Simulations of Scenarios with 100% Renewable Electricity in the National Electricity Market

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Why 100% renewable electricity?

- AR4 (IPCC, 2007) stabilisation target for 2°C
  - 80% to 95% below 1990 emissions by 2050
- Australian Government policy
  - 80% below 2000 emissions by 2050
- Some current jurisdictional targets
  - Australia: 20% by 2020
  - California: 33% by 2020
  - Germany: 80% by 2050
  - New Zealand: 90% by 2025
- IEA BLUE High Ren 2050 scenario (~75% renewable)

Outline

- Previous studies
- What we're doing (and not) doing
- Overview of simulation framework
- Baseline generation mix
- Results
- Sensitivity analyses
- Observations at 100%

Some Australian low carbon scenario studies

Year	Authors	Emission reduction
2004	Saddler, Diesendorf & Denniss for Clean Energy Future Group for WWF	50% below 2001 in CO_2 emissions from stationary energy by 2040
2006	Energy Futures Forum led by CSIRO	6 scenarios for energy to 2050, including 50% below 1990 in CO_2-e by 2050
2007	Diesendorf for Greenpeace	2 scenarios, including 33% below 1990 level in total CO_2-e by 2020
2008	Teske & Vincent for Greenpeace	37% below 2005 in energy-related CO_2 emissions by 2020
2010	Beyond Zero Emissions	Zero CO_2 emissions from stationary energy by 2020

What we're doing

- Could the NEM have reliably operated in 2010 using 100% renewable generation?

Map courtesy of ema.gov.au

What we're doing

- Simulating scenarios of 100% RElec in the NEM
  - Minimal assumptions
  - Available technology only
  - Main (temporary) assumption: “copper plate”
- Simulate 2010 hour by hour
  - Actual demand & weather conditions
  - Detailed modelling of generators
- Quantify reliability implications
  - Unserved energy (current NEM standard 0.002%)
  - Hours of unmet demand

What we're not doing

- A plan
- Covering national electricity demand
- Covering all end-use energy
  - transport, heating, industrial processes
- Complex demand response (yet)
- Transmission modelling (yet)
- Economics (yet)

Simulation overview

- Written in the Python programming language
- Framework + database
- Database
  - Electricity demand & wind generation (AEMO)
  - Solar radiation & weather records (BoM)
- Compact, easily desk checked code base
- Easy to add new generator types
- What-ifs can be easily tested on the fly

