Large-Scale Lithium Ion Battery Technology for Grid Applications

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A123 Systems

A Confluence of Factors

- Global warming
- Increased demand, reduced supply
- National security, Energy independence

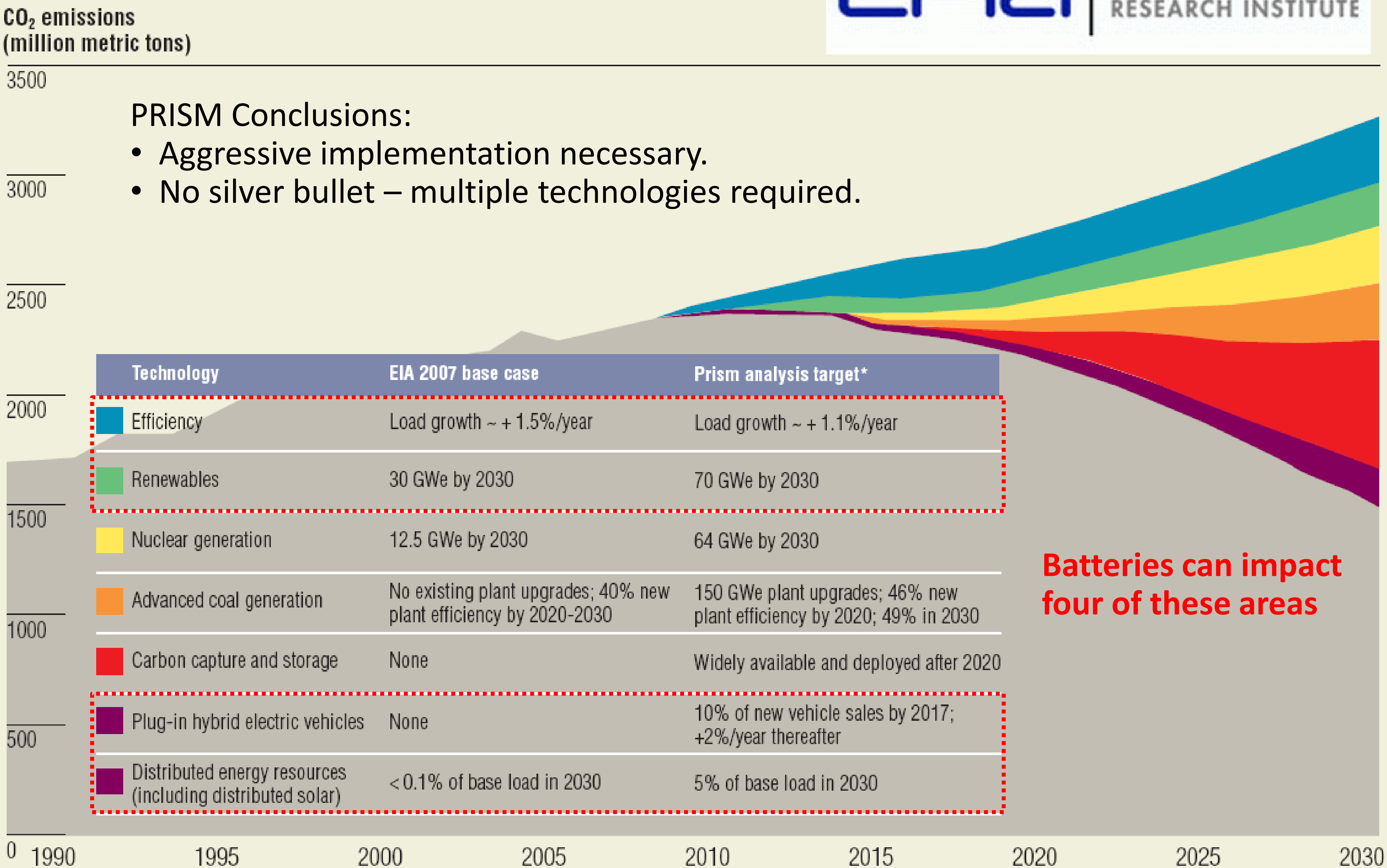
TABLE 1

U.S. ELECTRIC SECTOR

ELECTRIC POWER RESEARCH INSTITUTE

PRISM Conclusions:

- Aggressive implementation necessary.
- No silver bullet – multiple technologies required.



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Batteries can impact four of these areas

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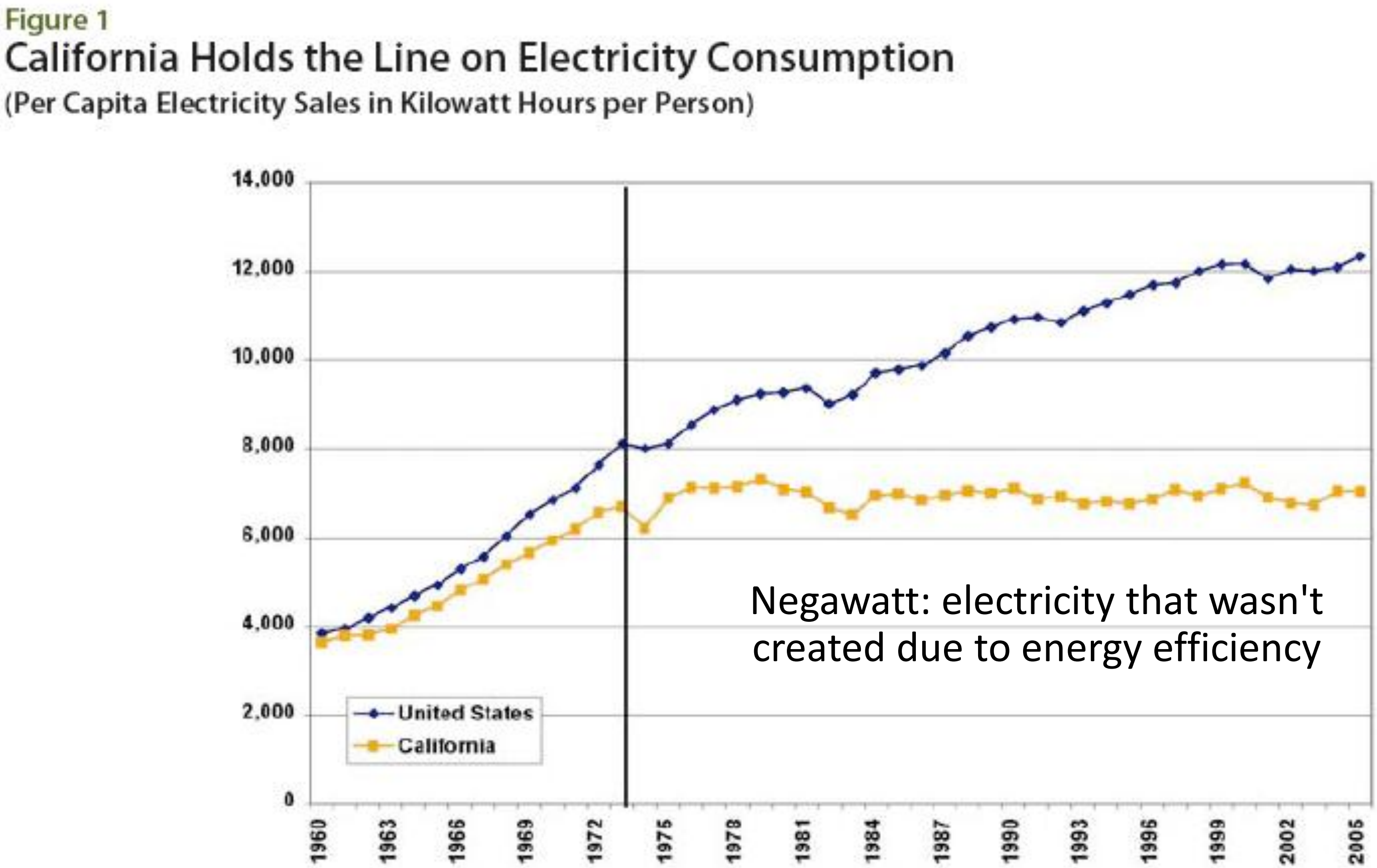
Efficiency: the best kind of "fuel"

