Simulations of Scenarios with 100% Renewable Electricity in Australia

Ben Elliston, Mark Diesendorf, Iain MacGill
University of New South Wales

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
- High emissions intensity: 90% fossil, ~184MT / y
- Low carbon electricity options
  - Nuclear power
  - CCS
  - **Renewable energy**

Why 100% renewable electricity?

- Government targets
  - Australia: 20% by 2020
  - California: 33% by 2020
  - EU-25: 21% by 2020
  - Germany: 80% by 2050 (SRU “100%”)
  - New Zealand: 90% by 2025
  - Scotland: 100% of consumption by 2020
- “Kombikraftwerk”, Univ. of Kassel

What we're doing

- Testing 100% renewable supply in NEM
- Generation sited in NEM regions only

Map courtesy of ema.gov.au

What we're doing

- Test 100% renewable supply in NEM
  - Minimise assumptions
  - Main assumption: “copper plate”
- Available technology only
- Simulate 2010 hour by hour
  - demand and weather records
  - detailed modelling of renewable generators (SAM)
- Quantify reliability implications
  - unserved energy (NEM standard 0.002%)
  - hours of unmet demand

What we're *not* doing

- Meeting all Australian electricity demand
- Meeting all end-use energy demand
  - heating, industrial processes, transport
- Modifying demand (yet)
- Economics (yet)
- Specifying a plan for deployment

Baseline generation mix

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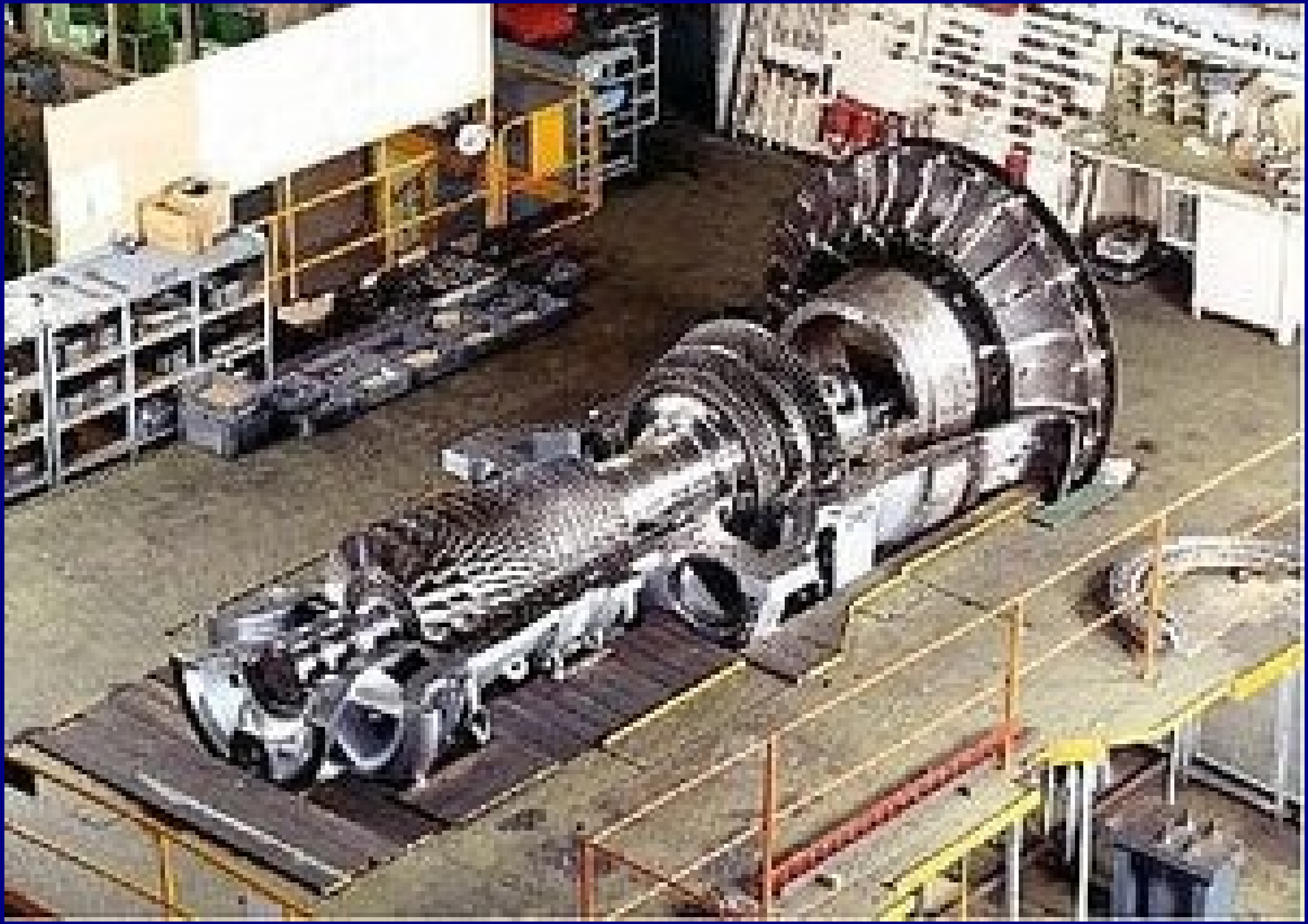
- Parabolic trough CST with 15h storage, 40%
- Photovoltaics (PV), 10%
- Existing hydro plants
  - 2.2GW with pumped storage (charged w/ spills)
  - 4.9GW without
- Gas turbines fuelled by biofuels
  - Aim to minimise fuel consumption

