Energy Systems Modelling

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Overview

New Zealand energy system characteristics

Energy systems modelling

TIMES: An integrated energy systems model
  ➢ Hydro under climate change
  ➢ Cost of decarbonisation
ENERGY IN NEW ZEALAND 20

2019 CALENDAR YEAR EDITION

Comprehensive information on and analysis of New Zealand’s energy supply, demand and prices

New Zealand energy use

..The other 60% still needs to be converted!

Source: Based on Energy in New Zealand, 2020 (MBIE)
Energy self-sufficiency

Figure A.2 New Zealand's Self-sufficiency

Source: Energy in New Zealand, 2020 (MBIE)
Oil Imports

Transport

Source: Energy in New Zealand, 2019 (MBIE)
Gas

Source: Energy in New Zealand, 2019 (MBIE)

Methanol and ammonia/urea production

Energy

Electricity
Coal Production and Consumption

Coal Consumption by Sector for 2019

- Industrial: 38%
- Electricity Generation: 40%
- Other Transformation: 16%
- Agriculture/Forestry/Fishing: 4%
- Commercial: 1%
- Residential: 0%

Source: Energy in New Zealand, 2020 (MBIE)
Electricity generation

| Source: Energy in New Zealand, 2012 (MBIE) |

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>2019 Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>0.582</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.174</td>
</tr>
<tr>
<td>Gas</td>
<td>0.126</td>
</tr>
<tr>
<td>Wind</td>
<td>0.051</td>
</tr>
<tr>
<td>Coal</td>
<td>0.049</td>
</tr>
<tr>
<td>Wood</td>
<td>0.007</td>
</tr>
<tr>
<td>Biogas</td>
<td>0.006</td>
</tr>
<tr>
<td>Solar</td>
<td>0.003</td>
</tr>
<tr>
<td>Waste Heat</td>
<td>0.001</td>
</tr>
<tr>
<td>Oil</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Electricity generation

Source: Energy in New Zealand, 2012 (MBIE)
New Zealand energy system
key characteristics

• 40% of GHG emissions

• Electricity ~80-85% from renewables
  • hydro ~60% (seasonal!), geothermal ~15-20%, wind ~5%

• Electricity and industry largest coal users (food processing, wood&pulp, steel etc.)

• Transport largest oil user

-> Largest emissions reduction potential in *process heat and transport*

**Electrification key enabler**

-> *Need for a model that encompasses the entire energy sector*
Approach energy as a inter-linked system rather than a set of elements

- Insights on substitution options linked to the system as a whole, that cannot be understood when analysing a single technology
  - Effects of fuel shifting or technology change across the sector
- Considering energy supply and demand across all sectors simultaneously, provides support for decision-makers in problems of identifying, quantifying, and controlling a system.
  - Effects of a government policy, e.g. ban, tax or subsidy
Evolution of energy system models

- **Energy balances**: simple representation of and energy system in data tables, an energy accounting approach

- **Reference Energy System** (RES): a network description of the energy system, captures all flows and activities (technological characteristics) within the system
  - Can incorporate future technologies
  - Can be used for economic, resource and environmental impact analysis of alternative development paths
  - Ability to apply optimisation techniques, given a set of end-use demands

- Initially typically used for national level modelling

- Increased need for modelling global energy resources and flows, incl. environmental effects
Energy system models classification by discipline and level of aggregation
• Objective: *Compilation of a full energy systems model for New Zealand for long-term integrated energy analyses*

• A collaboration between
  • BusinessNZ Energy Council (BEC) + Sapere Consulting + investors from the New Zealand energy sector
  • Energy Efficiency and Conservation Agency of New Zealand (EECA)
  • Paul Scherrer Institute (PSI), and
  • Energy Centre, University of Auckland (UoA)
TIMES modelling platform:

IEA Energy Technology Systems Analysis Program

- Linear programming optimisation tool
- Cost-minimisation
- Perfect foresight
- Social planner perspective

--> Provides endogenous investment decisions, given
   - Technical parameters,
   - Economic and policy parameters,
   - Bounds.