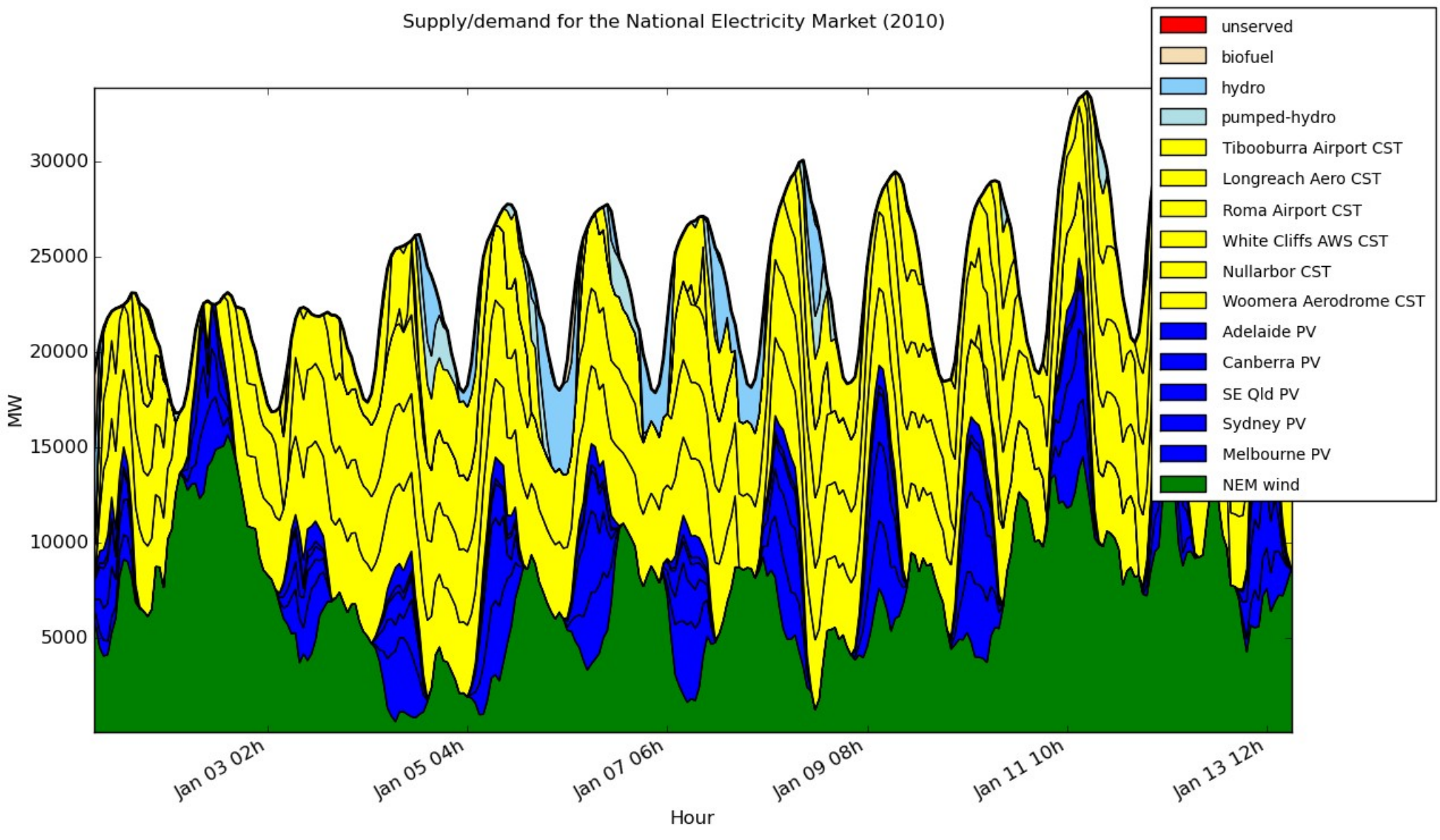
Baseline generation mix

Technology	Fraction (by energy)	Capacity (GW)	Remarks
Wind	30%	23.2	Existing NEM sites
CST	40%	15.6	Parabolic troughs, 15h storage, solar multiple 2.5
PV	10%	14.6	Roof-top PV in capital cities
Pumped hydro		2.2	Existing stations
Conventional hydro		4.9	Existing stations
Gas turbines		24.0	Biofuelled