Baseline generation mix

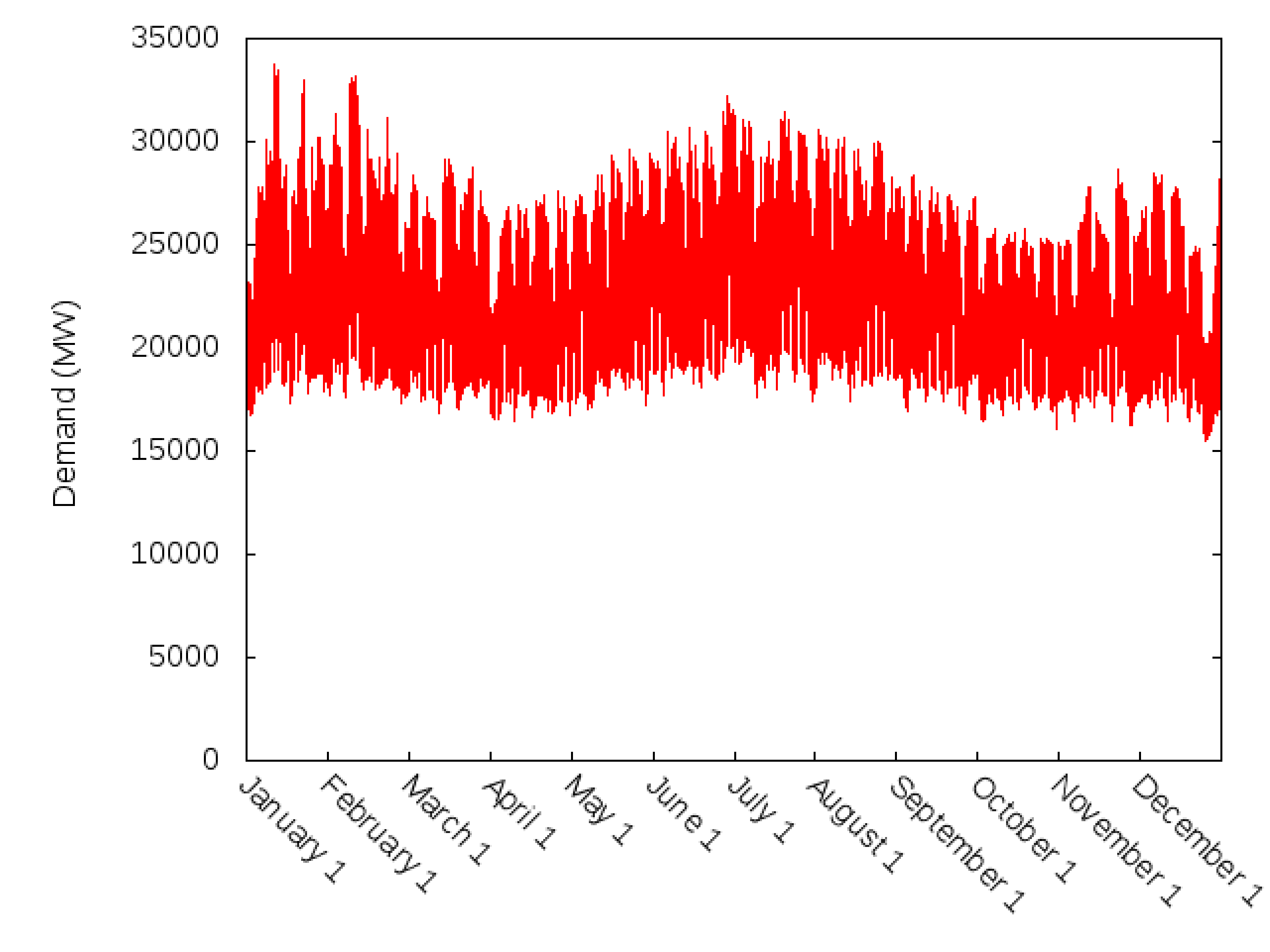


Baseline generation mix

- CST: 15.6 GW across 6 sites
  - Spanish target of 5 GW by 2020
- Wind: 23.2 GW from existing NEM sites
  - 42 GW now in USA
- PV: 14.6 GW
  - 16.5 GW now in Germany
- Pumped storage hydro: 2.2GW
- Hydro without pumped storage: 4.9 GW
- Gas turbines, biofuelled: 24 GW

