Transitioning to a 100% renewable electricity generation system: balancing the roles of wind generation, base-load generation and hydro storage

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GENERAL ASSUMPTIONS

- Centrally planned and operated system
- Single goal: optimal use of energy resources => minimisation of spillage
- Hydro operation allowed to vary
- Hydro lake system treated as single reservoir

PREVIOUS WORK

- Data: half-hourly generation, 2005-2007

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- All coal, gas, oil generation removed

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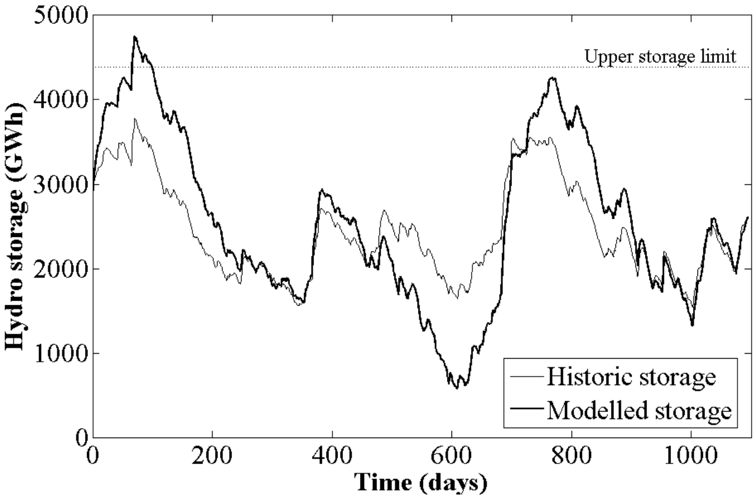
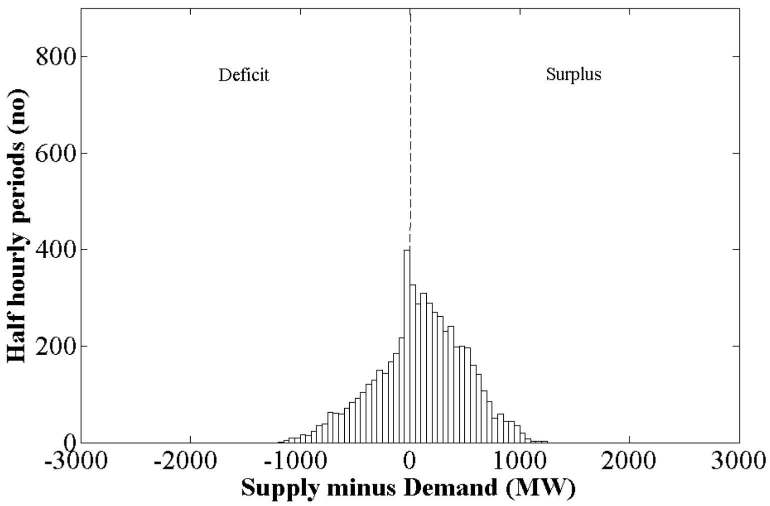
- All coal, gas, oil generation removed
- Hydro, biomass – capacity unaltered
- Wind & geothermal – capacity added
- Modelled surplus/deficit; storage...