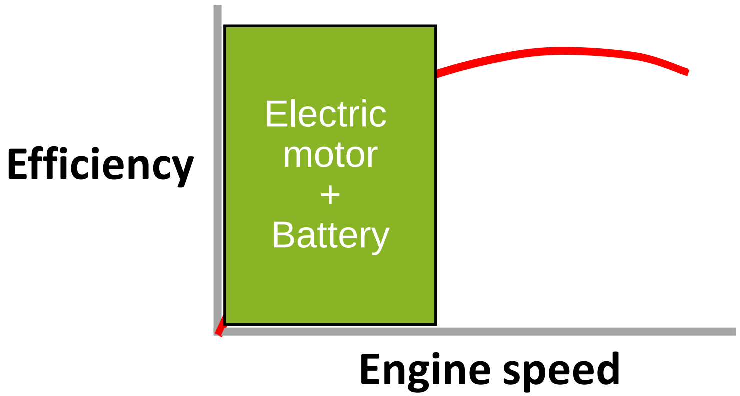


Source: California Energy Commission

Efficiency isn't just in *consumption*…

It is also at *generation*.

- Fuel-burning engines or generators have an optimum or preferred operating point (highest efficiency)
- Hybrid electric vehicles
  use efficient electric motors
  at low vehicle speeds
  to supplement engine
- Engine can operate at more
  efficient speed, boosting
  fuel economy and reducing emissions

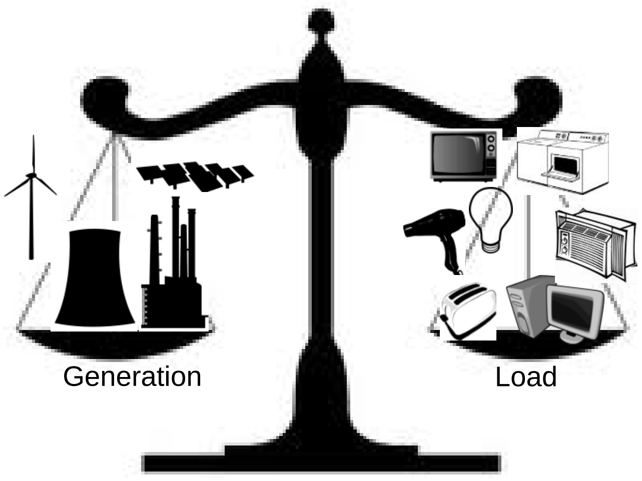


The same principle applies to the grid!

Generation and load must be balanced

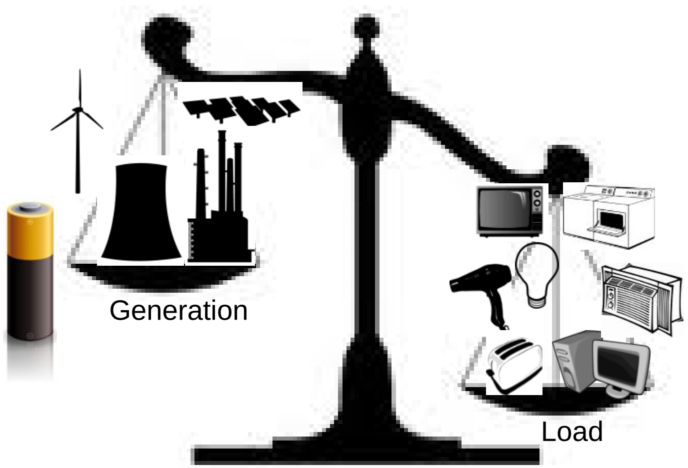
Electricity is the most perishable of all commodities: the instant it is created, it must be consumed

This balancing of generation and load must be done nearly instantaneously.



Energy storage decouples supply and demand

- The ability to store electricity changes the equation, by decoupling supply and demand.
- Stored energy can be discharged on demand, supplementing generation in times of high demand.
- Or, if excess generation exists, energy can be stored for later use.