Integrated data sources

- Electricity demand



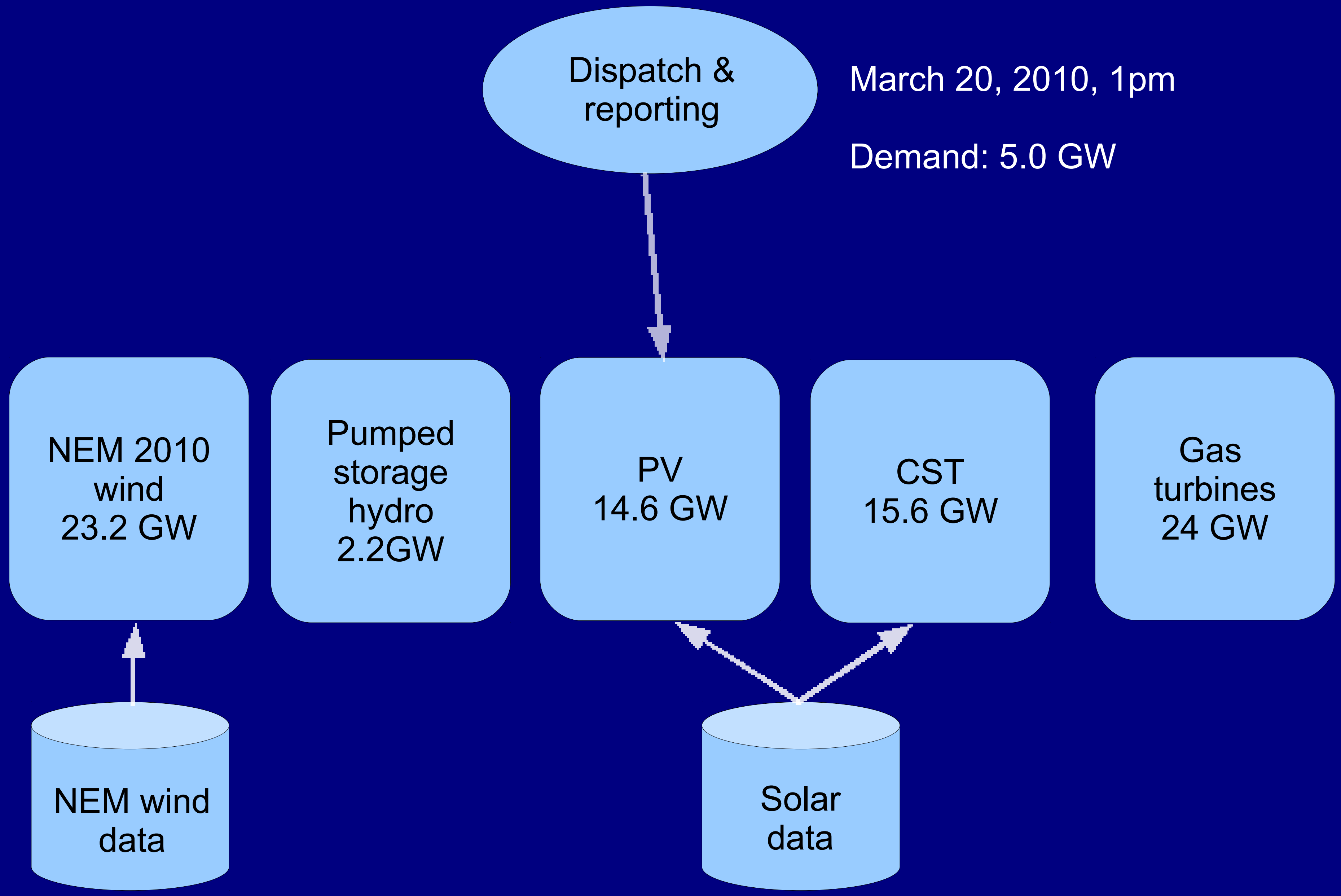
Integrated data sources

- Electricity demand
- Wind generation
- Solar radiation
- Weather records
  - Wind speed
  - Air temperature
  - Relative humidity