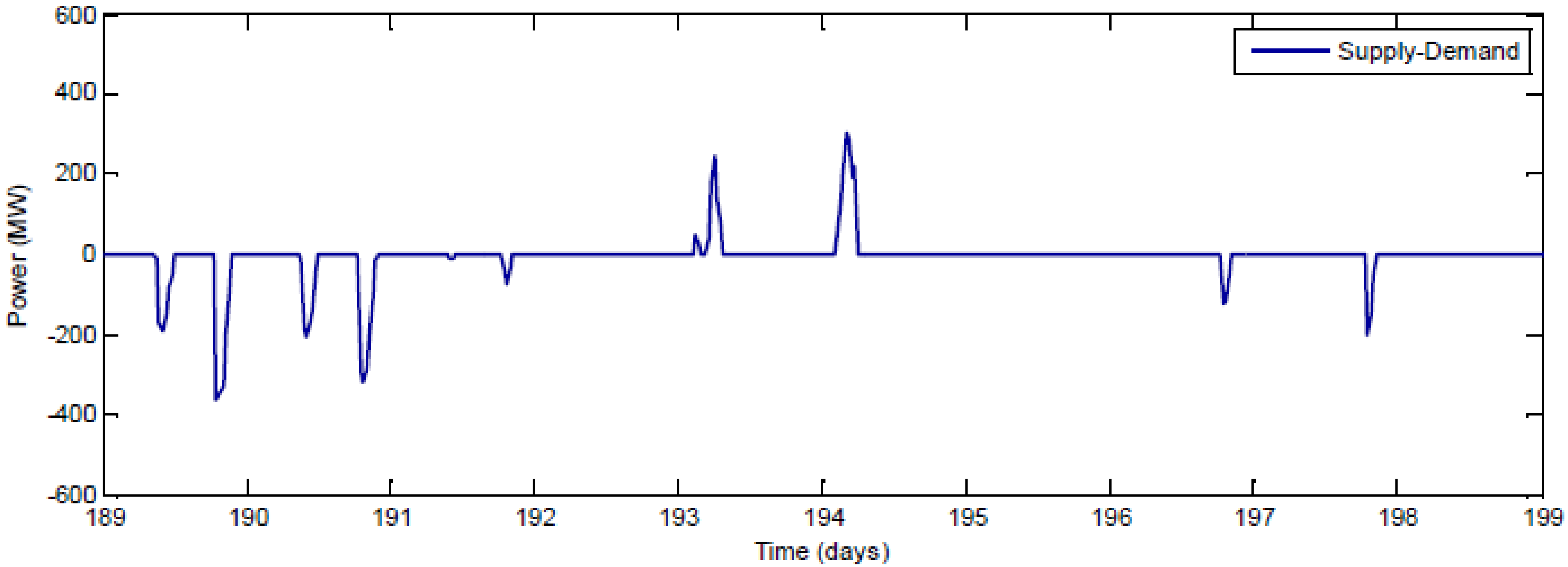
STEP 4: Wind (2230 MW)+ geothermal (1202 MW) + variable hydro scheduling

Lake levels



Deficits and surpluses

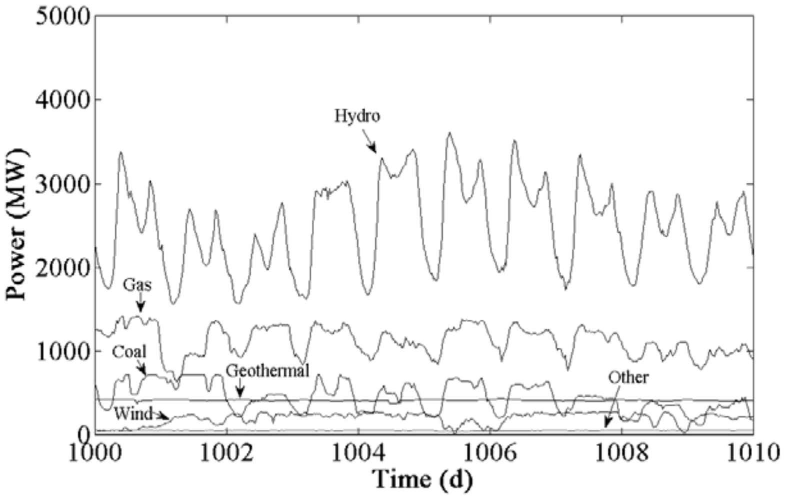




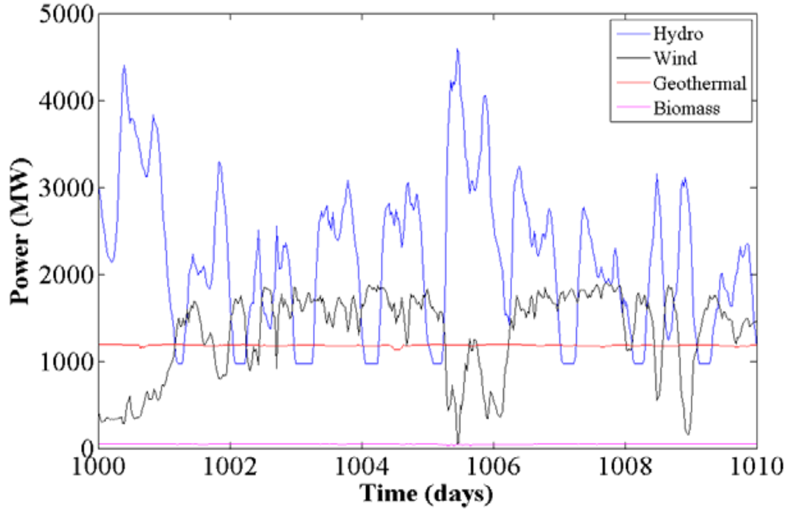
Supply-Demand
600
400
200
0
-200
-400
-600
Power (MW)
189
190
191
192
193
194
195
196
197
198
199
Time (days)