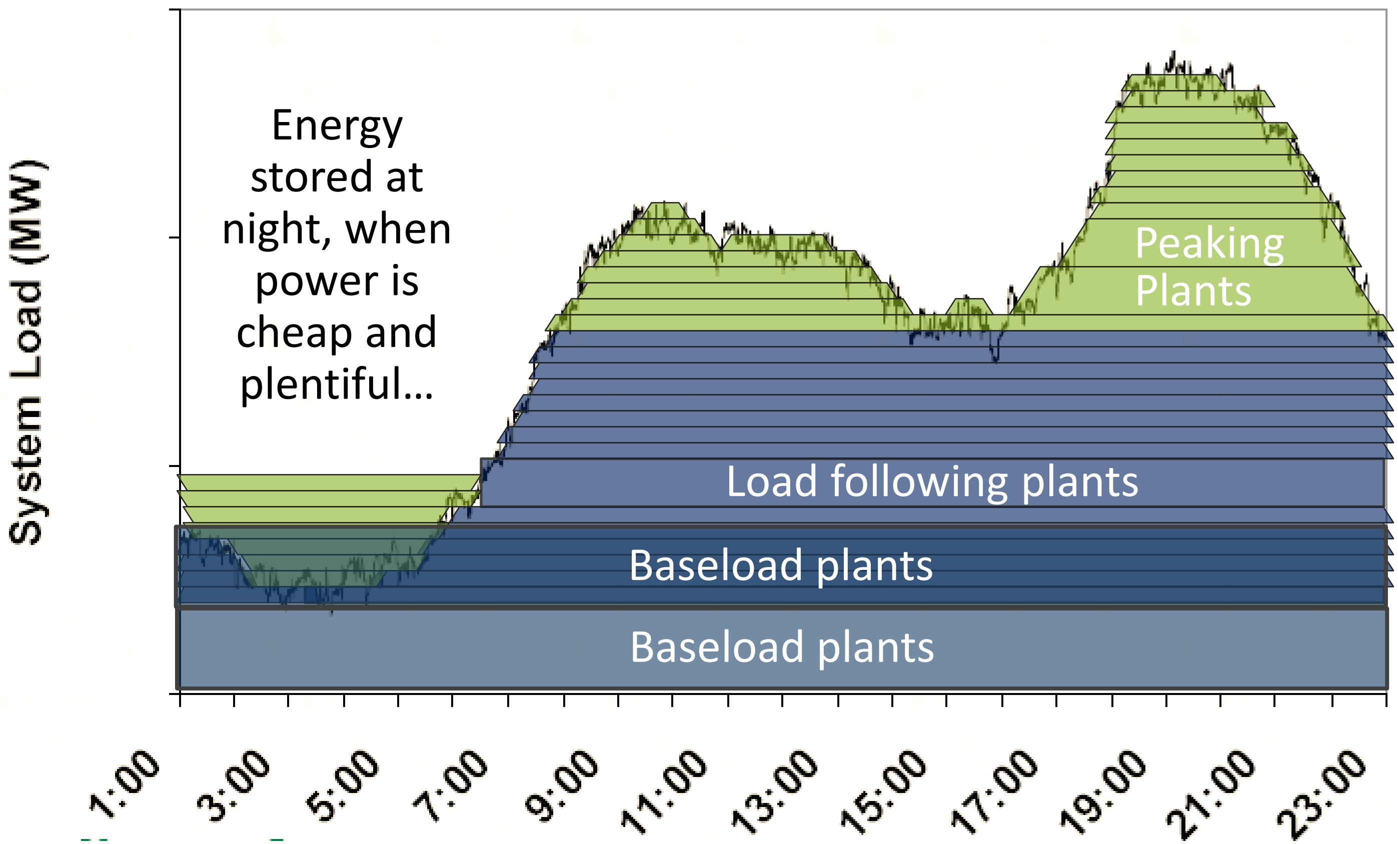
Supply ≠ Demand

(at least for short period of time)

Load shifting

Long time scale (hours)

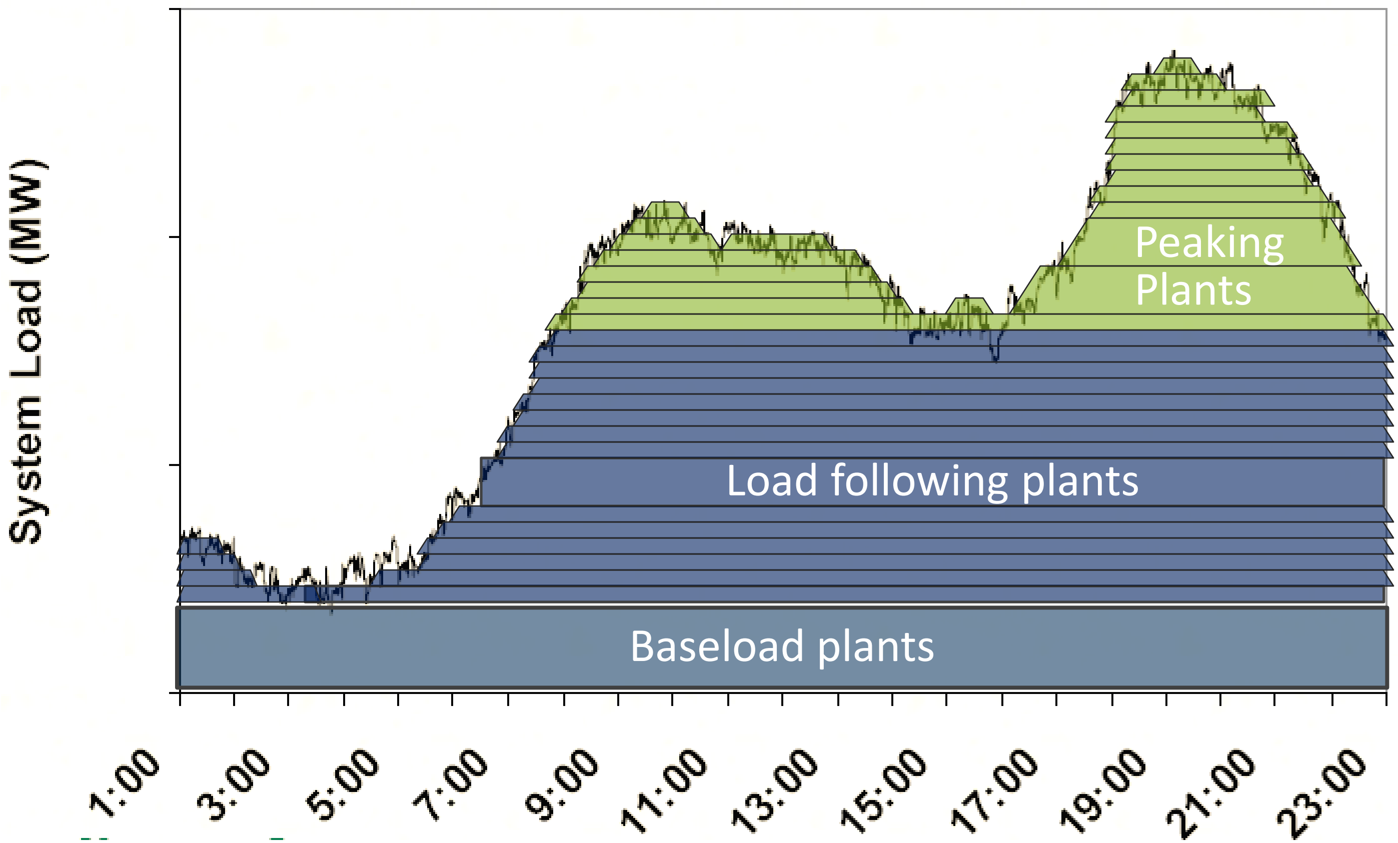
…for discharge during daytime peak hours



