California ISO
Your Link to Power

Striking the Balance: Reliability, Cost and the Environment.

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California Independent System Operator Corporation

A nonprofit public benefit corporation created by the state:

- Manages flow of electricity, ensuring reliable operation of the grid
- Facilitates market for day-ahead, real-time energy & ancillary services
- Provides open and non-discriminatory access to grid supported by comprehensive planning process
- Board appointed by governor and confirmed by state senate
- Regulated by Federal Energy Regulatory Commission (FERC)
- Main control center in Folsom; second control room in Southern CA

California ISO by the numbers

Approximately 80% of California's electricity load is managed by the ISO

- **55,027** MW of power plant capacity + 10 MW import capacity
- **50,270** MW record peak demand (July 24, 2006)
- **25,526** circuit-miles of transmission lines
- **30 million** people served
- **230 billion** annual kilowatt-hours of electricity delivered annually

New market

Provides transparent price signals to support forward contracting and future infrastructure investment

Day-ahead energy market

ISO Annual Billings

2009 - $6.4 billion

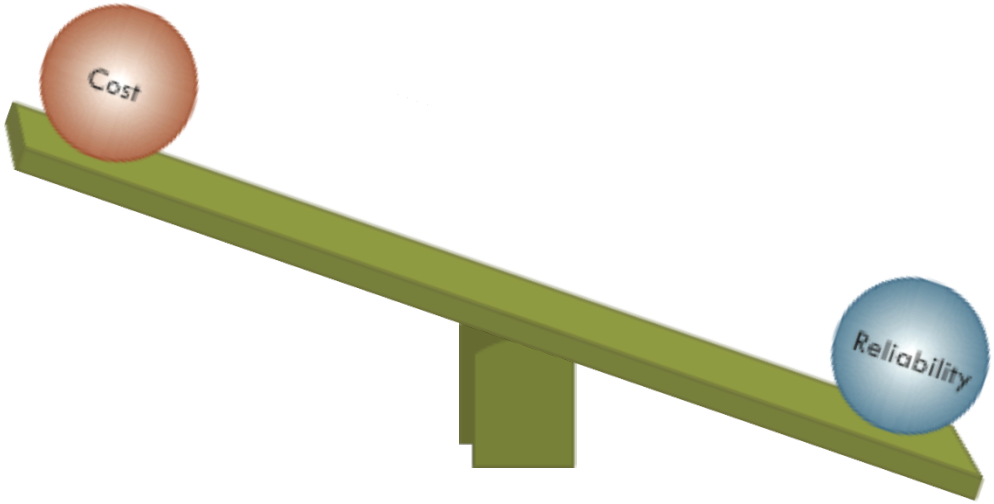
2008 - $2.7 billion

Full network model to manage congestion

Locational marginal pricing at 3,000 nodes

History and into the future…

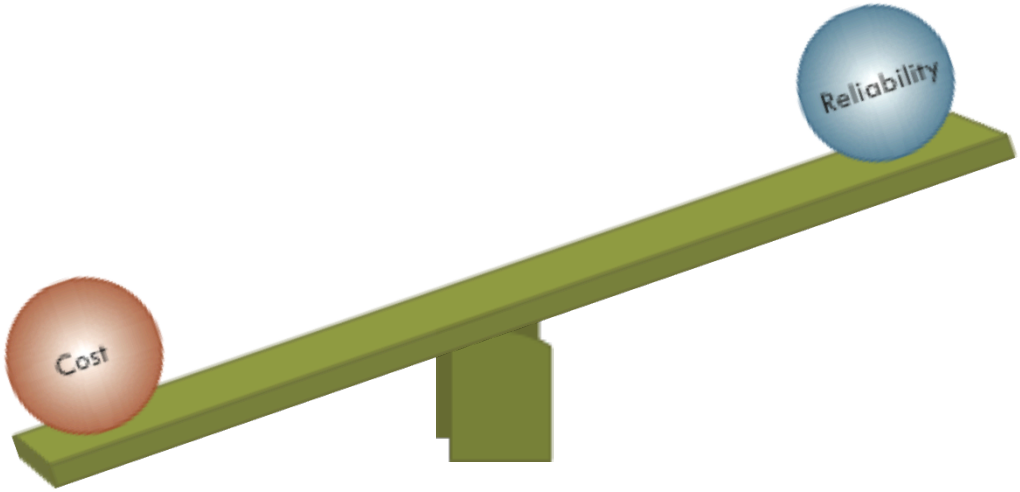
- The historical ~~balance~~ imbalance



Primary reliability and . . .

History and into the future…

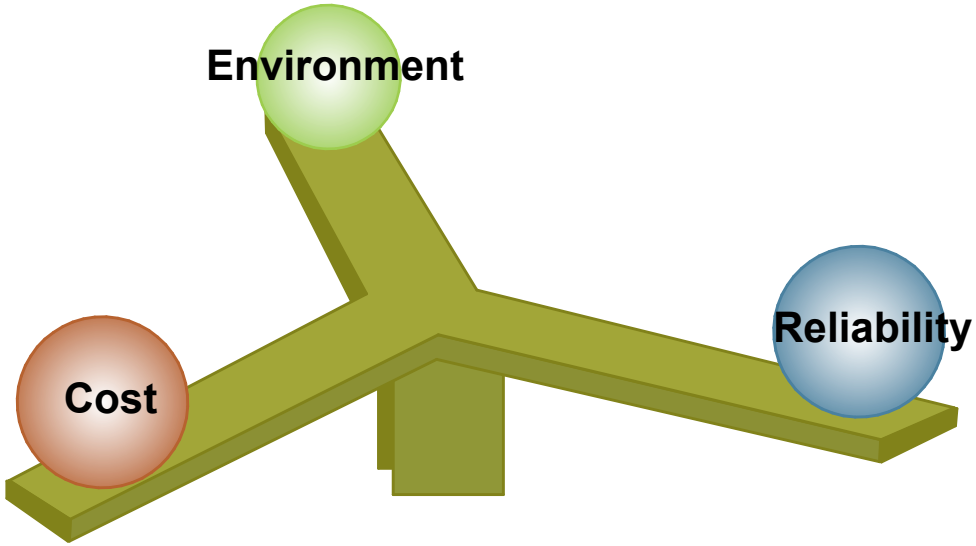
- The historical ~~balance~~ imbalance



. . . economics

History and into the future…

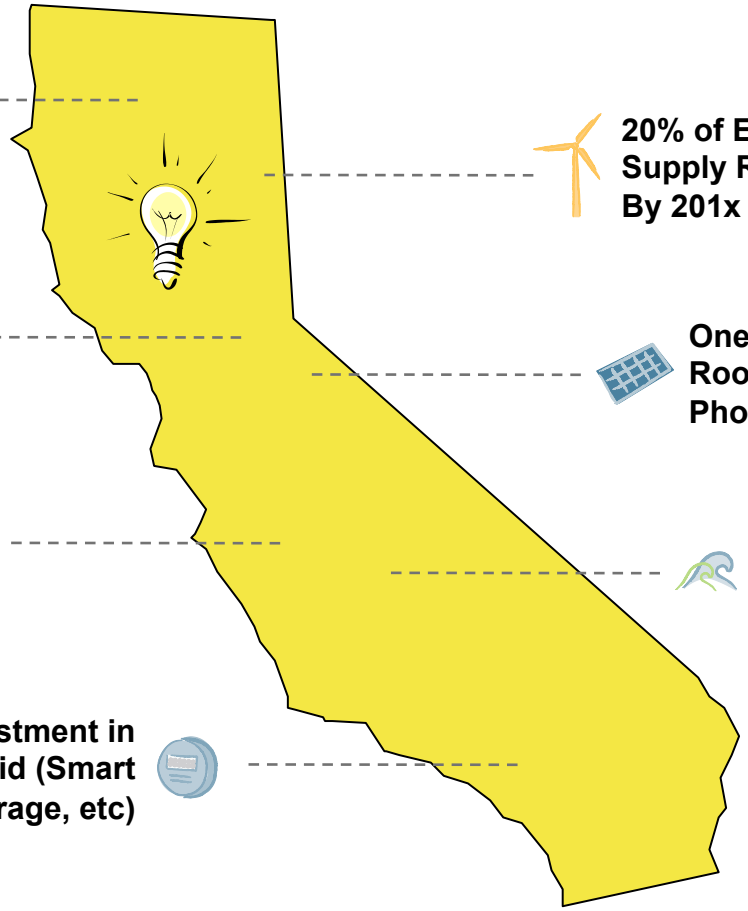
- The newcomer: "the environment"
- The dynamic point toward equilibrium



Rebalancing

- Now – Renewable resources and energy efficiency.
- Ten years forward – More of the new and more of the old……unless
- 30+ years forward – Cannot be more of the same!