GENERATION PATTERNS

HISTORIC (half-hourly)



STEP 4 (half-hourly)



REMAINING DEFICITS

- Step 4 peak => 1167 MW
- Demand-side measures; and/or
- Additional peaking plant
- Generation mixes…

Table 2: Generation mix (GM) characteristics

Parameter	Units	GM1	GM2	GM3	GM4
Installed capacity					
Hydro	MW	5347.0	5347.0	5347.0	5347.0
Wind	MW	2187.2	2187.2	2219.1	2219.1
Geothermal	MW	1202.0	1202.0	1202.0	1202.0
Biogas	MW	23.7	23.7	23.7	23.7
Wood thermal	MW	79.2	79.2	79.2	79.2
Additional peaking plant	MW	0	1167.0	0	355.0
Total	MW	8839.1	10006.1	8871.0	9226.0
System parameters					
WP (installed capacity)	%	24.7	21.9	25.0	24.1
WP (energy share)	%	18.5	18.4	18.7	18.7
WP (instantaneous – max)	%	48.7	-	48.7	-
Wind useful energy	%	97.3	97.3	97.2	97.2
Capacity credit	%	107.1	47.8	105.4	87.6

Notes: GM1: step 4 without additional peaking plant; GM2: step 4 plus additional peaking plant; GM3: step 5 without additional peaking plant; GM4: step 5 plus additional peaking plant.

PRESENT STUDY

- Explore: combinations of wind and base-load generation required to keep storage at or above acceptable levels…