Flattening load curve increases utilization and allows more efficient baseload

Challenge: cost of energy storage

Balancing generation and load

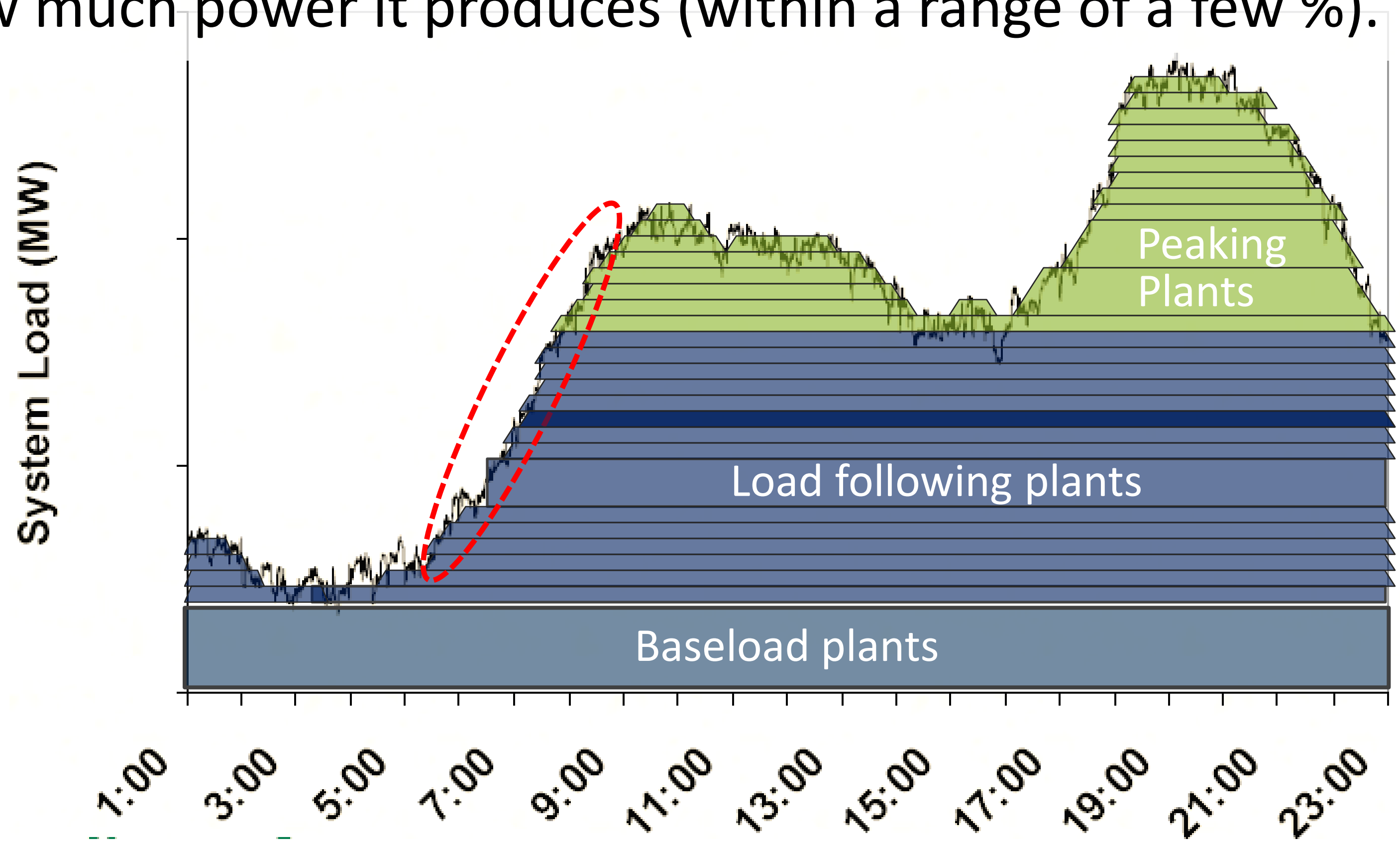


Problem: thermal plants take time to ramp up and down

Difficult to "fine-tune" generation

When you turn it on and how long it runs.

How much power it produces (within a range of a few %).



Difficult to match short fluctuations in load

Ancillary services

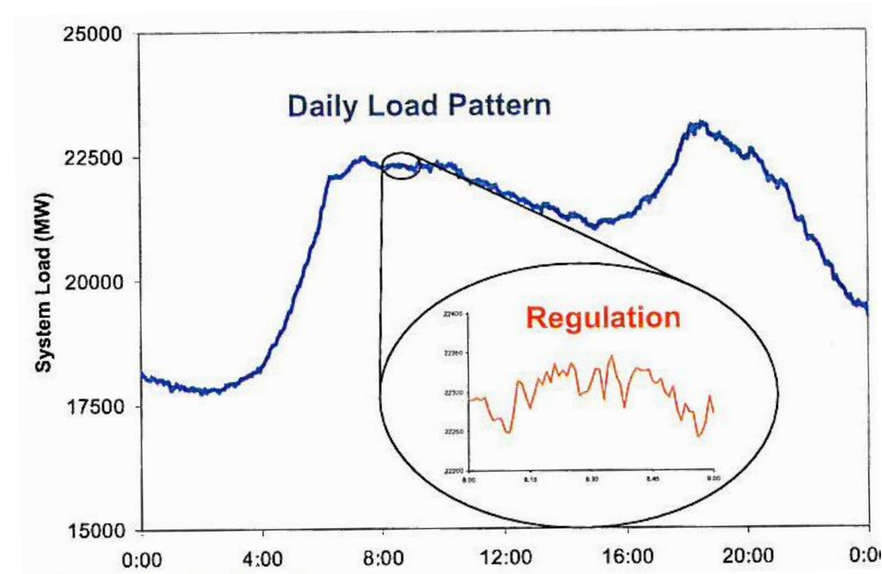
- Ancillary services provide the resources the system operator requires to reliably maintain the instantaneous and continuous balance between generation and load.
- Traditionally these grid services are provided by running select plants on the grid below their full load capability so that they can be called on and ramped up quickly as needed

Table 1. Definitions of key ancillary services

Service	Service Description		
	Response Speed	*Duration*	*Cycle Time*
Regulation	Power sources online, on automatic generation control, that can respond rapidly to system-operator requests for up and down movements; used to track the minute-to-minute fluctuations in system load and to correct for unintended fluctuations in generator output to comply with Control Performance Standards (CPSs) 1 and 2 of the North American Reliability Council (NERC 2002)		
	~1 min	*Minutes*	*Minutes*
Spinning reserve	Power sources online, synchronized to the grid, that can increase output immediately in response to a major generator or transmission outage and can reach full output within 10 min to comply with NERC's Disturbance Control Standard (DCS)		
	Seconds to <10 min	*10 to 120 min*	*Days*
Supplemental reserve	Same as spinning reserve, but need not respond immediately; units can be offline but still must be capable of reaching full output within the required 10 min		
	<10 min	*10 to 120 min*	*Days*
Replacement reserve	Same as supplemental reserve, but with a 30-min response time; used to restore spinning and supplemental reserves to their pre-contingency status		
	<30 min	*2 hours*	*Days*
Voltage control	The injection or absorption of reactive power to maintain transmission-system voltages within required ranges		
	Seconds	*Seconds*	*Continuous*

Regulation

- Power source online, available continuously
- Respond to automatic generation control (AGC) signals
- Increase or decrease power output
- Balances generation and load on minute-to-minute basis



Why use energy storage for ancillary services?