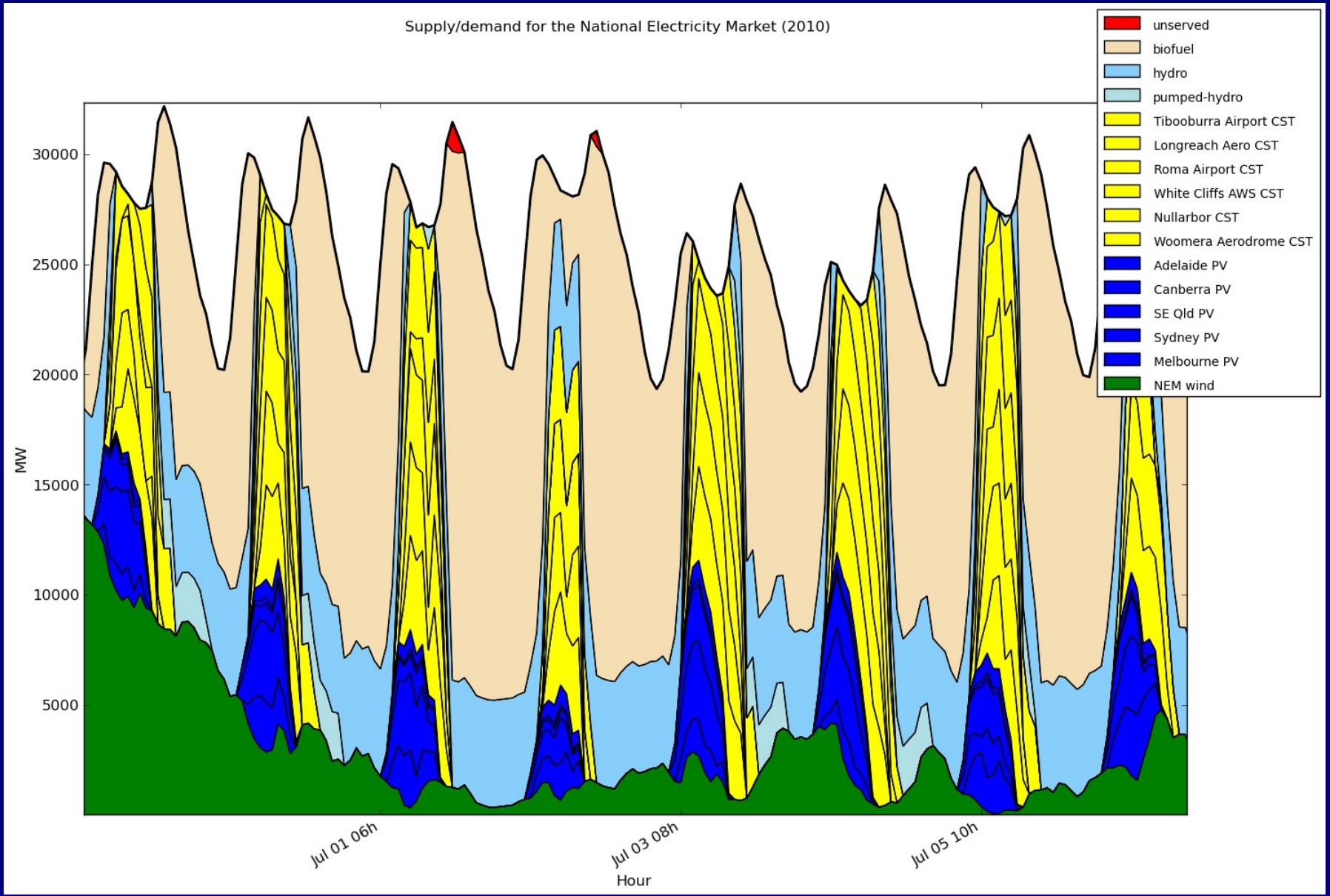
Baseline simulation summary

Total NEM demand (TWh)	204.4
Spilled energy (TWh)	10.2
Spilled hours	1,606
Unserved energy (%)	0.002
Unmet hours	6
Gas turbine electrical energy (TWh)	28.0
Largest supply shortfall (MW)	1,333

January 1 – 13


Supply/demand for the National Electricity Market (2010)
unserved
biofuel
hydro
pumped-hydro
Tibooburra Airport CST
Longreach Aero CST
Roma Airport CST
White Cliffs AWS CST
Nullarbor CST
Woomera Aerodrome CST
Adelaide PV
Canberra PV
SE Qld PV
Sydney PV
Melbourne PV
NEM wind
MW
30000
25000
20000
15000
10000
5000
Jan 03 02h
Jan 05 04h
Jan 07 06h
Jan 09 08h
Jan 11 10h
Jan 13 12h
Hour

June 29 – July 6



Sensitivity analyses

Reduce demand during winter peaks (baseline gas turbine capacity)

Demand fraction	Unmet hours	Maximum shortfall (MW)
1.00	6	1,333
0.99	6	1,019
0.98	4	704
0.97	2	389
0.96	2	75
0.95	0	0

Sensitivity analyses

Increase CST solar multiple: 2.5 → 4.0

Solar multiple	Unmet hours	Spilled hours	Spilled energy (TWh)	Gas turbine generation (TWh)
2.5	6	1606	10.2	28.0
3.0	0	1922	12.3	22.8
3.5	0	2182	13.9	19.1
4.0	0	2380	15.2	16.5