  - etc.

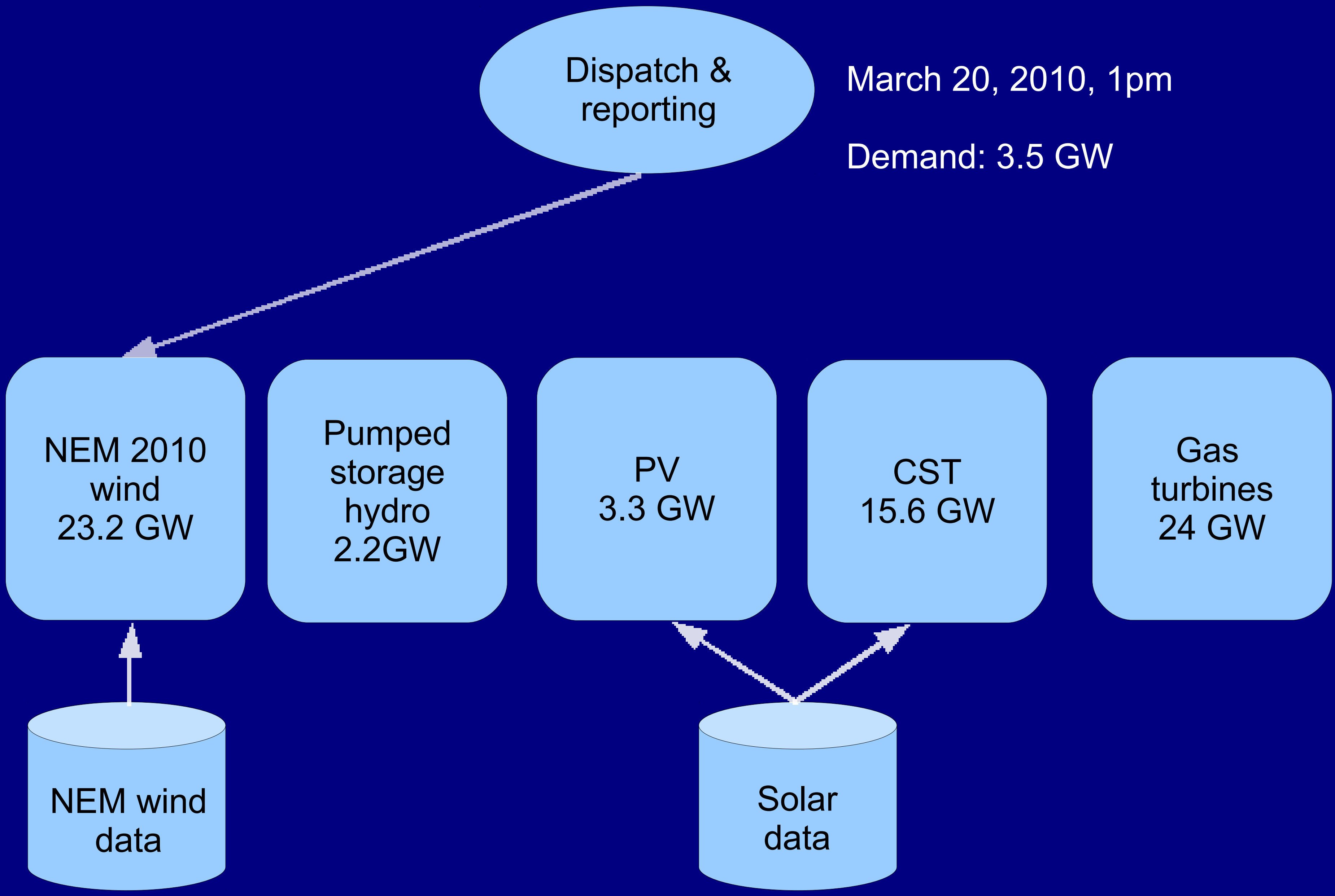
Simulation overview

- Written in the Python programming language
- Changes can be made on the fly
- Compact, easily desk checked code base
- Easy to add new generator classes
- Open source (GPL license)