- Generators offering ancillary services operate below their full load capability (and peak operating efficiency)
  - So that they can be called on and ramped up quickly as needed
  - Result: inefficiency, higher fuel consumption, greater emissions
- Advanced batteries capable of providing rapid charge and discharge cycles as well as high period over a long period may cost effectively provide these services
  - Through the use of batteries, the portion of the thermal power plant capacity normally reserved for ancillary services to provide reserve capacity services and frequency regulation can be freed up to operate at full capacity and produce more electricity and associated revenue

Energy storage for regulation services

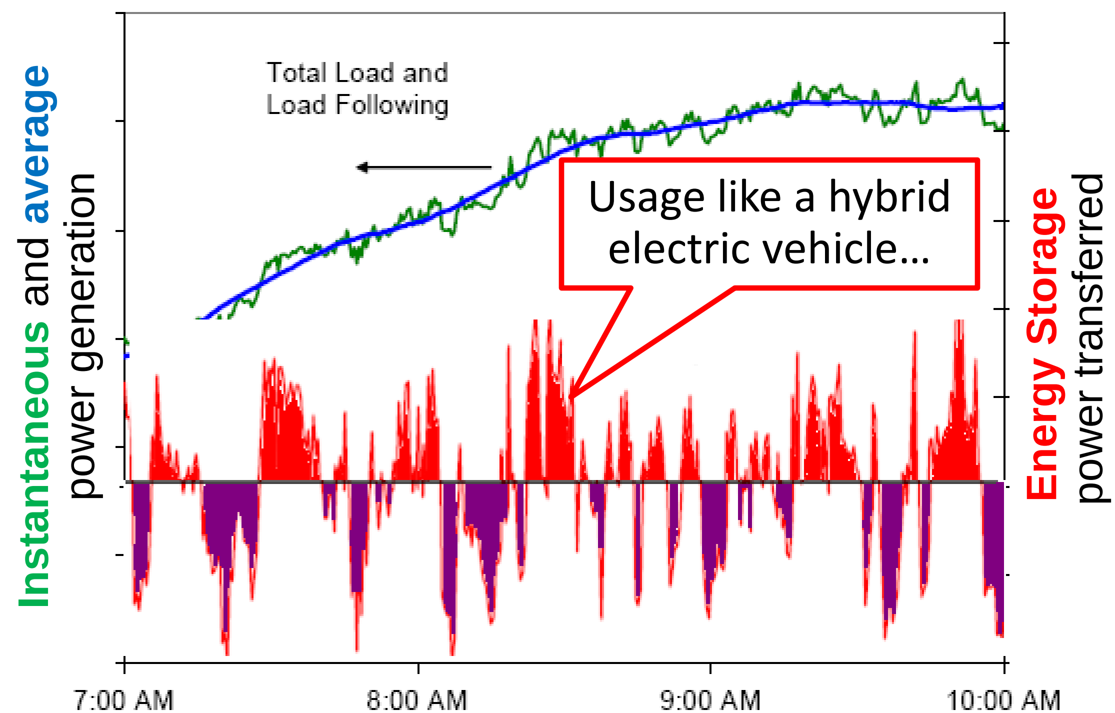
Standard
power
plant

95

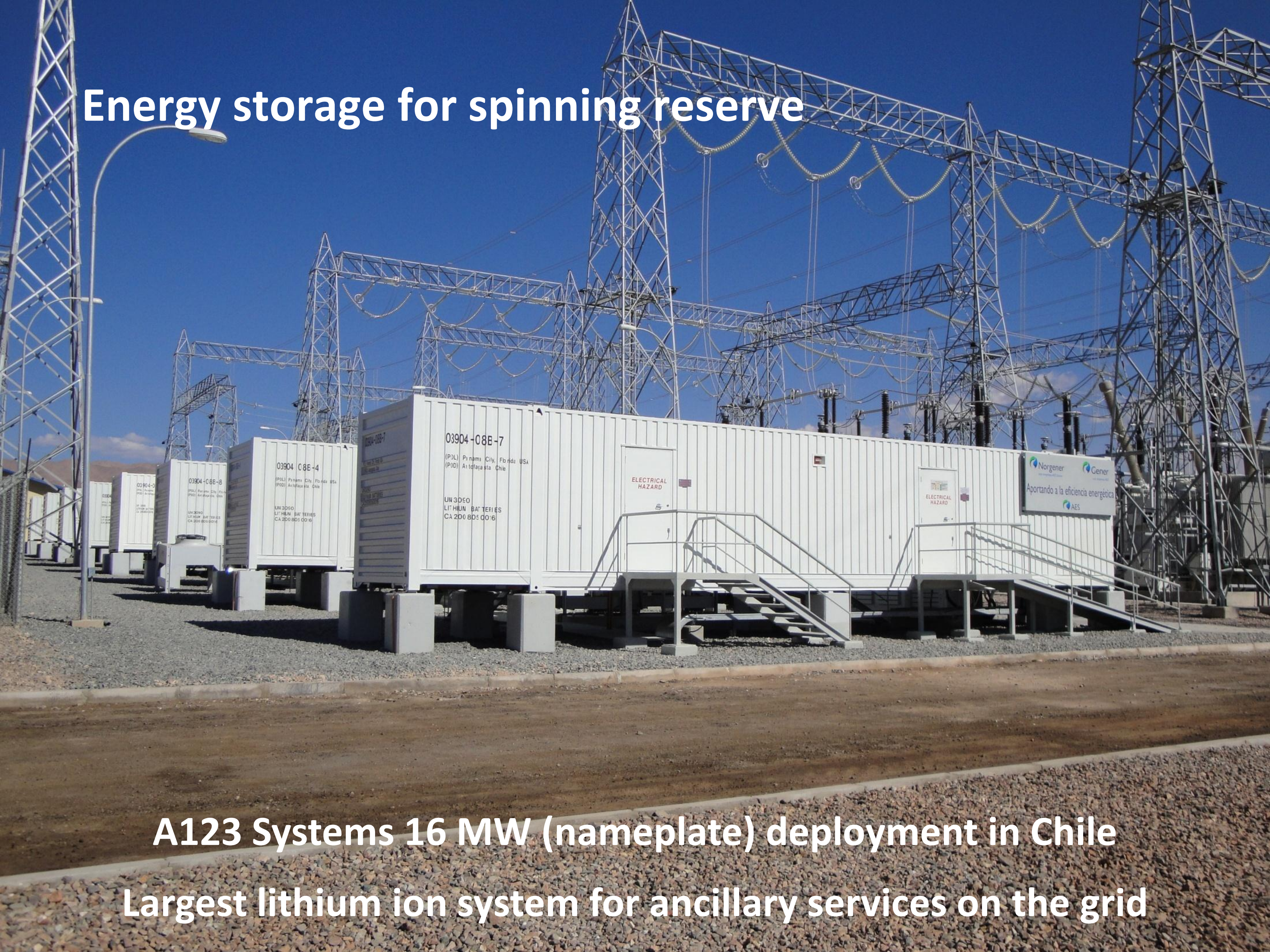
to

100
MW
output

Energy storage provides power (discharges)
Average output of power plant
Energy storage is charged by power plant