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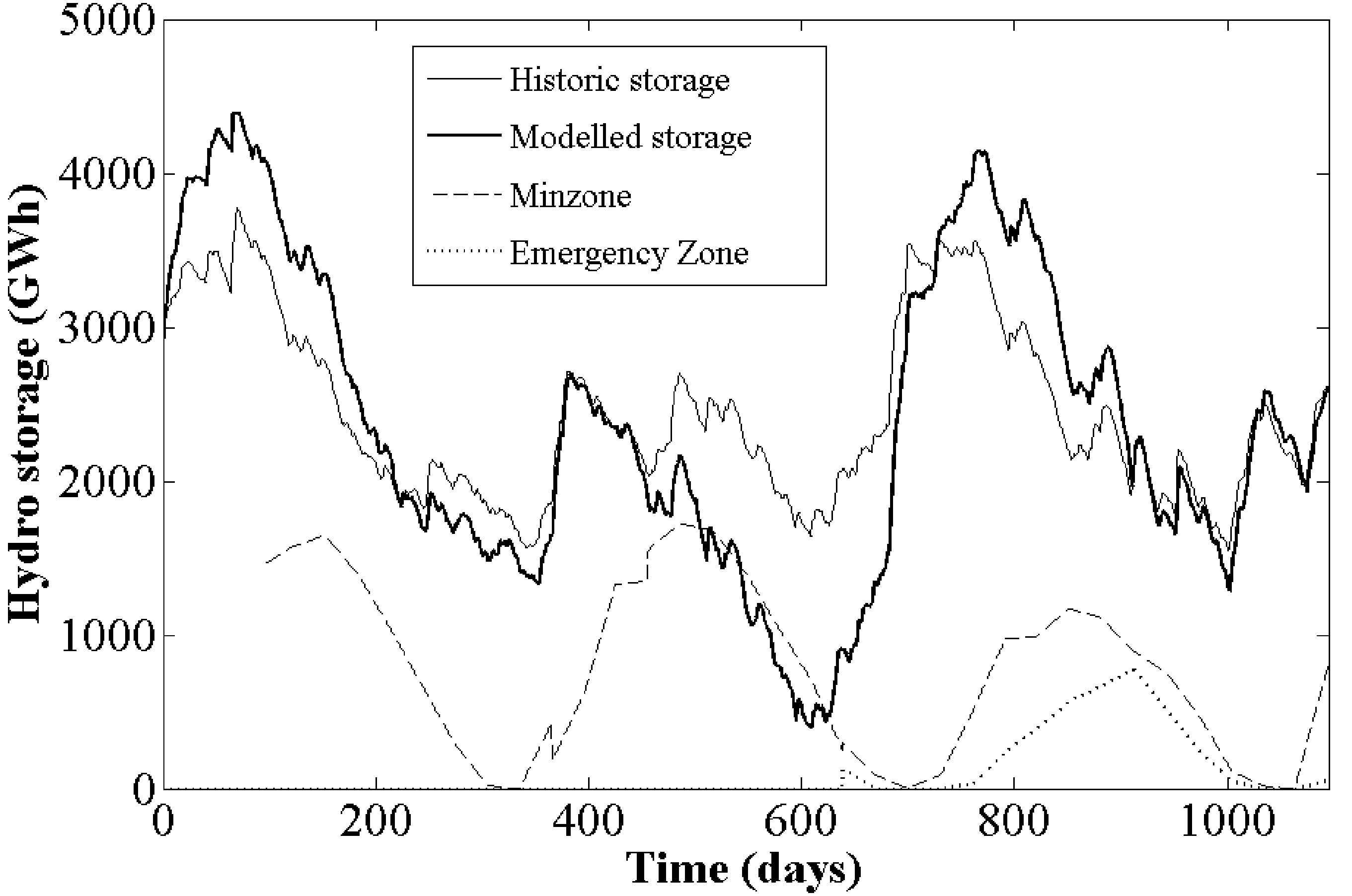
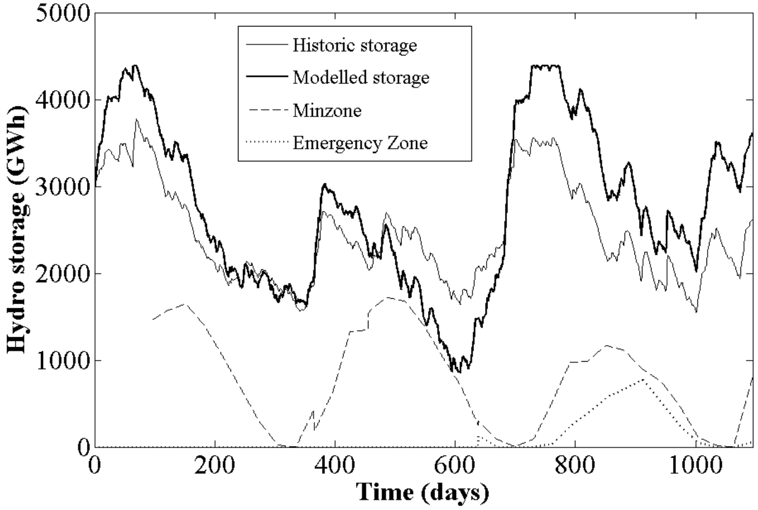
- EC/EA: Minzone, Ezone, hydro risk curves…
- Consider: additional peaking plant, hydro spillage, storage capacity, demand-side management

Previous step 4 with “Minzone” and “Ezone” curves added

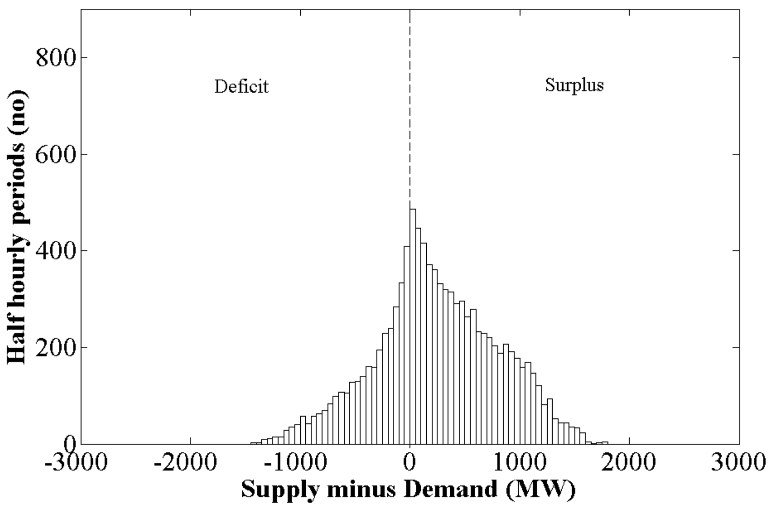


Scenario 1: Base-load (500+431 MW) + Wind (3266 MW)