Into the future - Accommodating the climate change initiatives



33% of Energy Supply from Renewable Resources by 2020

20% of Energy Supply Renewable By 201x

CO2 Emission Level Rolled Back to 1990 Level by 2020

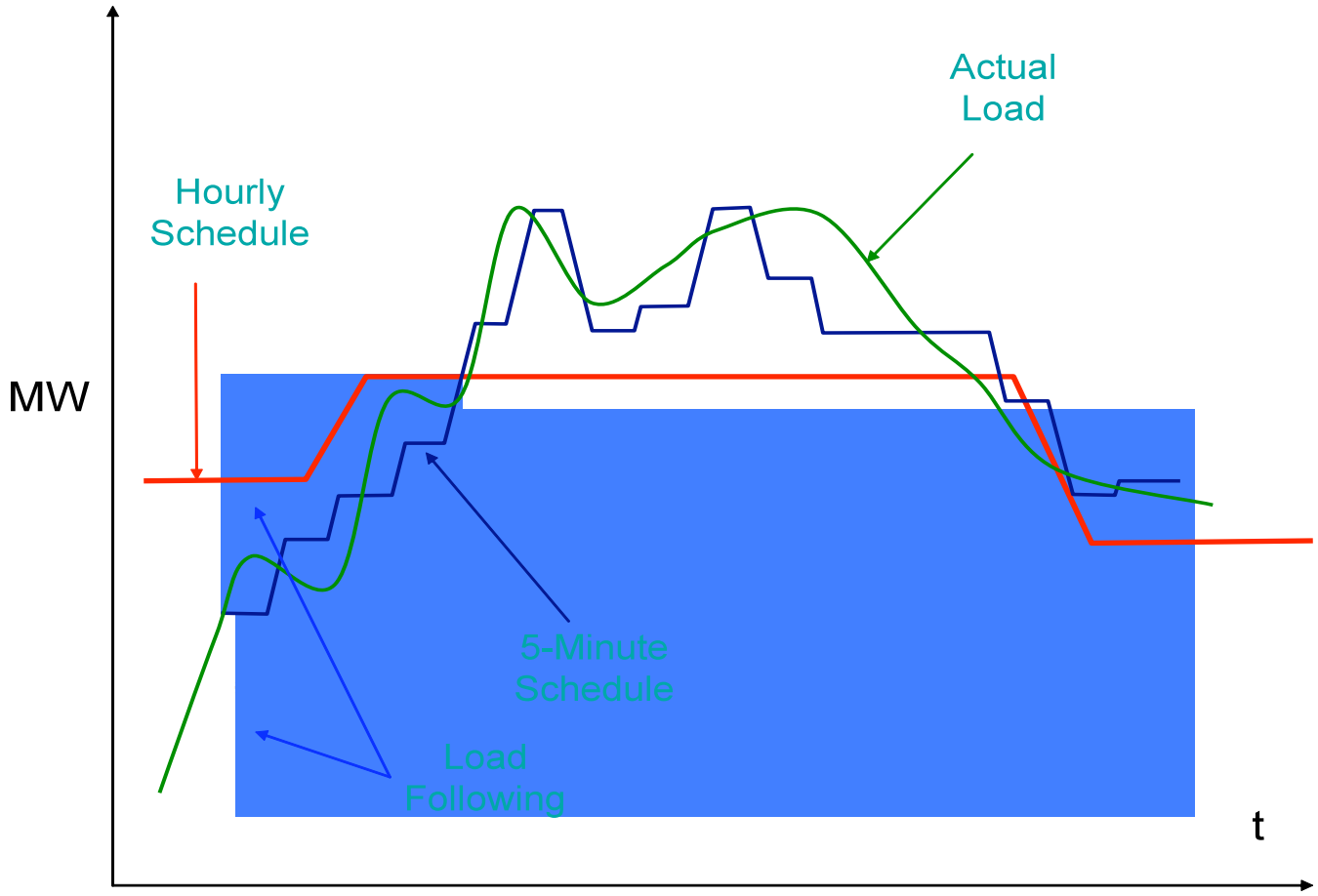
One Million Roof-Top Photovoltaics

$1 Billion/Year Investment in Energy Conservation

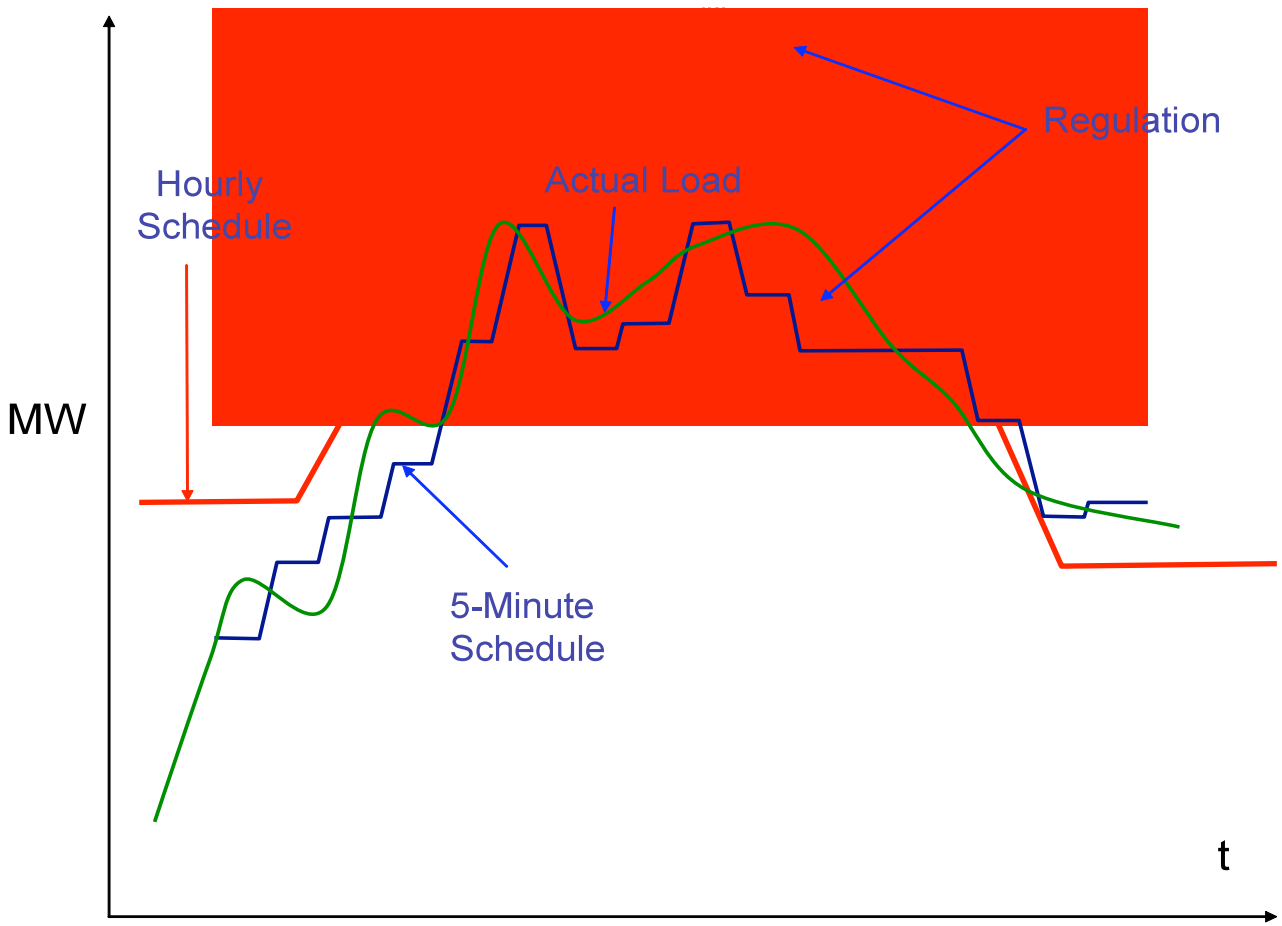
Ban Once-Through Cooling Technology on all Coastal Plants by 20xx