Energy storage for spinning reserve



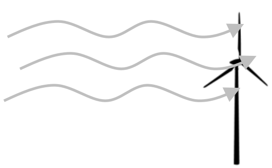
A123 Systems 16 MW (nameplate) deployment in Chile

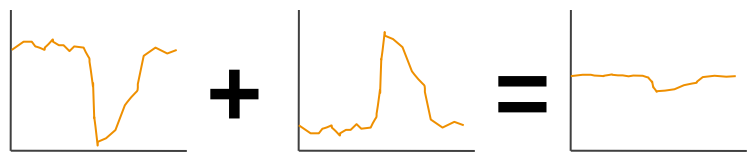
Largest lithium ion system for ancillary services on the grid

Energy storage enables renewables

	Power Generated		Power from Energy Storage		Net Power	
Wind		+		=		Firm wind power Enable greater penetration
Solar		+		=		Firm solar power Enable greater penetration

Wind

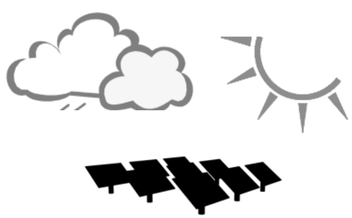


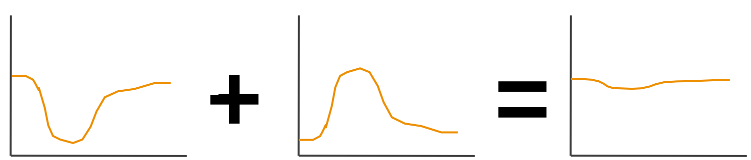


Firm wind power

Enable greater penetration

Solar





Firm solar power

Enable greater penetration

Challenges to greater wind penetration

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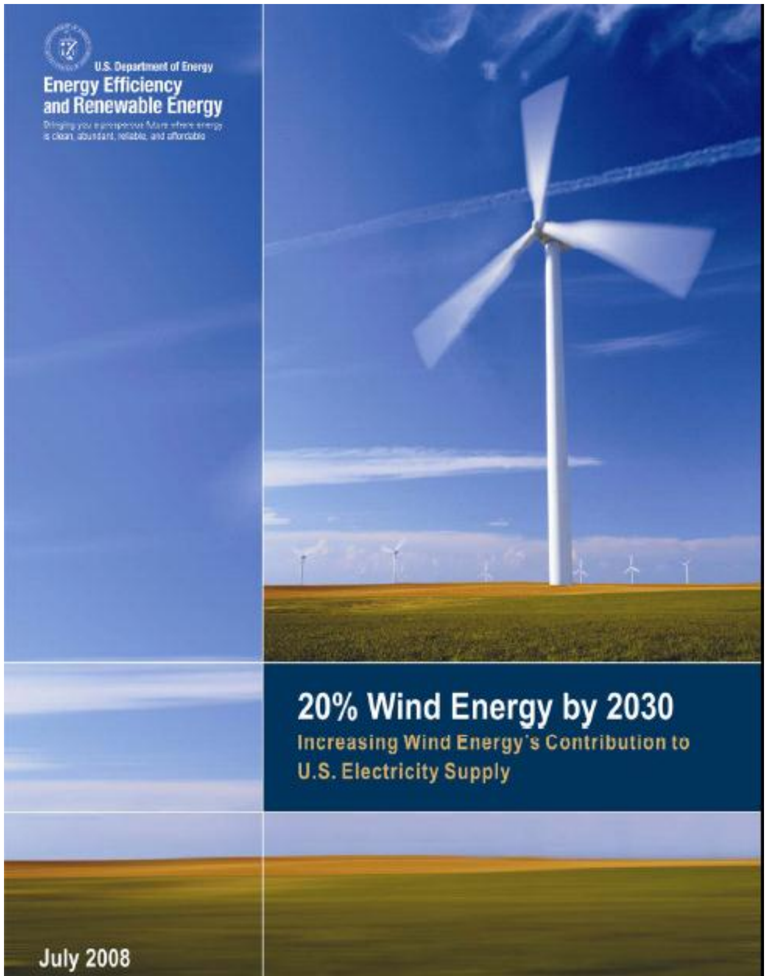


There are two separate and distinct power system challenges to obtaining 20% of U.S. electric energy from wind:

1. The need to reliably balance electrical generation and load over time when a large portion of energy is coming from a variable power source such as wind, which, unlike many traditional power sources, cannot be accessed on demand or is "nondispatchable."

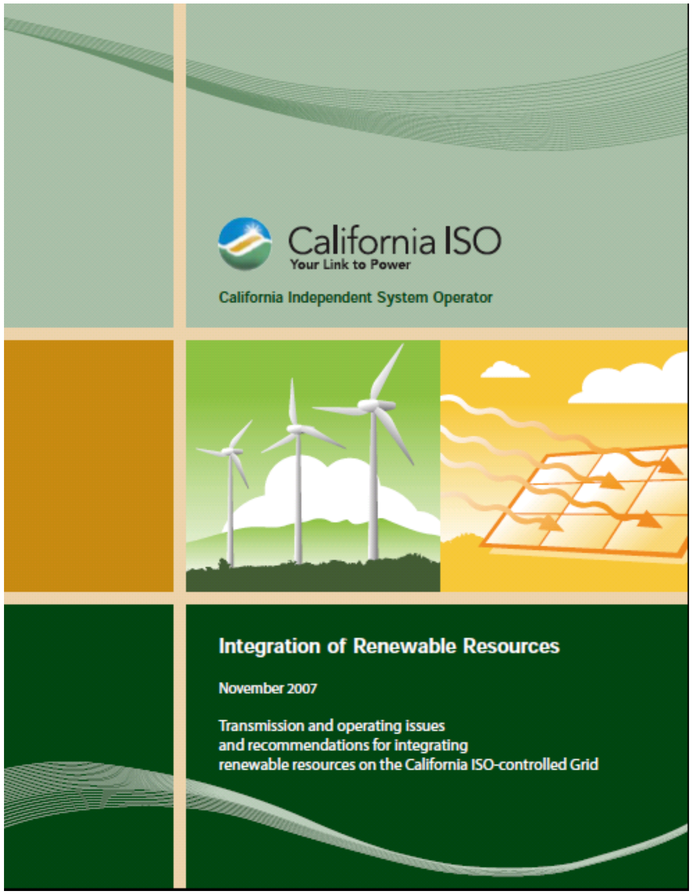
2. The need to plan, build, and pay for the new transmission facilities that will be required to access remote wind resources.