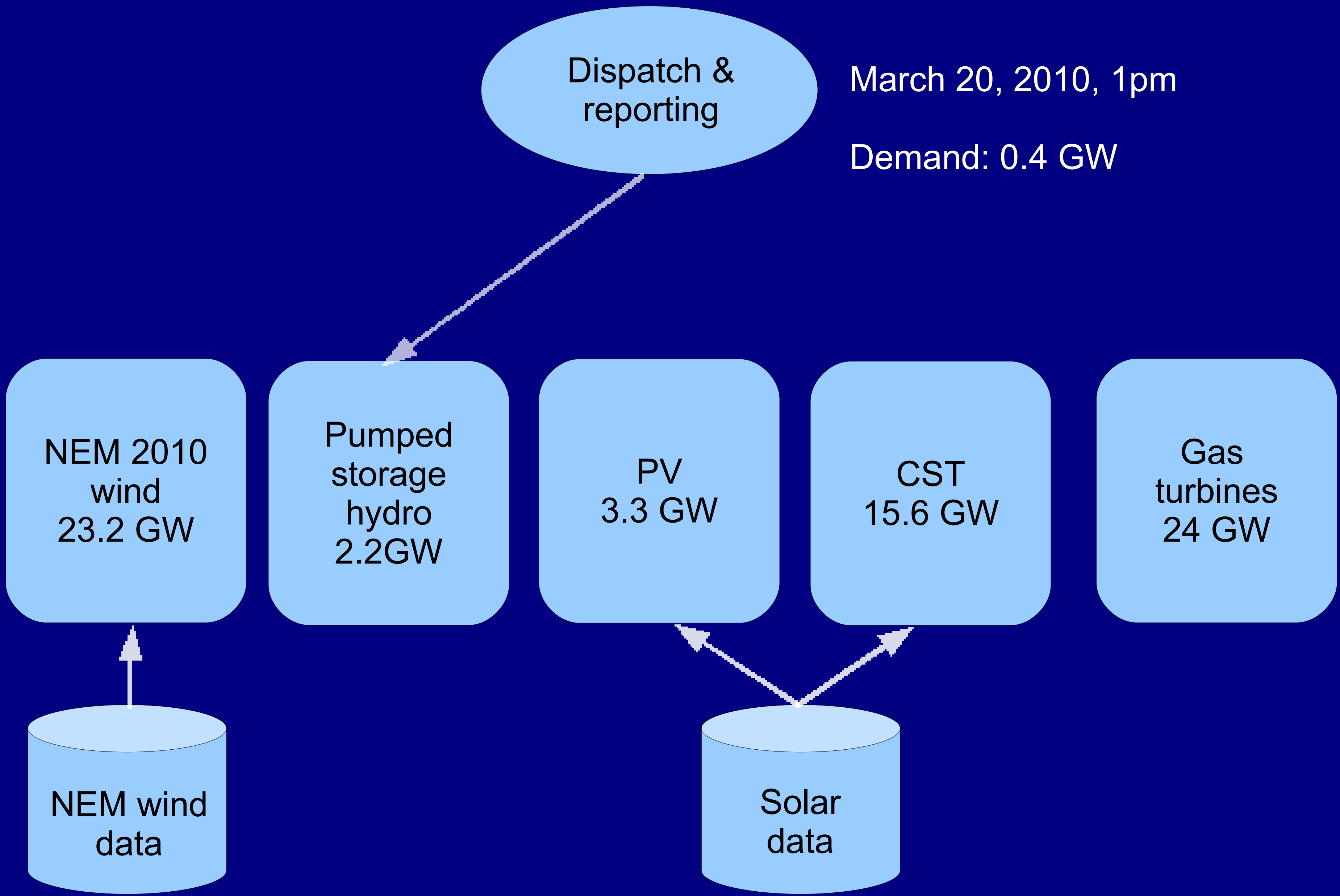
Simulation example



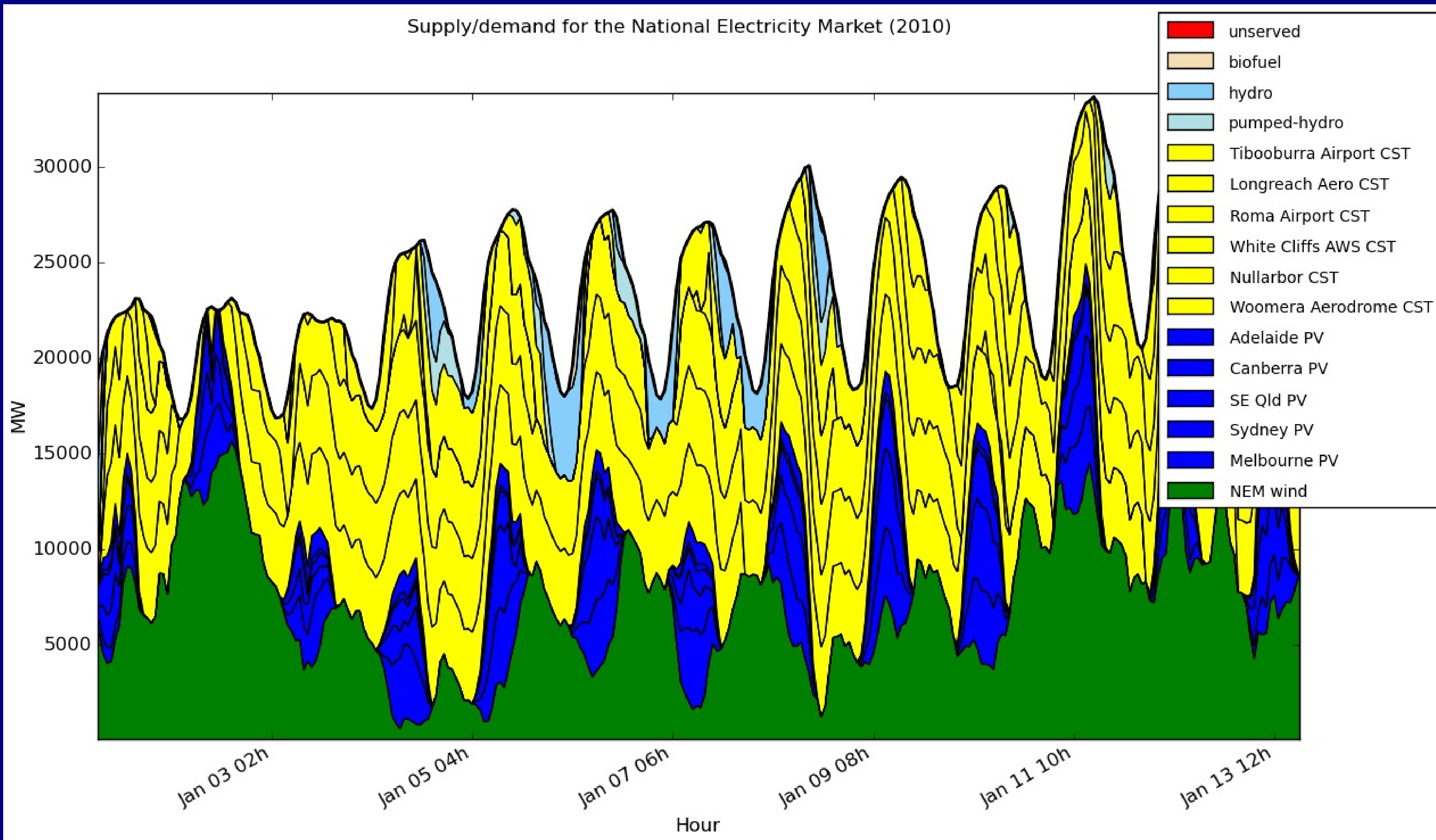
Simulation example



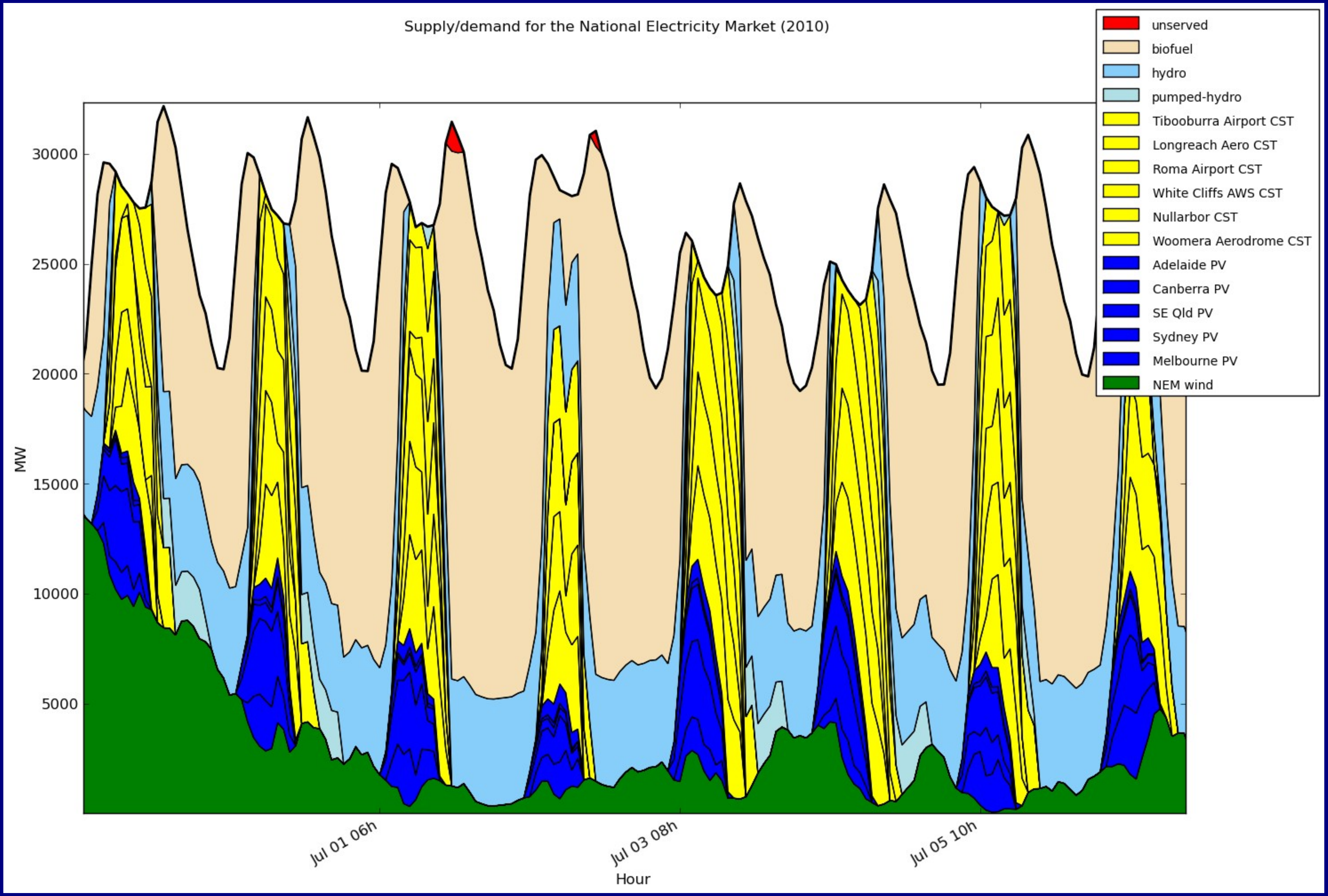
Simulation example



Simulated summer week



Simulated winter week



Baseline simulation summary

Spilled energy (TWh)	9.0
Spilled hours	1442
Unserved energy	0.002%
Unmet hours	6
Gas turbines electrical demand (TWh)	28.1
Largest supply shortfall (MW)	1333

Sensitivity analysis

- Reduce demand during winter peaks (with 24GW peaking capacity)

Demand fraction	Unmet hours	Maximum supply shortfall (MW)
1.00	6	1333
0.99	6	1019
0.98	4	704
0.97	2	389
0.96	2	75
0.95	0	0

Sensitivity analysis

- Reduce CST storage: 15 to 5 full-load hours

Hours storage	Gas turbine generation (TWh)	Spilled hours	Unmet hours
15	28.1	1442	6
5	35.9	980	6

Sensitivity analysis

- Increase CST solar multiple: 2.5 to 3.0

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Solar multiple	Unmet hours	Spilled hours	Spilled energy (TWh)	Gas turbine generation (TWh)	Gas turbine capacity (GW)
2.5	6	1442	9.0	28.1	24
3.0	0	1737	10.8	22.9	22

Sensitivity analysis

- Double CST capacity: 15.6 to 31.2 GW

Capacity (GW)	Unmet hours	Spilled hours	Spilled energy (TWh)	Gas turbine generation (TWh)
15.6	6	1442	9.0	28.1
31.2	2	4782	62.7	19.2