Lake levels



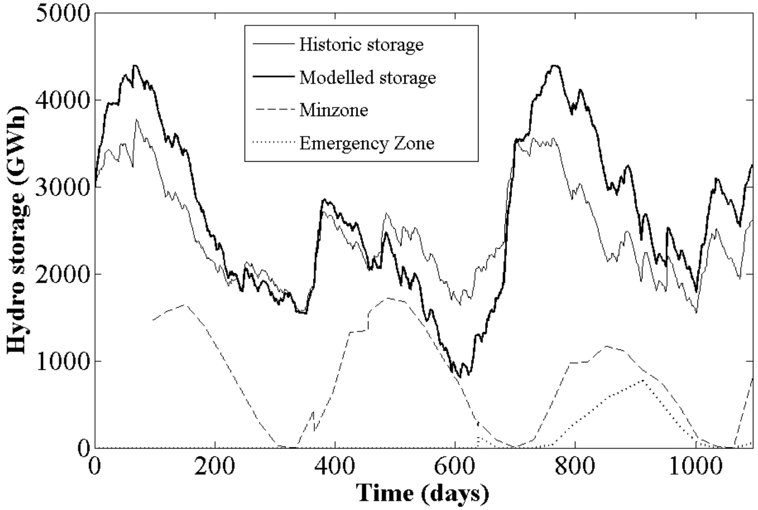
Deficits and surpluses

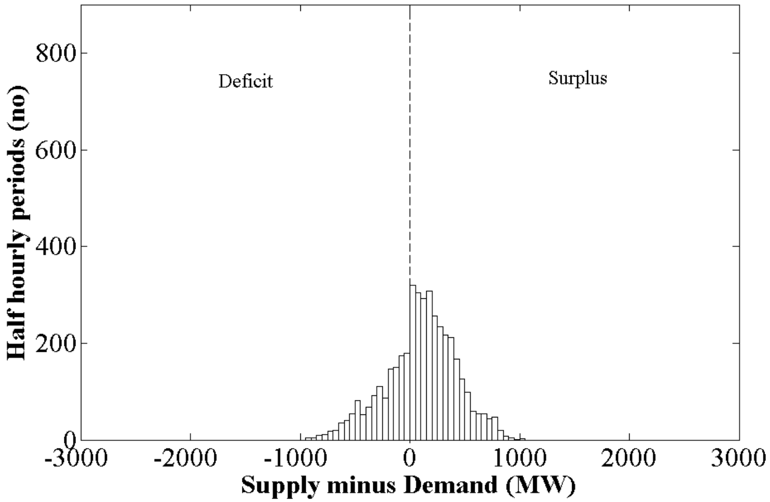


Scenario 2: Base-load (1000+431 MW) + Wind (1801 MW)