Sensitivity analyses

Increase CST capacity by 1GW per plant

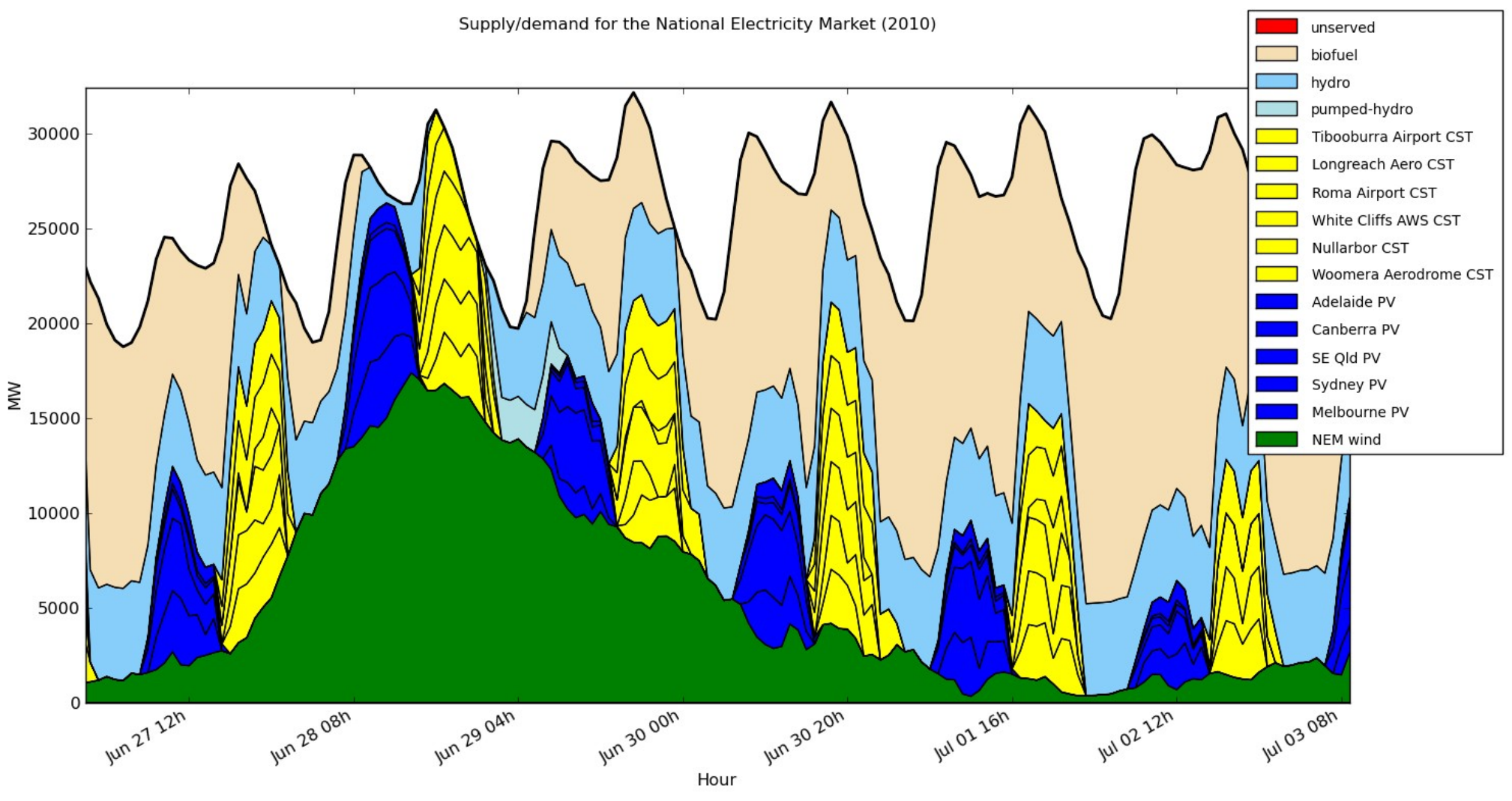
CST capacity (GW)	Unmet hours	Spilled hours	Spilled energy (TWh)	Gas turbine generation (TWh)
15.6	6	1606	10.2	28.0
21.6	4	3276	27.2	22.5
27.6	2	4422	50.5	20.0
33.6	2	5083	76.4	18.7
39.6	0	5456	103.3	17.9

Sensitivity analyses

Delay CST dispatch by *n* hours

Delay (hours)	Unmet hours	Spilled hours	Gas turbine generation (TWh)
0	6	1606	28.0
1	2	1597	27.2
2	0	1572	26.4
3	0	1528	25.7
4	0	1497	25.1
5	0	1478	24.7
6	**0**	**1454**	**24.5**
7	0	1450	24.8
8	1	1488	25.6
9	10	1528	26.6
10	20	1573	27.7

7h delayed CST dispatch (winter)



Sensitivity analyses

Impact of reducing peak demand on gas turbine capacity required to maintain NEM reliability standard

Gas turbine capacity (GW)	Peak demand reduction (%)
22	0
21	0
20	2
19	5
18	9
17	12
16	16
15	19

Observations at 100%

- 2010 NEM load reliably met with renewable energy
  - System security from gas turbines & demand response
  - 14% energy demand met from bioenergy
- 100% RElec is challenging
  - Hydro of limited help (“biofuel saver”)
  - Refinements (e.g. ↑ wind regime diversity) may reduce bioenergy
  - Demand response clearly needed
- “Baseload plant” an outmoded concept
  - Goal is to reliably meet all demand
  - Baseload always met in the simulation, *peak* load is harder
- Next steps: remove “copper plate” and economic modelling

Questions?

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