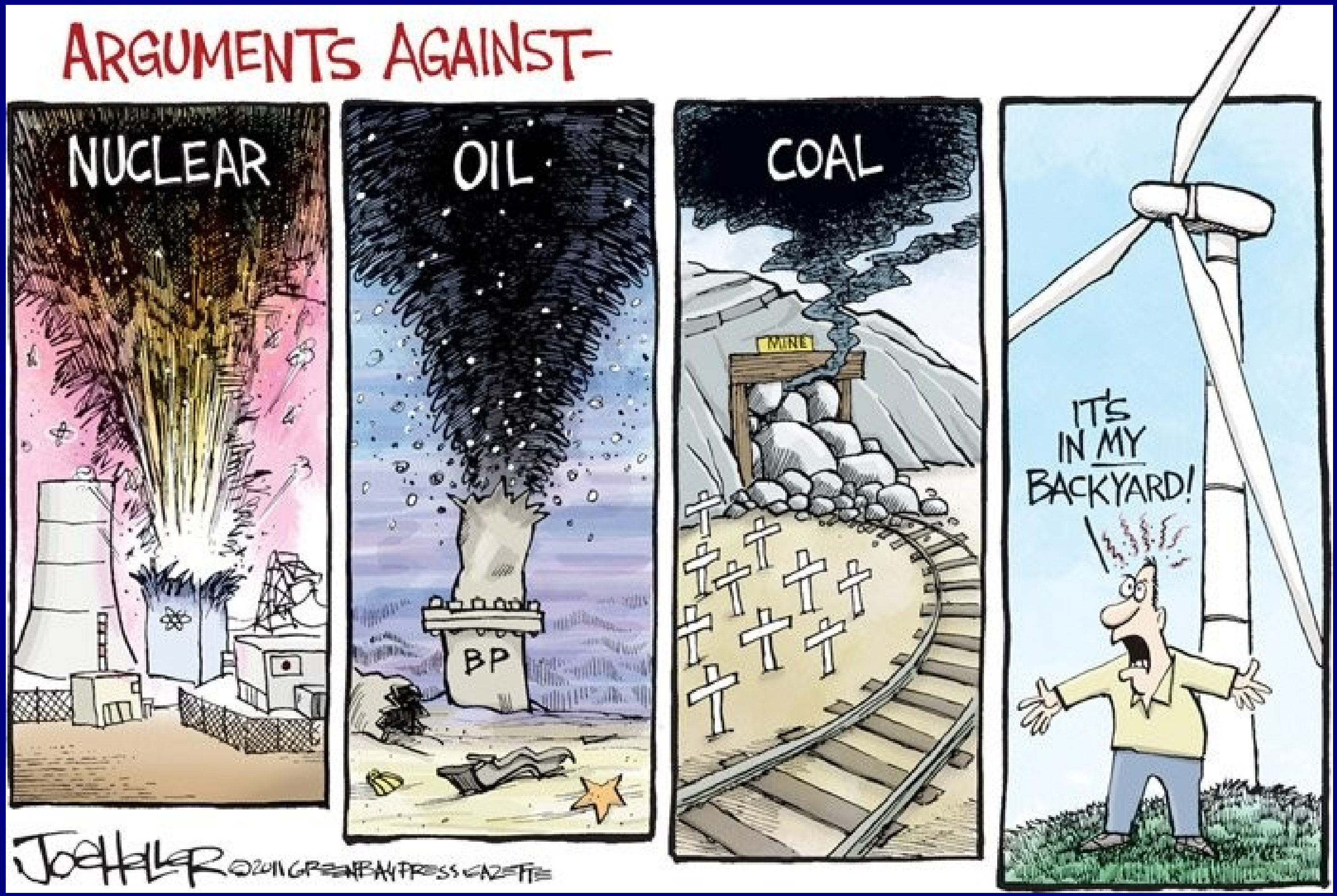
Observations at 100%

- Australia lacks long-term energy storage
- Hydro of limited help (“biofuel saver”)
- Seasonal solar variation makes high solar penetration difficult – size for winter or summer?
- Security from high capacity peaking plants
- Current wind generation is too highly correlated

Conclusions

- NEM load can be reliably met using such a mix
  - Baseload can be met, peak load is harder
- Biomass used for about 14% of total supply
- 100% RElec is challenging
  - Using available technology
  - Improvements can reduce biomass requirement
  - Demand side management needed
- Economic analysis is needed

Questions?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