Lake levels

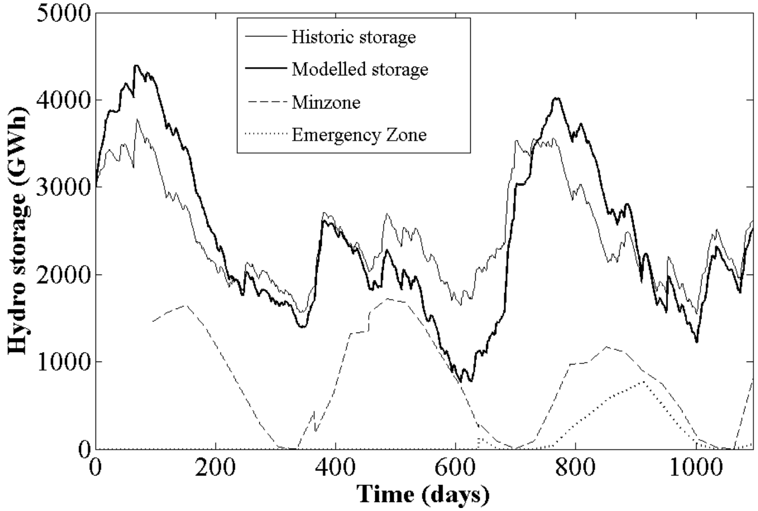
Deficits and surpluses



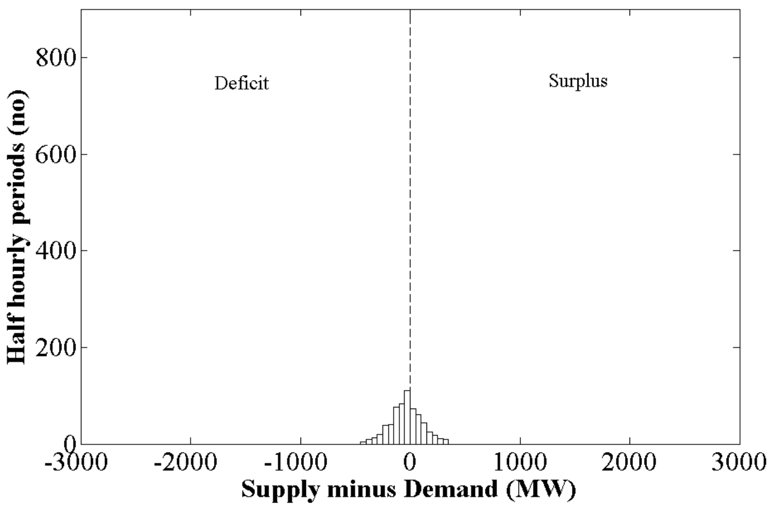


Scenario 3: Base-load (1500+431 MW) + Wind (400 MW)

Lake levels



Deficits and surpluses



RESULTS & DISCUSSION

- S1: peak deficit 1433 MW; wind spillage 1823 GWh; hydro spillage 1070 GWh

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- S3: peak deficit 448 MW; wind spillage 13 GWh; hydro spillage 240 GWh

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- S2: peak deficit 940 MW; wind spillage 389 GWh; hydro spillage 534 GWh
- S3: peak deficit 448 MW; wind spillage 13 GWh; hydro spillage 240 GWh
- Tension: plentiful and cheap wind vs peaking and spillage issues

Table 3: Generation mix characteristics with additional peaking plant

Parameter	*Units*	*Scenario 1*	*Scenario 2*	*Scenario 3*
Installed capacity:				
Hydro	MW	5347.0	5347.0	5347.0
Wind	MW	3266.0	1801.0	400.0
Geothermal plus new base-load	MW	931.0	1431.0	1931.0
Biofuels	MW	102.9	102.9	102.9
Additional peaking plant	MW	1432.9	940.2	448.0
Total	MW	11097.8	9622.1	8228.9
Model outputs (over 3 y):				
WP (installed capacity)	%	29.5	18.7	4.9
WP (energy share)	%	25.6	14.6	3.3
Wind capacity credit	%	31.0	59.3	514.1
Peaking plant capacity factor	%	1.59	0.71	0.02
ALOL[a]	d/y	0	0	0