$x Billion Investment in Smart Grid (Smart Meters, Storage, etc)

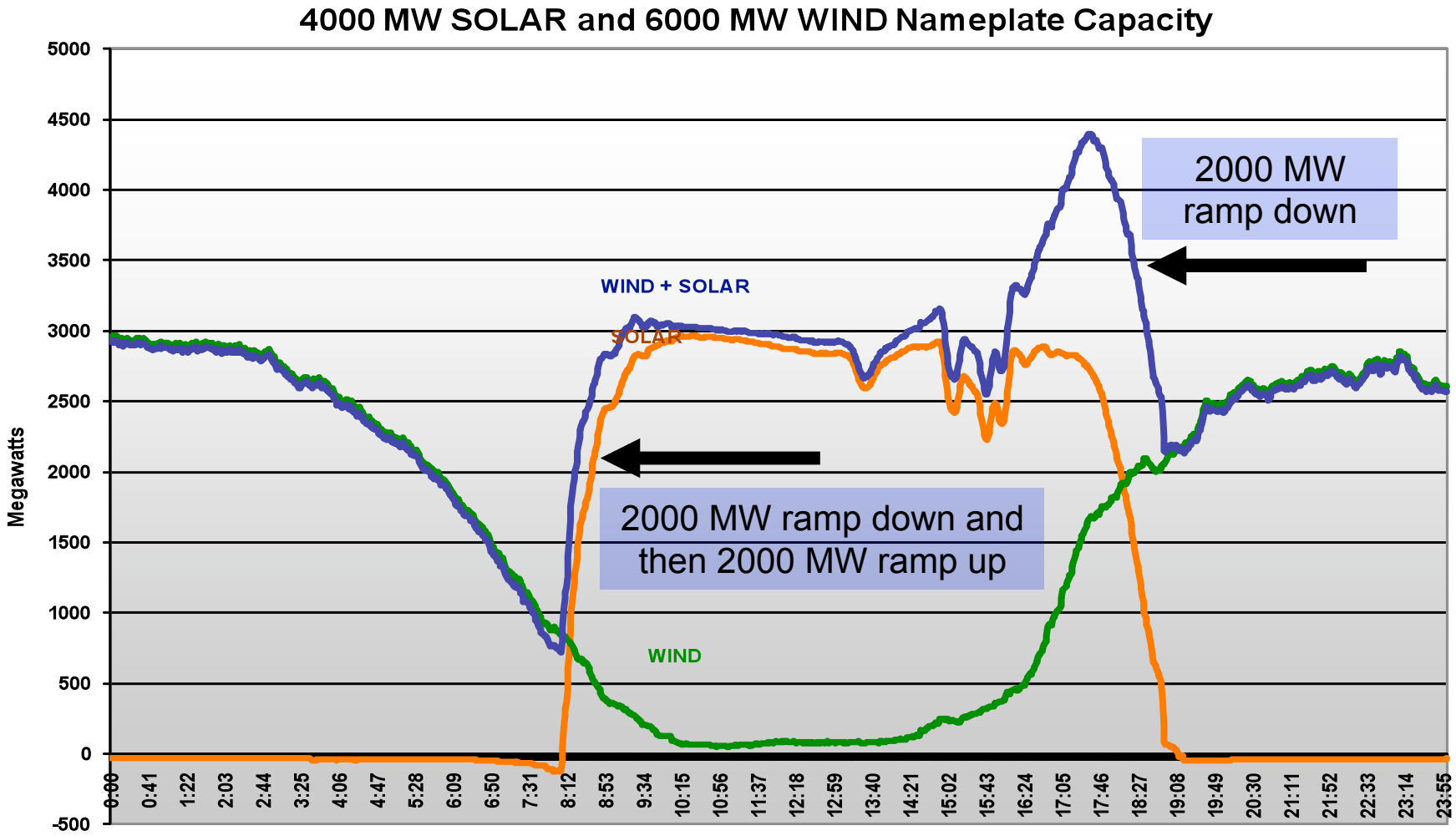
Depiction of hourly load-following capacity requirement



Regulation requirement shown as the red shaded area



Example of ramping challenges



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Data based on summer production profiles

Factors impacting higher renewable penetration

Impediments

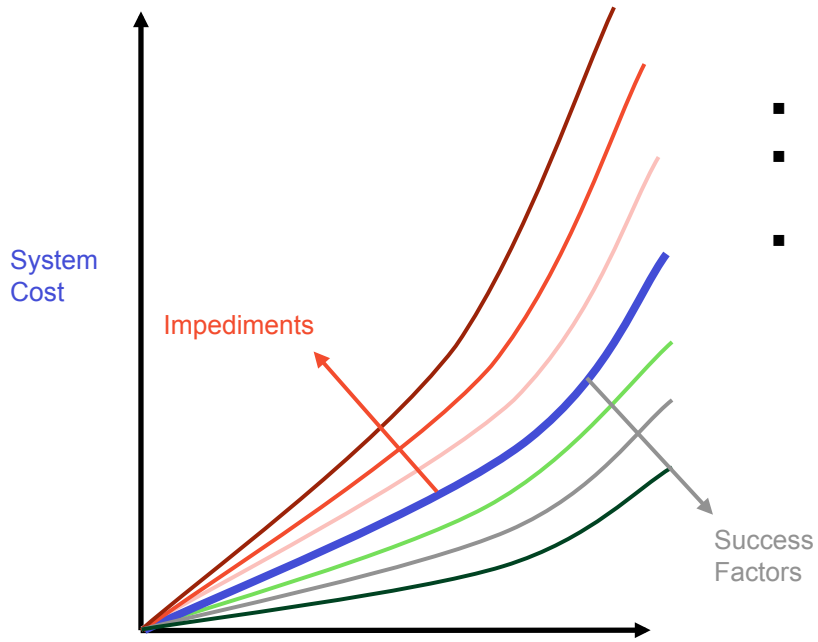
- Lack of transmission
- Lack of control area cooperation
- Inflexibility due to market rules and contracts
- Unobservable DGs
- Inflexible operation strategies during light load & high risk periods

