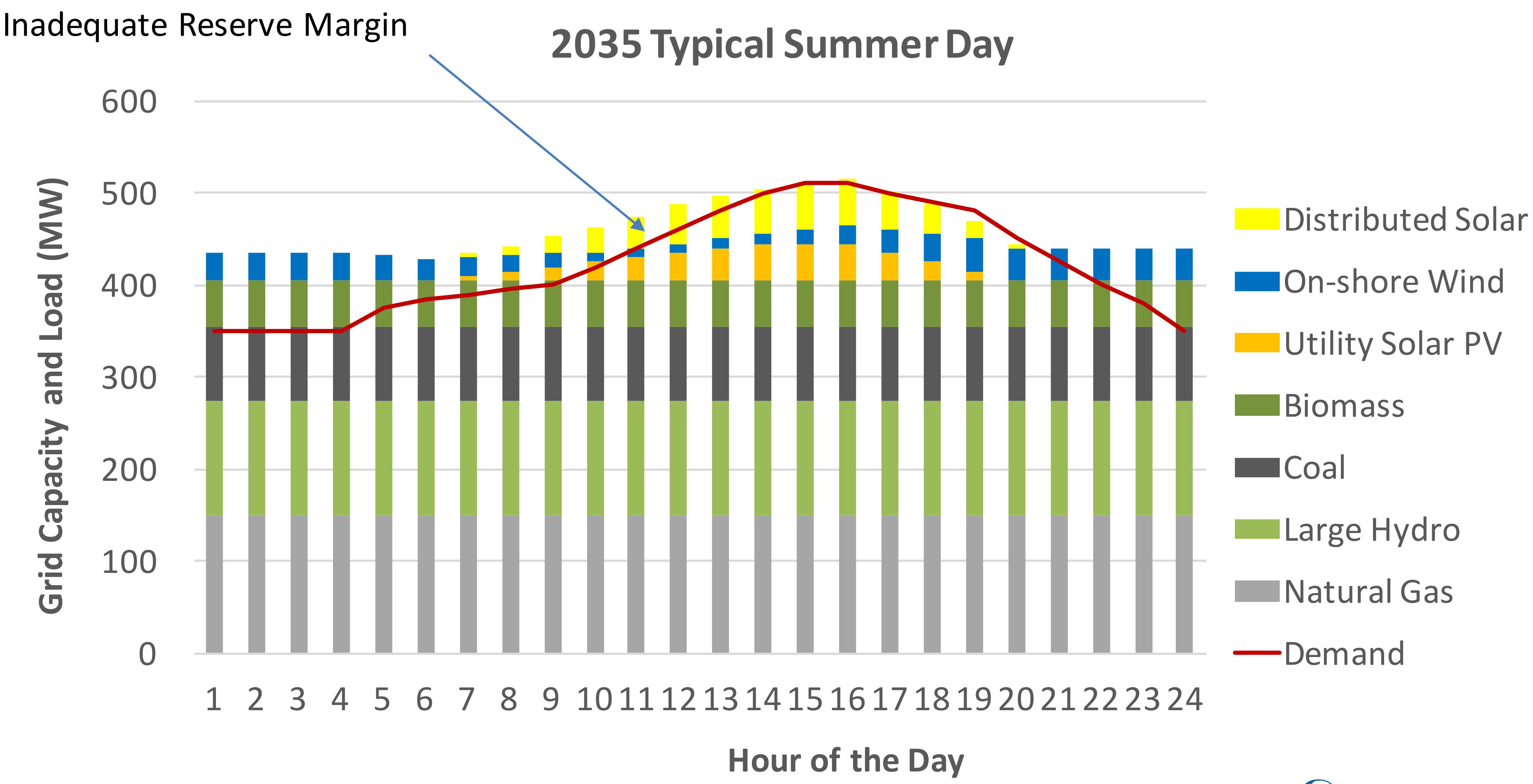
Modeling to Assess System Flexibility and Resilience



Source: California Independent System Operator

Recommendations for RE Integration

Modeling to Assess System Flexibility and Resilience



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Thanks!

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