Note: [a] actual loss of load

RESULTS & DISCUSSION 2

- Security of supply maintained

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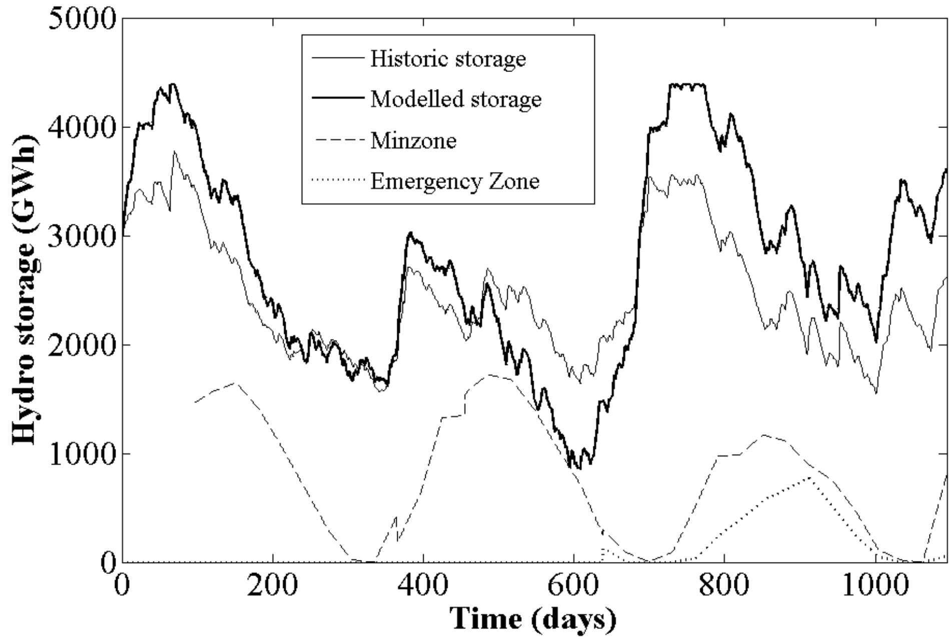
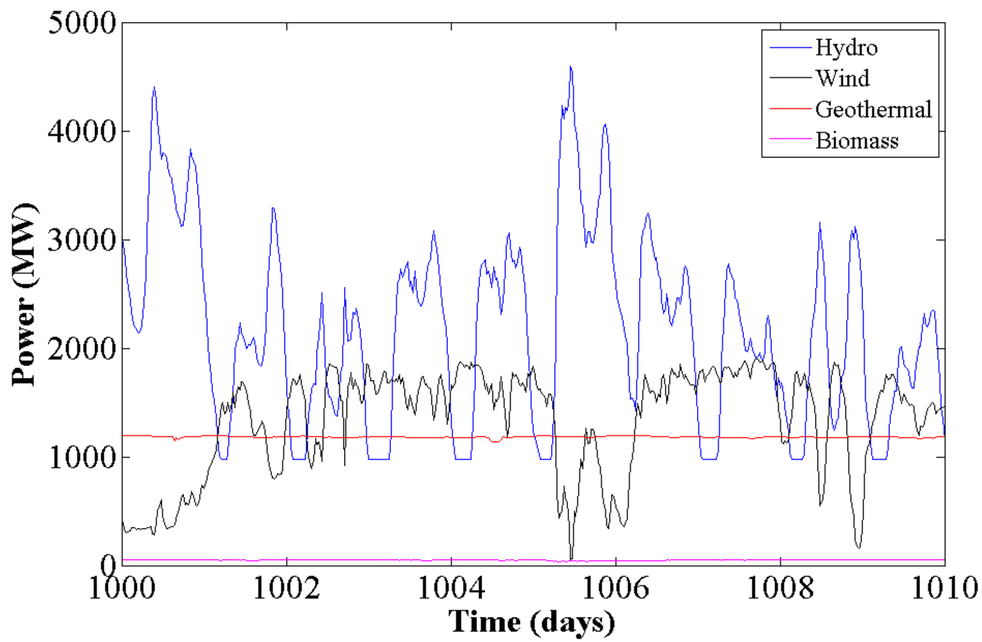
- DSM: water heating; industrial…

RESULTS & DISCUSSION 2

- Security of supply maintained
- Peaking options: pumped storage; biomass-gas; fossil gas (transitional)
- Base-load: geothermal, hydro…
- DSM: water heating; industrial…
- Base-load scheduling can minimise hydro spillage…



Historic storage
Modelled storage
Minzone
Emergency Zone
Hydro storage (GWh)
Time (days)
0
1000
2000
3000
4000
5000
0
200
400
600
800
1000



Hydro
Wind
Geothermal
Biomass
Power (MW)
Time (days)
0
1000
2000
3000
4000
5000
1000
1002
1004
1006
1008
1010

CONCLUSIONS

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- Wind is plentiful and cheap; geothermal is limited; new hydro is constrained
- Transitional planning must consider the appropriate balance.

APPENDIX: GHG Data

(Source: MED)