Success factors

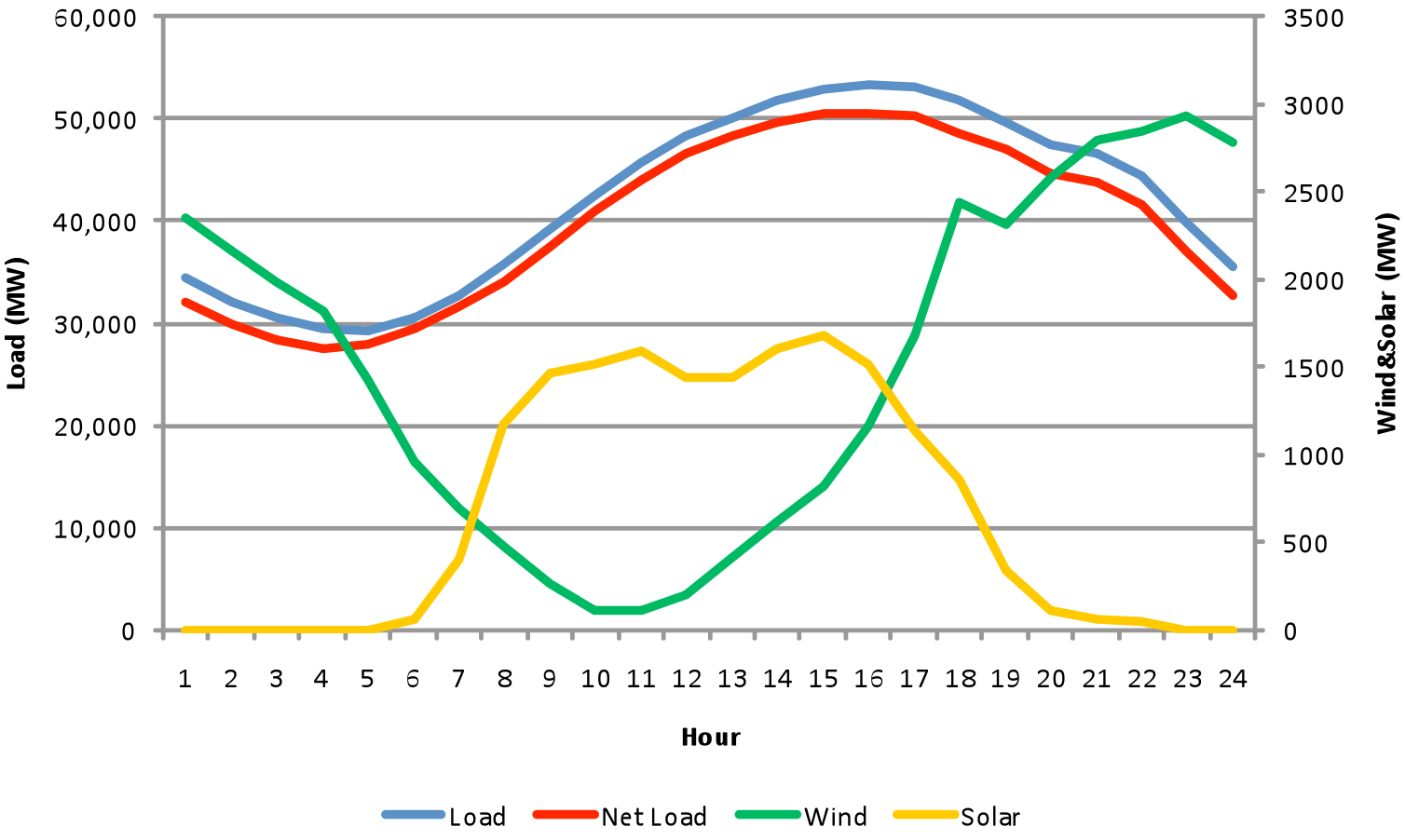
- Forecasting
- Thermal fleet
  - Higher quick starts
  - Deeper turn-down
  - Faster ramps
- More spatial diversity
- Renewable + DG + Demand A/S
- Grid-friendly renewables

System cost

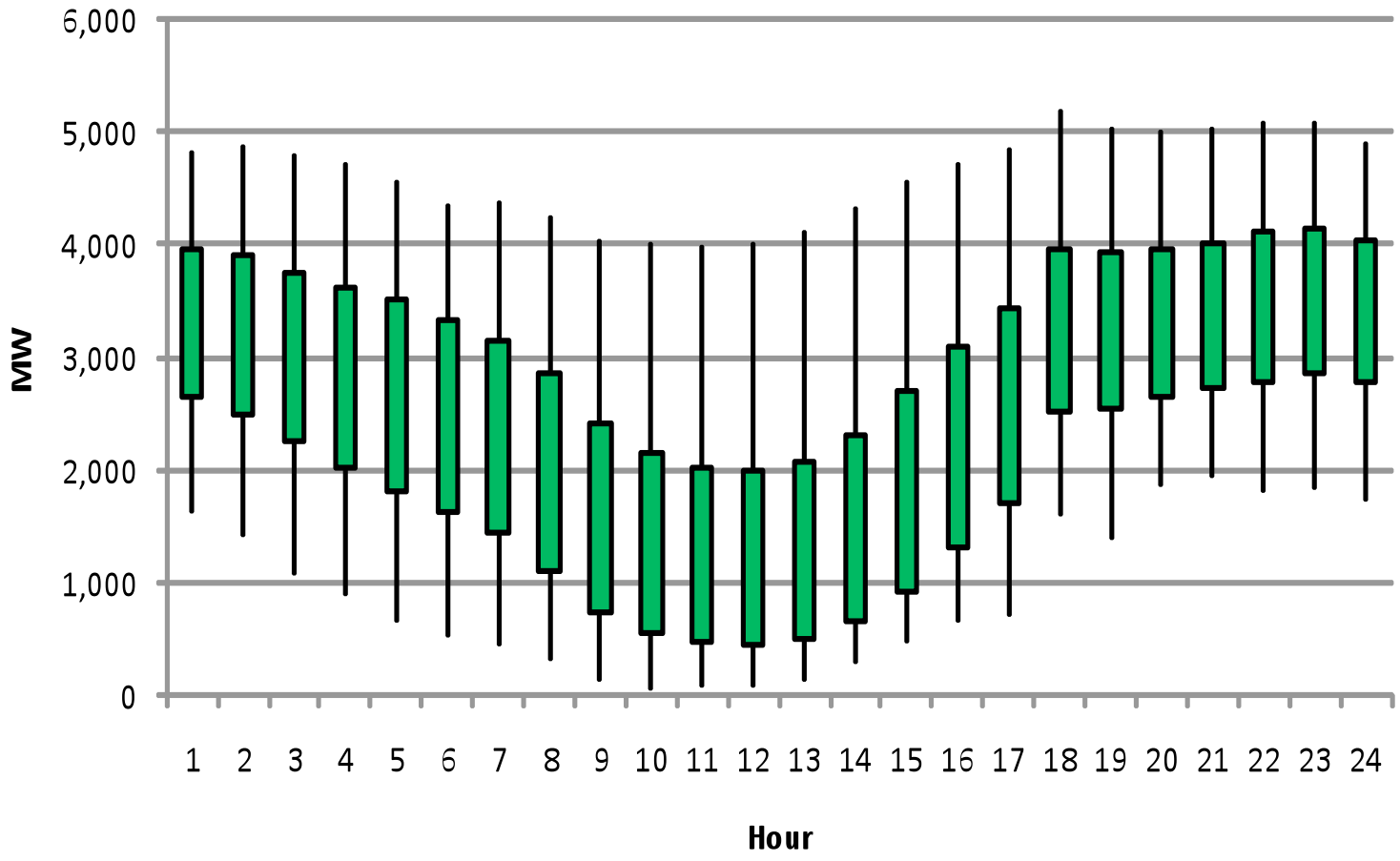
- Unserved Energy
- RPS miss
- Higher COE
- Higher Emission
- Higher O&M



