Transmission Pricing Advisory Group

TPAG briefing: GEM analysis from stage II of the Review

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Note: This presentation has been prepared for discussion with the Transmission Pricing Advisory Group. Content should not be interpreted as representing the views or policy of the Electricity Authority.

What is GEM?

- Generation Expansion Model (GEM) – a long term planning or capacity expansion model
- GEM constructed to support preparation of GPAs and grid investment approvals, i.e. need to make assumptions about demand growth and generation development when assessing grid upgrades
- GEM has been used for many other analyses
  - Impact of electric vehicle uptake
  - Impact of schemes to reduce peak demand
  - Impact on renewable generation of alternative regimes for funding investment in transmission

GEM overview

- Basics
  - GEM is a long term capacity expansion planning model
  - Formulated as a mixed integer programming problem (MIP)
  - Deterministic – no stochastic processes to deal with uncertainty in demand, hydro inflow, gas price etc
  - Coded using GAMS and solved with CPLEX
  - Input data compiled in an Excel spreadsheet
  - Output files generated as tab or comma delimited text files
  - Matlab scripts used to process output files
  - Publicly available
- Objective function
  - Minimise discounted system costs
    - Capital expenditure on generation plant and transmission grid
    - Fixed and variable operating costs (including meeting reserves)
    - Penalties on potential infeasibilities