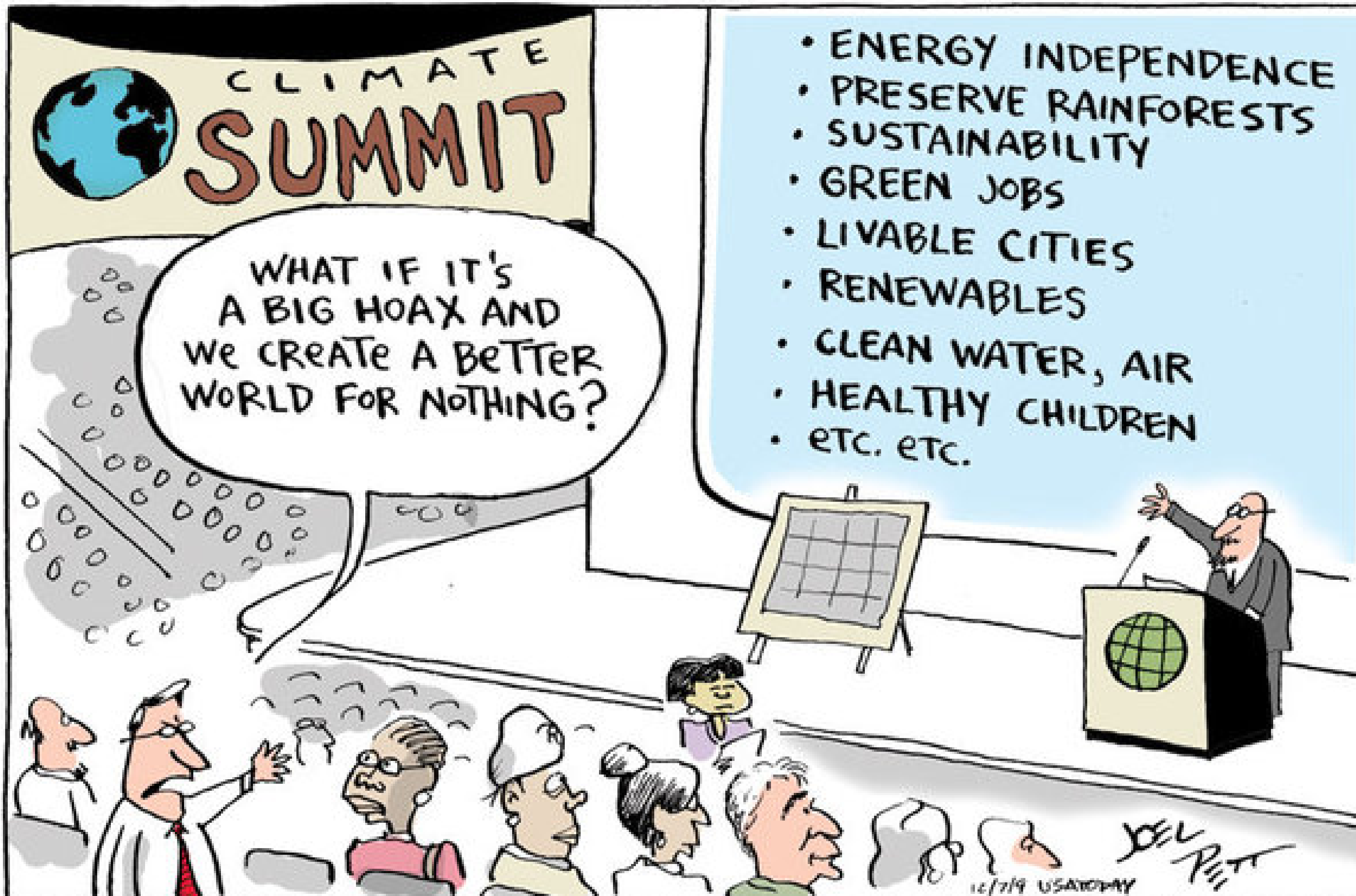
	GWh	CO_2 (kt)	CH_4(t)	CO_2 eq. (kt)	CO_2 (kt/GWh)	CH_4 (t/GWh)	CO_2 eq. (kt/GWh)
Mokai	448	19.4	131.9	22.2	0.04	0.29	0.05
Ngawha	74	42.5	405.0	51.1	0.57	5.47	0.69
Ohaaki	316	82.7	607.1	95.4	0.26	1.92	0.30
Pohipi	207	6.1	8.1	6.3	0.03	0.04	0.03
Rotokawa	221	17.4	-	17.4	0.08	0.00	0.08
Wairakei	1337	49.2	786.7	65.7	0.04	0.59	0.05
Total	2603.0	217.4	1938.8	258.1	0.08	0.74	0.10

APPENDIX

- Impact on electricity emissions factor:
- MfE (2008): 0.195 kg CO_2-e/kWh
- Our system: assuming a) 0.10 kg CO_2-e/kWh for geothermal; b) all new baseload is geothermal; c) negligible emissions from remaining generation
- New factors: 0.019-0.039 kg CO_2-e/kWh

FURTHER READING

- Mason, I.G., Page, S.C, and Williamson, A.G., 2010. A 100% renewable electricity generation system for New Zealand using hydro, wind, geothermal and biomass resources. Energy Policy 38(8) 3973-3984.



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• PRESERVE RAINFORESTS
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• GREEN JOBS
• LIVABLE CITIES
• RENEWABLES
• CLEAN WATER, AIR
• HEALTHY CHILDREN
• etc. etc.
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WISE ADVICE

- “The problems that exist in the world today cannot be solved by the level of thinking that created them”. Albert Einstein

THANKS FOR LISTENING

Any questions