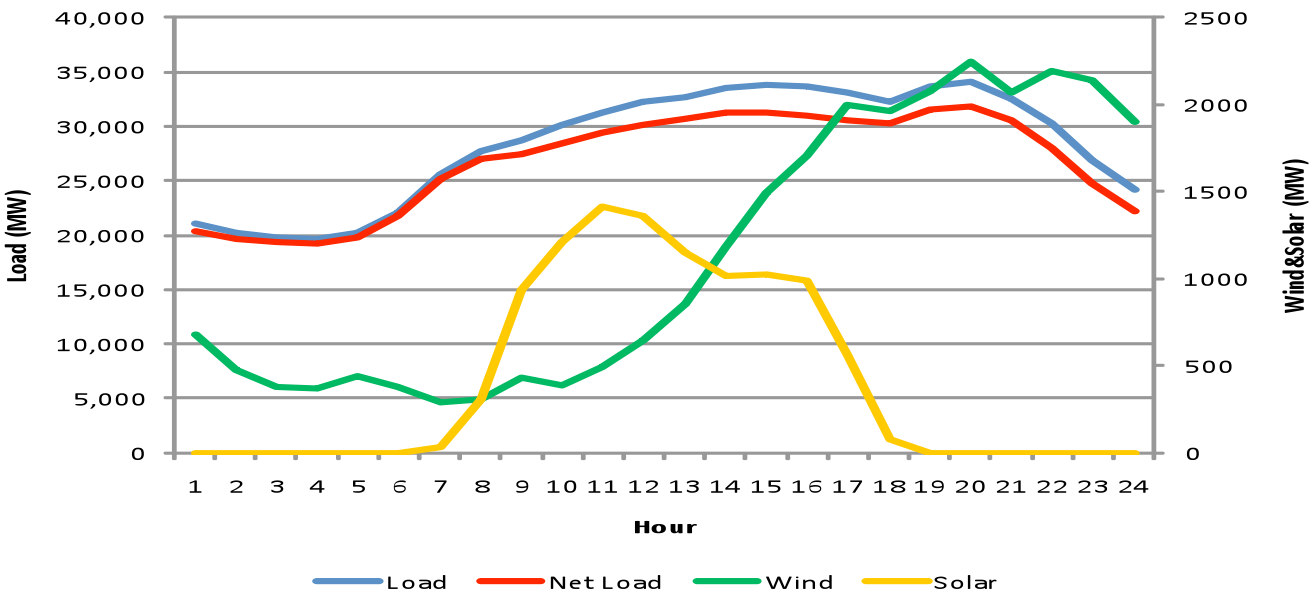
Summer 2012 – a specific July date simulation



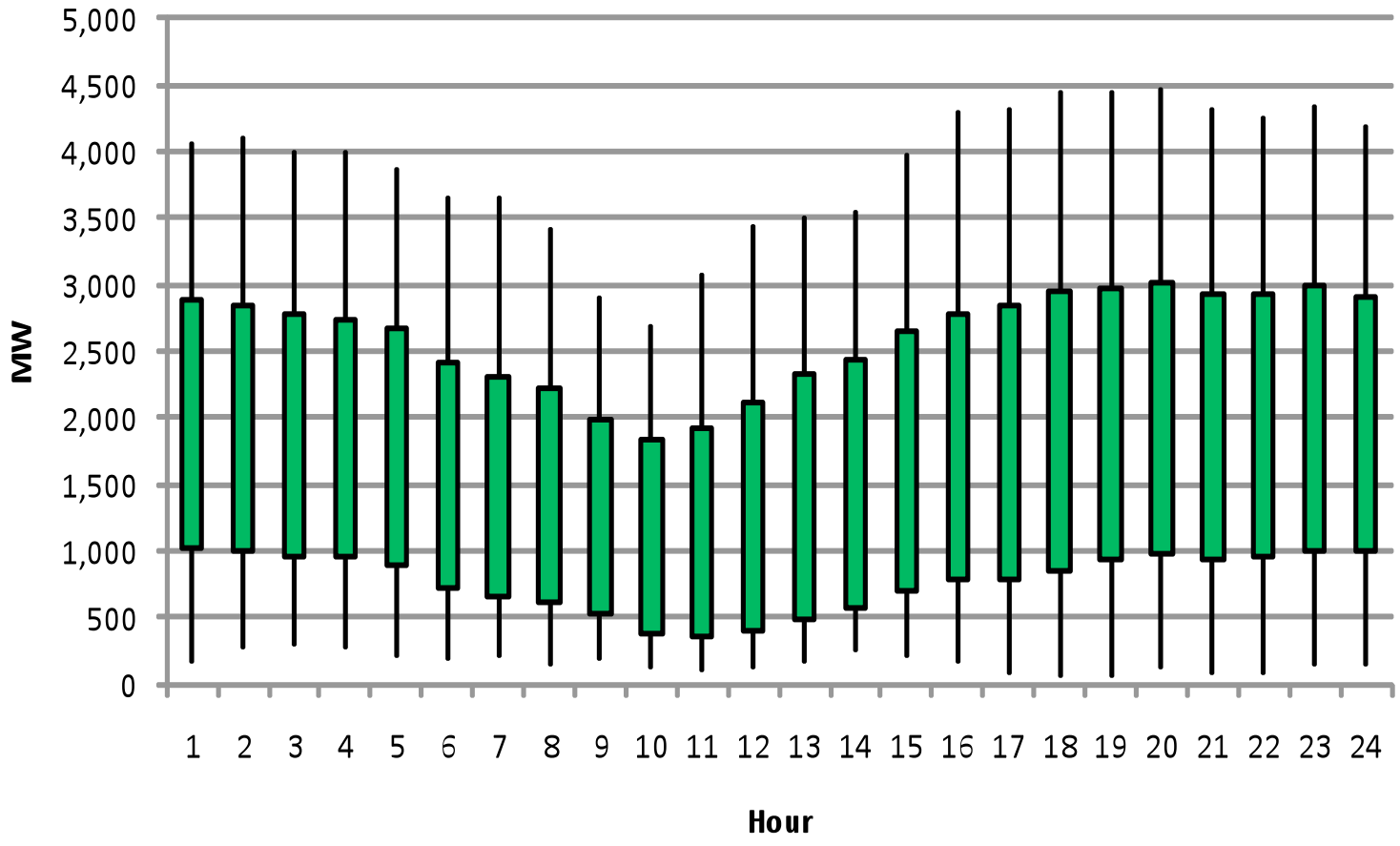
Summer – all days



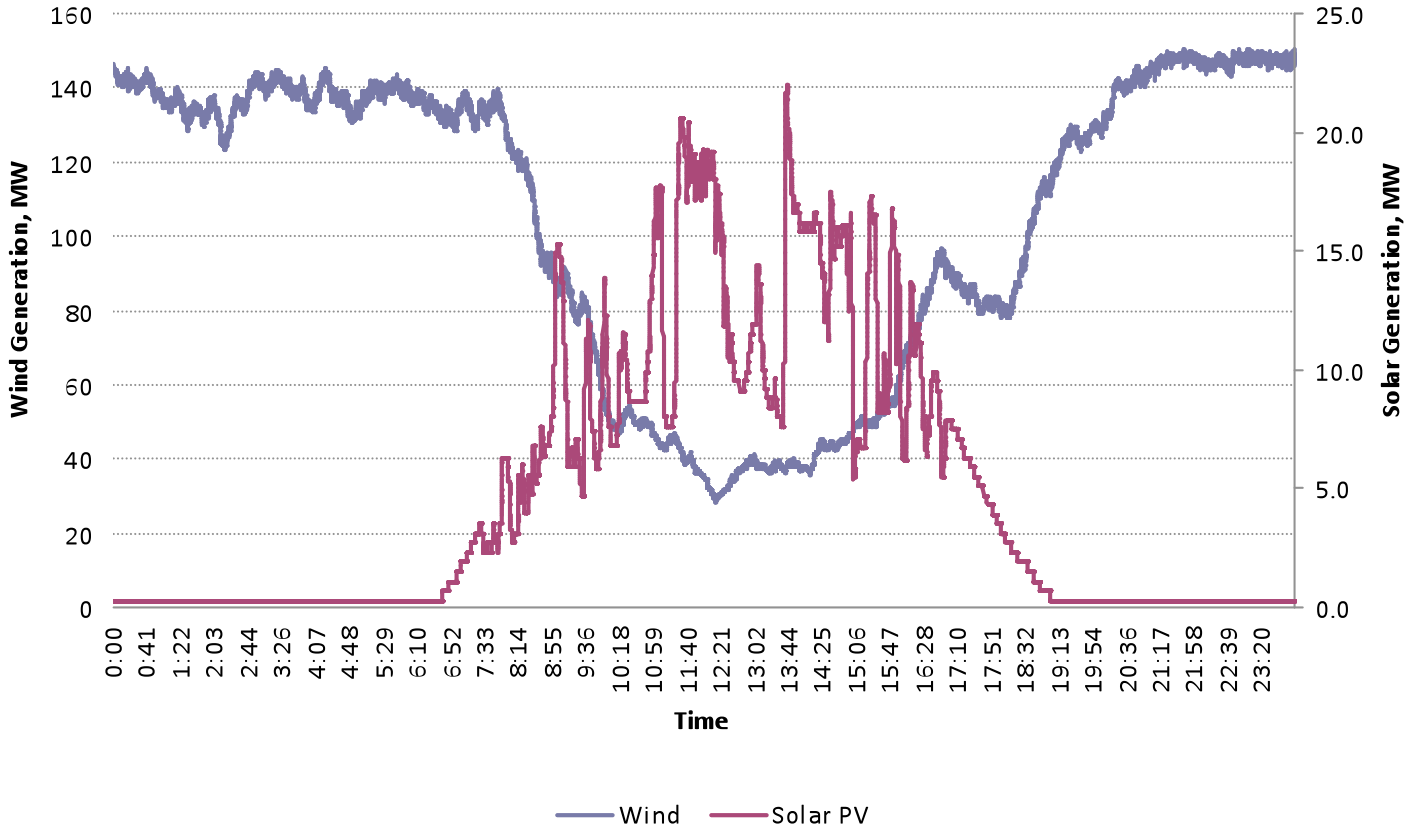
Fall 2012 – a specific October date simulation