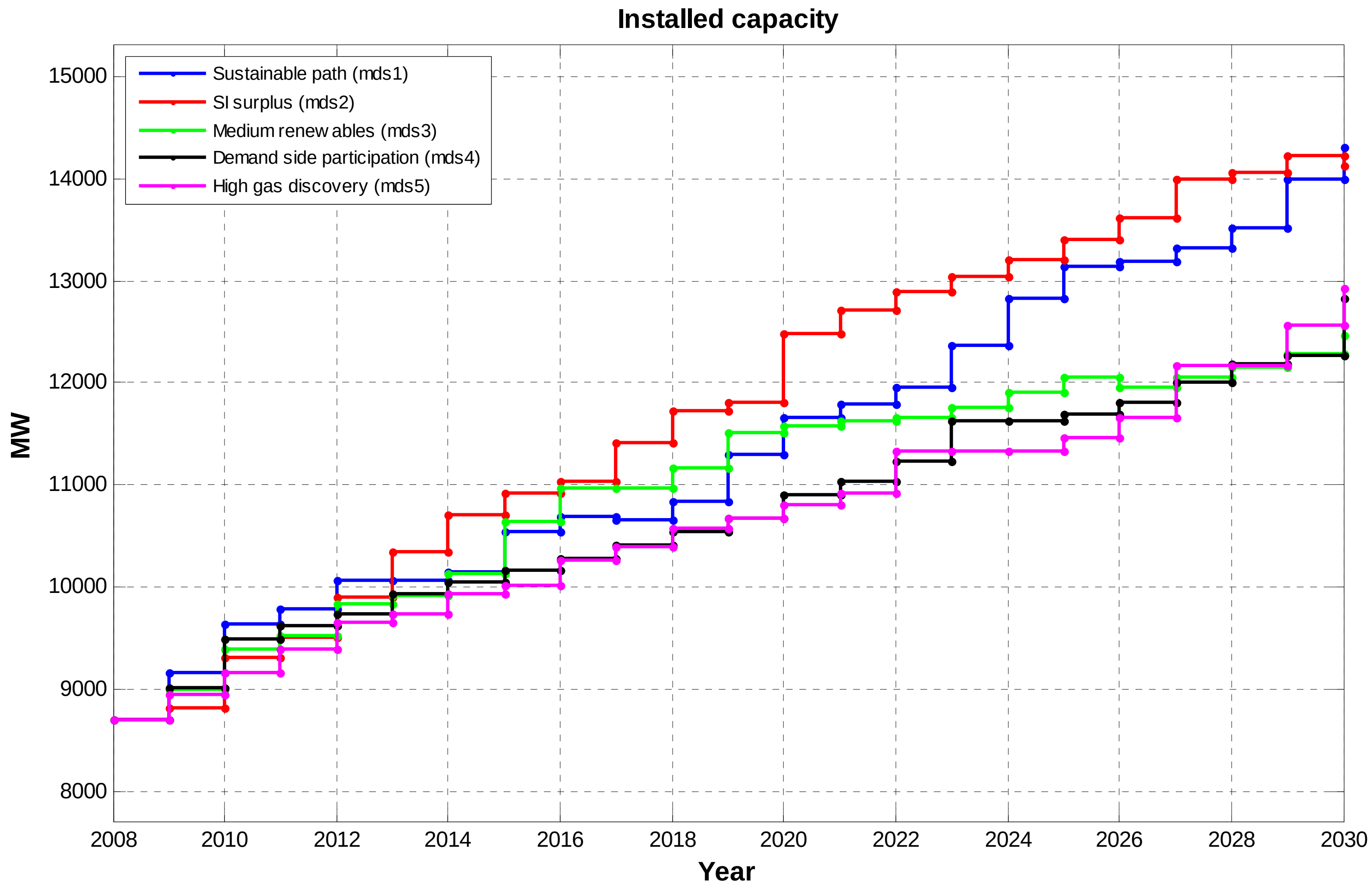
GEM overview cont'd

- Constraints
  - Compute all costs (including HVDC charge), 4 equality constraints
  - Generation build decision and capacity balance, 5 constraints
  - Accounting equations – generation by period by year, and fuel by year
  - Energy balance constraint
  - Peak or system security constraints (N, N-1, N-2), 3 constraints
  - Meet peak without wind, 2 constraints
  - 7 technical operating constraints – minimum and maximum capacity factors, minimum utilisation by technology type, limits on fuel availability, e.g. gas, and limit on energy from a single fuel type, e.g. wind, and hydro generation limited by inflows.
  - 2 constraints for renewables targets – energy and capacity
  - 3 constraints to control operation of pumped hydro schemes
  - Determine transmission losses and capacities, 2 constraints
  - Transmission investment (endog or exog), 4 constraints
  - 12 constraints associated with provision of reserves

Generation scenarios – key drivers

- Selection criteria:
  - Uncertain
  - Material to generation and transmission investment
  - Quantifiable
- Key drivers:
  - Carbon price
  - Availability of renewable generation
  - Fate of existing thermal plant
  - Fuel availability and cost
  - State of the HVDC link
  - Penetration of plug-in hybrid electric vehicles to the vehicle fleet
  - Status of Tiwai smelter
  - Extent of demand-side participation

Build schedule



Using GEM to estimate value of locational price signals

- A crude approach to determining an upper bound on monetised benefit of locational pricing signals
- GEM is a long term planning model – determines optimal capacity expansion
- Can co-optimise generation and transmission capacity expansion
- GEM runs based on final 2010 SOO/GPAs assumptions
- Modelled time horizon: 2010-2040 (31 years)
- All integer variables relaxed between their bounds (0,1)
- HVDC charge to SI generators turned off

Experimental design

- Step1a: solve 2-region GEM, (run 1a)
    - No transmission investment except HVDC
- Step 1b: solve 18-region GEM, (run 1b)
    - Impose generation build from run 1a
    - Permit intra-island AC transmission investment
    - Call this the postage stamp solution
- Step 2: solve 18-region GEM (run 2)
    - Co-optimise generation and transmission expansion
    - Call this the locational pricing solution
- Step 3: compare postage stamp and locational pricing solutions

Results

	mds1	mds2	mds3	mds4	mds5	*average*
Postage stamp pricing						
Total costs	21,162	20,807	17,219	18,393	16,577	*18,832*
Generation costs	19,862	19,500	15,946	17,098	15,288	*17,539*
Transmission costs	1,300	1,306	1,273	1,295	1,289	*1,293*
Locational pricing						
Total costs	21,154	20,795	17,214	18,365	16,561	*18,818*
Generation costs	19,858	19,502	15,947	17,095	15,300	*17,540*
Transmission costs	1,296	1,293	1,267	1,269	1,262	*1,278*
Postage stamp pricing less locational pricing						
Total costs	8	12	5	28	16	*14*
Generation costs	4	-1	0	3	-11	*-1*
Transmission costs	4	13	6	26	27	*15*

Potential issues

- Revisiting some assumptions from 2010 SOO
  - Peak constraints may be too severe
  - Loss adjustment factors
- Unlikely to change conclusions regarding economic investments

Extra slides

The 5 scenarios

Scenario	Carbon price ($/t CO_2e)	Coal and lignite price ($/GJ)	Gas price ($/GJ) in 2020-2030-2040	Renewables available	Demand side
2010 Sustainable path (mds1)	60	5.5-2.7	15-25-25 (LNG import)	Extensive hydro, wind and geothermal. Biomass available	Baseline + electric vehicles + Extensive participation
2010 Roaring forties (mds2)	50	5.5-2.7	15-19-19 (LNG import)	Extensive hydro, wind in SI and less geothermal. Biomass available	Baseline
2010 Medium renewables (mds3)	30	5.5-2.7	13-13-7 (indigenous)	Extensive wind and geothermal, and some hydro available. Biomass available	Baseline + Tiwai phase out in 2025
2010 Coal (mds4)	20	5.5-2.7	13-13-7 (indigenous)	Extensive wind and geothermal, and little hydro available. Biomass available	Baseline
2010 High gas discovery (mds5)	40	5.5-2.7	8-8-8 (LNG export)	Extensive wind and geothermal, and some hydro available. Biomass available	Baseline

Peaking plant