Energy storage helps address both challenges

Wind is non-dispatchable

- *Capacity* resources are available on demand
  - + Traditional generators can be scheduled, depending on demand
- Wind is an *energy* resource
  - + Can not guarantee that wind energy will always be available
  - + Wind will not replace traditional generators
- Energy storage and wind work in synergy

Integrating intermittent renewable generation requires more flexible resources



Wind generation, solar generation and system load are all quite variable.

"The variability of any one of these elements may be offset by the other or they can be additive and increase the total variability on the system. **To accommodate this increase in variability, the California ISO needs increased flexibility from other resources** such as hydro generation, dispatchable pump loads, **energy storage systems**, and fast ramping and fast starting fossil fuel generation resources. The portfolio of future California resources must reflect this need for very flexible generation resources to assist with the integration of large amounts of intermittent resources."

As wind generation further increases, the amount of variability will increase non-linearly.

Transmission is a potential constraint

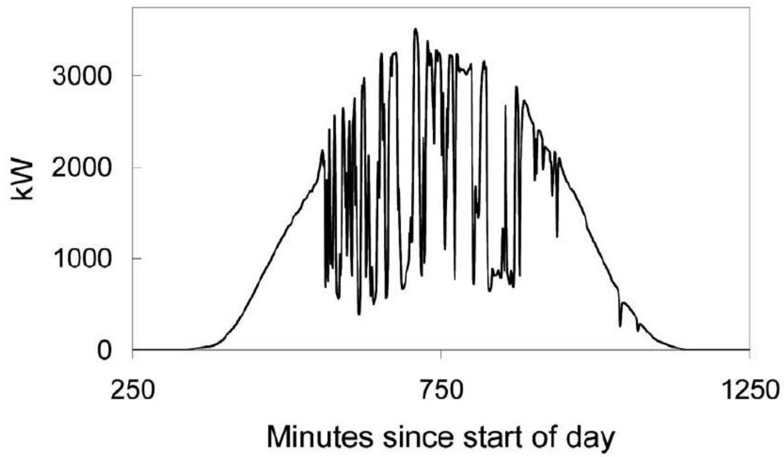
- Wind and solar resources are often located far from population/load centers
- Transmission lines may not be sized to handle all of the available power
- Energy storage works with transmission assets, to increase the utilization
  - Higher utilization of existing transmission assets can bridge the significant time needed to permit and build new transmission capacity
  - Higher utilization of future built transmission assets will allow even greater amounts of clean renewable energy to be delivered

Cost, efficiency, emissions are real issue

- Question is not: "can we integrate renewables?"
  - Sufficient capacity exists to balance renewables, up to 20% penetration
  - Highest- cost, least-used plants, which have significant emissions
- The real question is: "how do we integrate renewables in the most efficient, cost-effective way, with the least emissions?
  - If the goal is clean energy and reduced emissions, using fossil-fired generators to back up renewables is at cross-purposes to the goal
  - A holistic view must be taken, addressing the issues of cost/benefit

Distributed energy storage

- Advantages of energy storage
  - + Easy to site energy storage, compared to many other assets on grid
  - + Most problems on the grid are local;
    Local distributed resources can more effectively address problem
  - + Flexible: energy storage can be used for many different purposes
- One example: net zero energy buildings
  - + Rooftop photovoltaics are a primary method
  - + High penetration will challenge grid stability (partly cloudy day)
  - + Distributed energy storage is the perfect solution



" The Character of Power Output from Utility-Scale Photovoltaic Systems"
Aimee Curtright and Jay Apt, Carnegie Mellon Electricity Industry Center Working Paper CEIC-07-05

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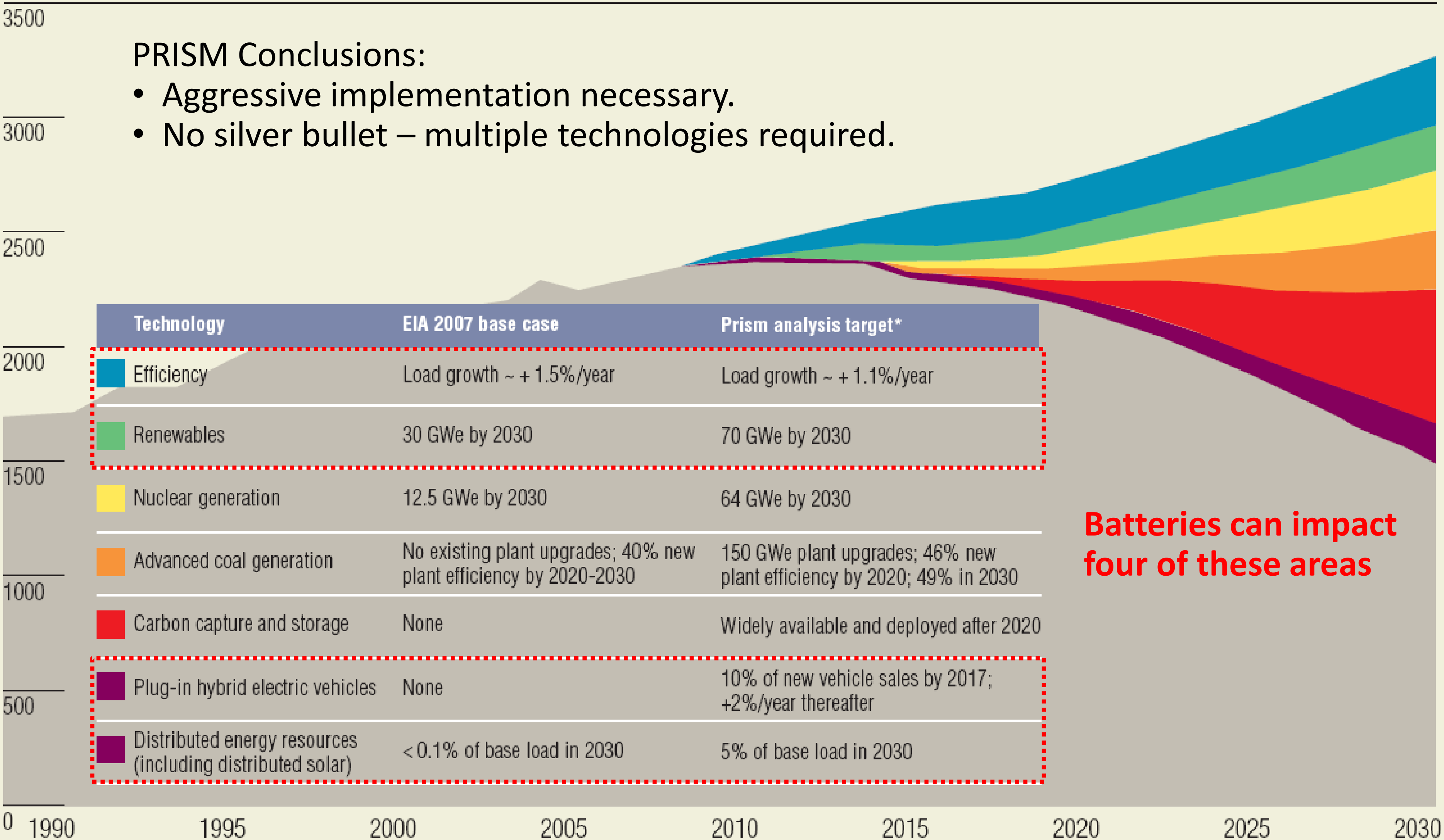