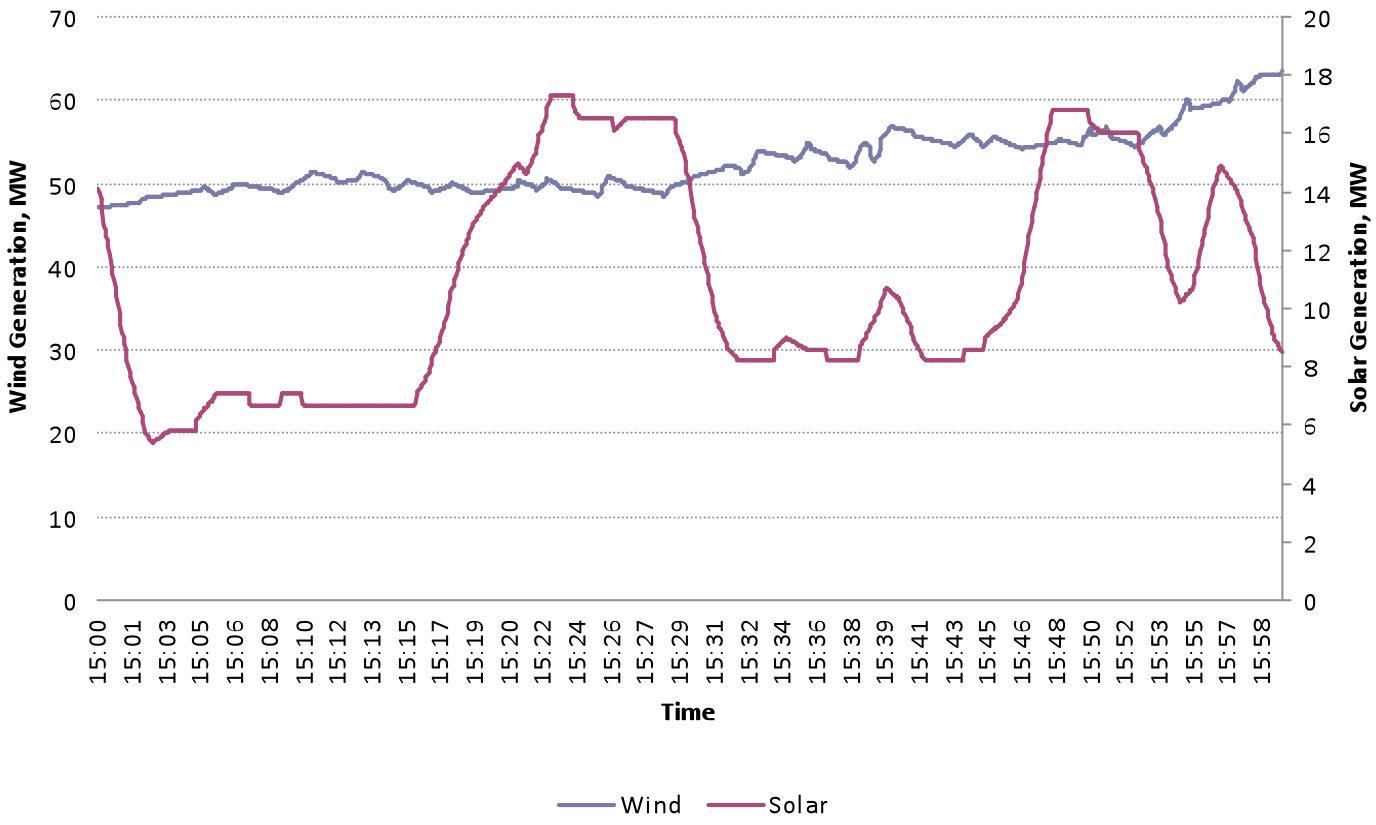
Fall – all days



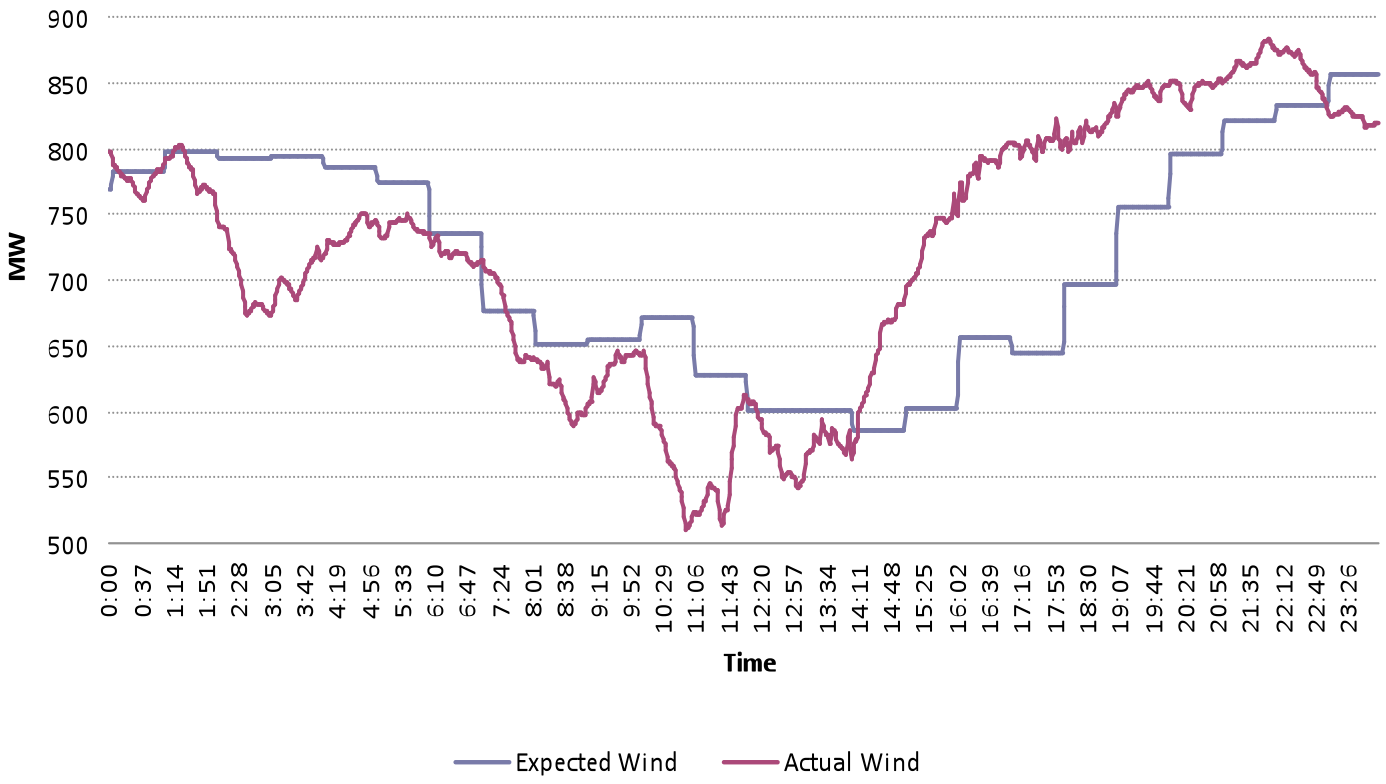
Sub-hourly wind and solar generation of a specific location for a day



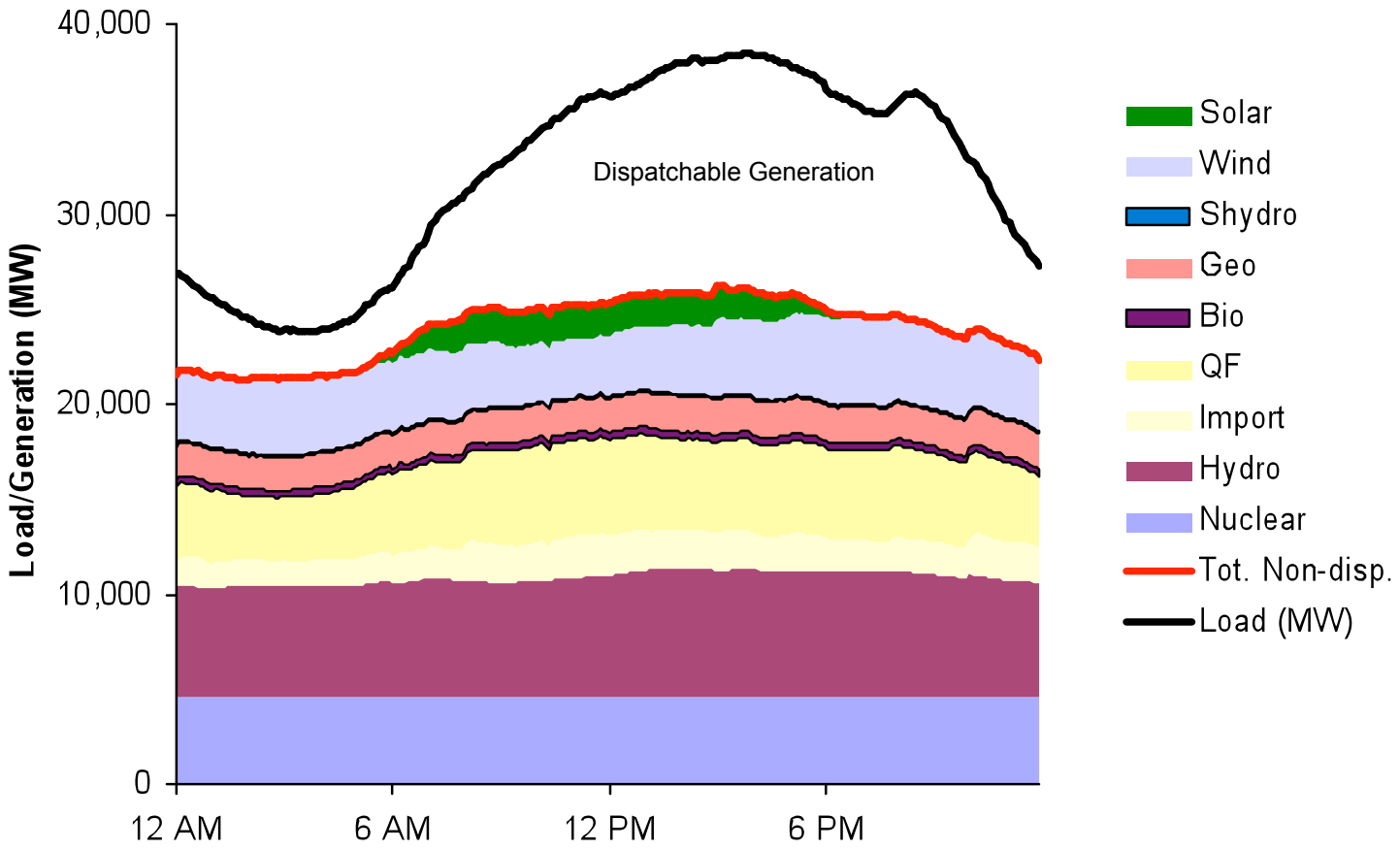
Sub-hourly wind and solar generation profile for an hour



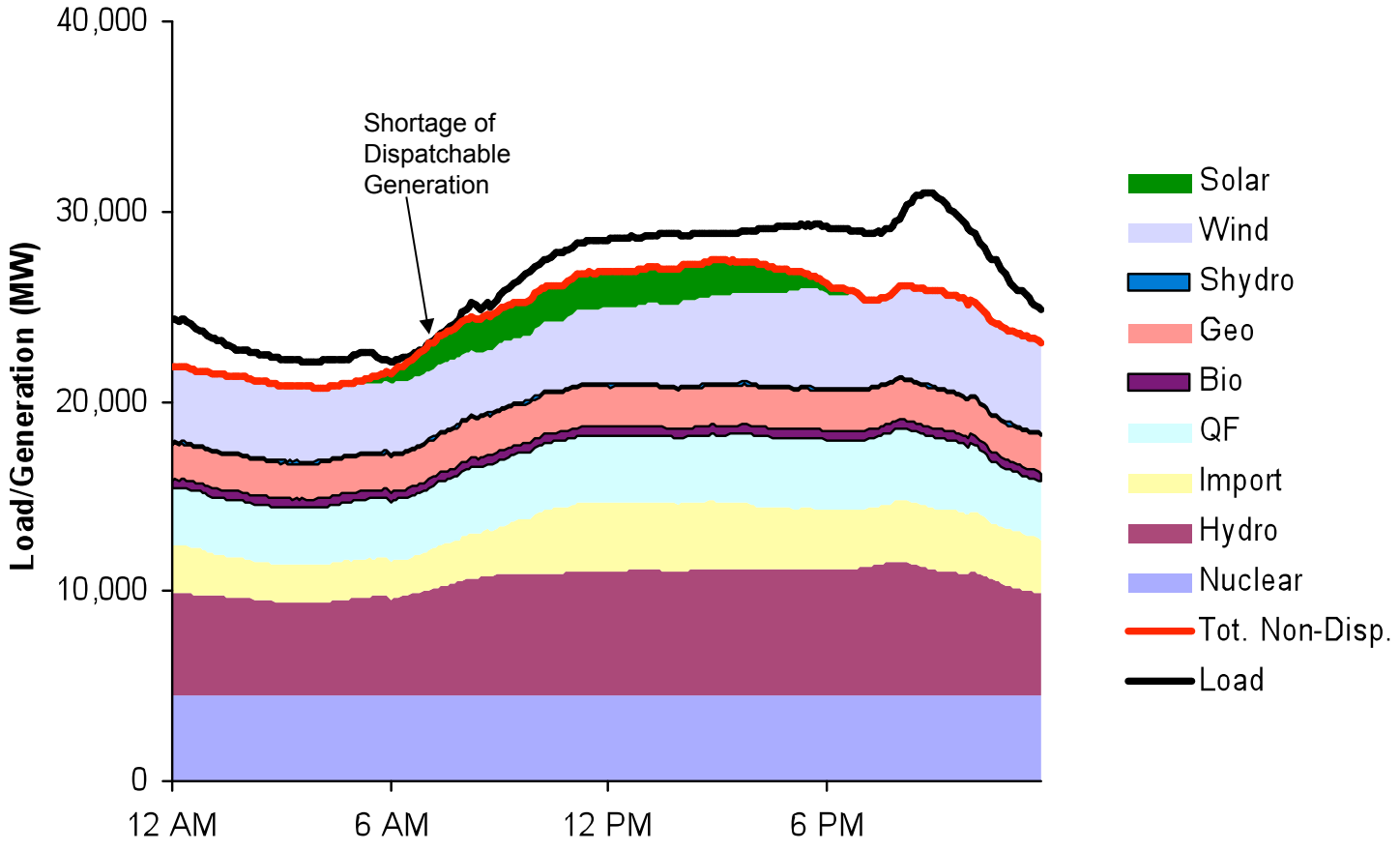
Forecasted and actual generation profile for a day