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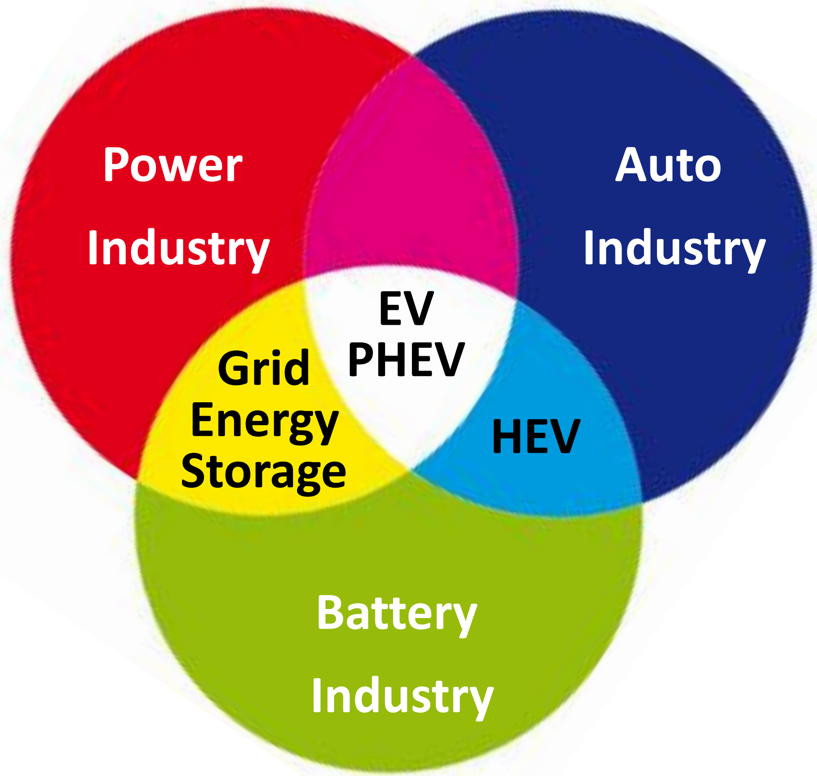
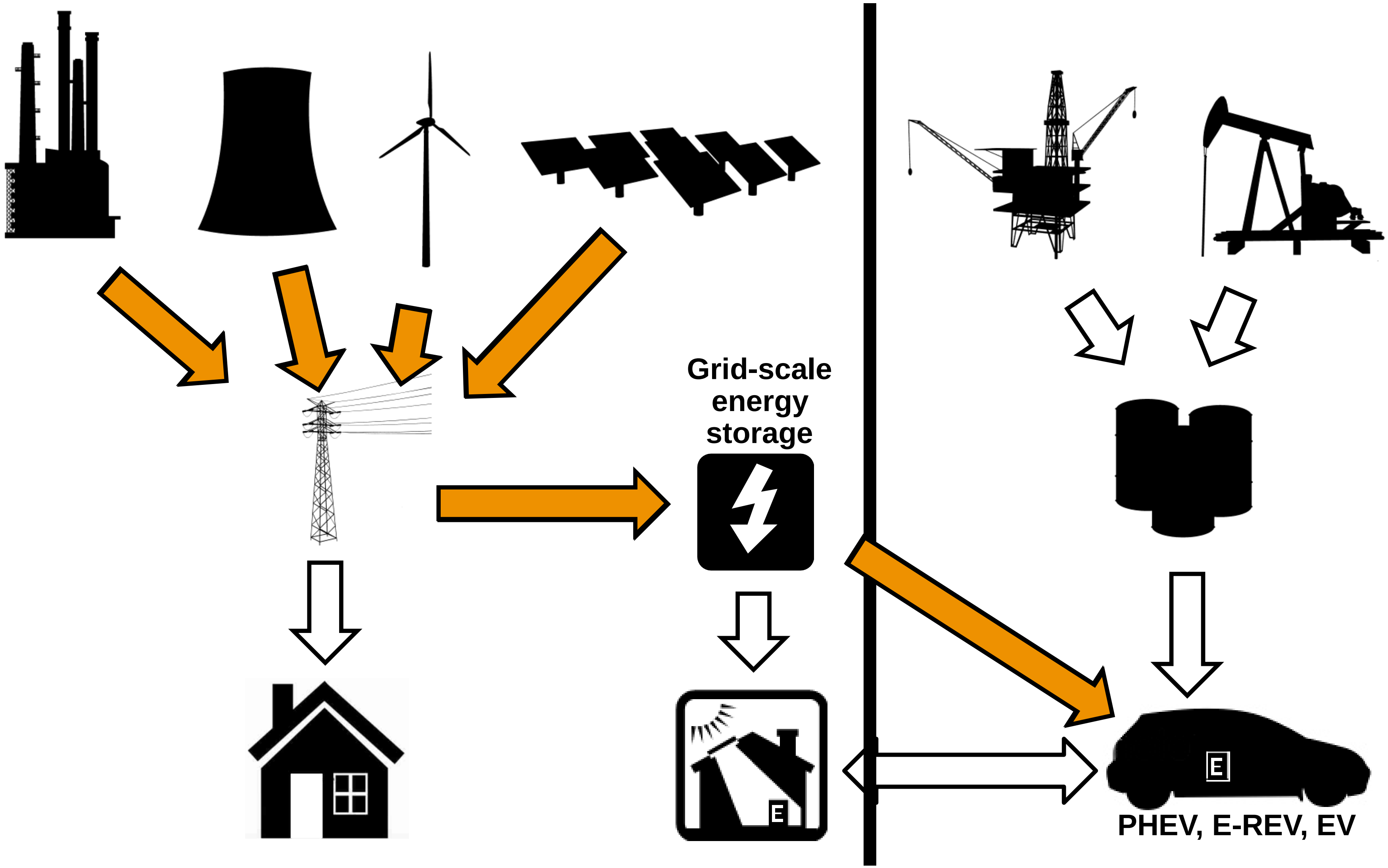
Energy storage is the key

- Advances in battery technology are enabling new applications



Energy Ecosystem



Conclusions

- Energy storage for grid and transportation applications will be significant
- Energy storage can help achieve important policy objectives, including:
  - Higher efficiency, reduced emissions
  - Increased renewable penetration
  - Greater use of distributed energy resources
  - Greater energy security, through diversification of energy for transportation
- A123 is interested in engaging with stakeholders interested in moving these areas forward

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