Load and non-dispatchable generation on May 17, 2010



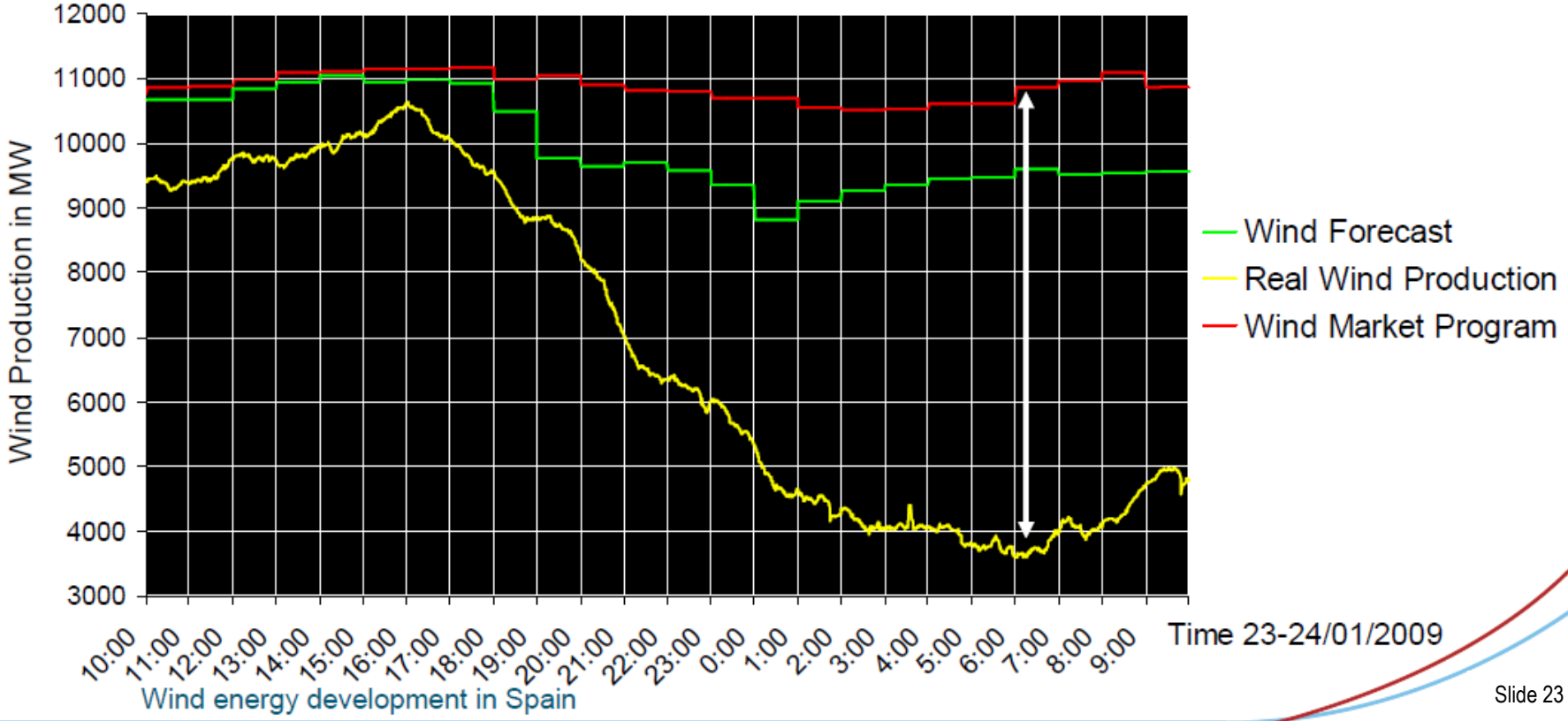
Load and non-dispatchable generation on May 28, 2010



Cornerstones of the Spanish leadership in wind energy (IV)

Wind prediction errors may be very large. Storm Klaus.

- On January 23rd and 24th 2009 the storm Klaus hit the Iberian peninsula. Some wind parks recorded winds up to 220 km/h.
- Most turbines in the north of Spain shut down due to their over-speed protection.
- Difference between real and scheduled wind production was greater than 7 000 MW.



Expected regulation and load-following capacity (MW) requirements

	Spring		Summer		Fall		Winter	
	2006	2012	2006	2012	2006	2012	2006	2012
Max Regulation Up Requirement (MW)	277	502	278	455	275	428	274	474
Max Regulation Down Requirement (MW)	- 382	- 569	- 434	- 763	- 440	- 515	- 353	- 442
Max Load-following Up Requirement (MW)	2,292	3,207	3,140	3,737	2,680	3,326	2,624	3,063
Max Load-following Down Requirement (MW)	- 2,246	- 3,275	- 3,365	- 3,962	- 2,509	- 3,247	- 2,424	- 3,094

Expected regulation and load-following ramp rate (MW/Min) requirements

	Spring		Summer		Fall		Winter	
	2006	2012	2006	2012	2006	2012	2006	2012
Max Regulation Ramp Up Rate (MW)	67	122	75	118	70	114	73	107
Max Regulation Ramp Down Rate (MW)	- 66	- 90	- 76	- 97	- 72	- 90	- 79	- 90
Max Load-following Ramp Up Rate (MW)	150	168	166	194	147	181	143	165
Max Load-following Ramp Down Rate (MW)	- 138	- 162	- 145	- 169	- 134	- 167	- 158	- 198

10 years forward

- 33% RPS is massive on the national and global scales.
- High level of uncertainty (technological and financial viability).
- More thermal support unless storage, demand response, and smart grid take off.
- The environmental debate – “air green vs. habitat green”.
- Electric vehicle impact – is that the right approach?

Expected regulation and load-following capacity (MW) requirements

	Spring			Summer			Fall			Winter		
	2006	2012	2020	2006	2012	2020	2006	2012	2020	2006	2012	2020
Max Regulation Up Requirement (MW)	277	502	1135	278	455	1444	275	428	1308	274	474	1286
Max Regulation Down Requirement (MW)	- 382	- 569	- 1,097	- 434	- 763	- 1,034	- 440	- 515	- 1,264	- 353	- 442	- 1076
Max Load-following Up Requirement (MW)	2,292	3,207	4,423	3,140	3,737	4,841	2,680	3,326	4,565	2,624	3,063	4,880
Max Load-following Down Requirement (MW)	- 2,246	- 3,275	- 5,283	- 3,365	- 3,962	- 5,235	- 2,509	- 3,247	- 5,579	- 2,424	- 3,094	- 5,176

Expected regulation and load-following ramp rate (MW/Min) requirements

	Spring			Summer			Fall			Winter		
	2006	2012	2020	2006	2012	2020	2006	2012	2020	2006	2012	2020
Max Regulation Ramp Up Rate (MW)	67	122	447	75	118	528	70	114	472	73	107	344
Max Regulation Ramp Down Rate (MW)	- 66	- 90	- 310	- 76	- 97	- 300	- 72	- 90	- 301	- 79	- 90	- 303
Max Load-following Ramp Up Rate (MW)	150	168	325	166	194	313	147	181	324	143	165	296
Max Load-following Ramp Down Rate (MW)	-138	-162	-451	-145	-169	-434	-134	-167	-438	-158	-198	- 427

30+ years forward……

- EPRI PRISM 2.0
- Picking narrow resource portfolio now will be wrong at best.
- What happens if we abandon coal technology?
- Can 50-80% reduction in emission be achieved without nuclear?

What have we done?

- Transmission infrastructure
- Market products for services
- Supporting and piloting storage technology
- Wind and solar forecasting
- Renewable operation center
- Guiding policy-making
- Smart Grid architecture

No better time for education and research!