Minimisation of total discounted system costs:

\[
\min \text{ Capital cost, O&M costs & fuel costs over all technologies + Cost from imports - Revenues from exports + CO}_2\text{ emission costs - Salvage value of the investments}
\]

By choosing optimal variables on:

- Investment, installed capacity, energy output per technology
- CO\(_2\) emissions per region
- Imports/exports of energy carriers

Subject to constraints:

- On energy carriers: balance equations, potentials
- On technologies: deployment rate, availability, potentials
- On energy system: reserve capacity in electricity sector, CCUS
- Additional constraints subject to scenario
Energy resources

Renewables

- Hydro
- Geothermal
- Wind
- Solar
- Biomass
- Tidal
- etc

Fossil fuels

- Coal & lignite
- Oil
- Natural gas

Fuels

- Oil refining
- Electrolysis

Energy generation

- Hydro
- Geothermal
- Wind
- Solar
- Thermal generation
- Fuel cells
- Other
- Storage

Energy distribution

- Electricity
- Petroleum products
- Natural gas

Energy demand sectors

Technologies

- Residential or services
- Heat pumps
- Lights
- Appliances
- ... 

Transport

- EVs
- Hybrids
- ICE vehicles
- Rail
- Aviation
- Shipping
- ...

Energy service demands

- Heating
- Cooling
- Lighting
- ...

- Passenger mobility
- Freight
- ...

- Industrial processes
- ...

- Agricultural production

- Industry
- Agriculture

International energy prices (oil, natural gas, coal, ...)

Technology characterisation (efficiency, lifetime, costs, ...)

Resource potentials (renewables availability, existing reserves, ...)

Macro-economic drivers (GDP, population, number of households, ...)

TIME-NZ
# Energy service demands

<table>
<thead>
<tr>
<th>Sector</th>
<th>Demand driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential sector</td>
<td>StatsNZ* population and household size</td>
</tr>
<tr>
<td>Commercial</td>
<td>NZIER** Retail trade</td>
</tr>
<tr>
<td>Transport</td>
<td>Ministry of Transport base scenario</td>
</tr>
<tr>
<td>Industry</td>
<td>NZIER Manufacturing (except food processing)</td>
</tr>
<tr>
<td>Agriculture Industry: food processing</td>
<td>NZIER Agriculture</td>
</tr>
</tbody>
</table>

*Statistics New Zealand  
**New Zealand Institute for Economic Research

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### Energy service demand growth assumptions

![Energy service demand growth assumptions graph](image-url)
TIMES-NZ time resolution

- **Time horizon:** 2015, 2018, 2020:5:2060
- **24 time-slices**

**Seasonal level**
- Summer: 92 days
- Fall: 91 days
- Winter: 91 days
- Spring: 91 days

**Weekly level**
- Week days: 261
- Weekend days: 104

**Daily level**
- Day: 13 hours
- Night: 10 hours
- Peak: 1 hour
1) Climate change impact on hydro
Availability factors (AF)

- Historical lake levels for major catchments (>90% of hydro capacity)
- Expected change in precipitation under RCP scenarios
- Snow melt model

-> expected change in seasonal AF by island


Note:
- Demand peaks in winter
- Most hydro capacity on South Island
Installed capacity under climate change (CC) sensitivity

Climate change impact:
Solar favoured at expense of wind to balance decreased hydro availability in summer.

RCP8.5 0.0: No CC
RCP8.5 0.5: Some CC
RCP8.5 1.0: Expected RCP8.5
RCP8.5 1.5: More than expected CC
Generation output by season under climate change sensitivity

RCP 8.5
2035

SUM
FAL
WIN
SPR
2) Cost of decarbonisation

• Exploring different levels (50%-80%) of decarbonisation of the energy sector
  
  • Target = decrease total energy sector CO2 emissions by 2050 by x% from 2005 levels
  • x: 50%, 55%, 60%, ..., 80%

• Difference in total system cost vs. tonnes CO2 mitigated
New Zealand GHG emissions

Emissions reduction scenarios

Climate Change Response Amendment Act: Target of net-zero carbon emissions by 2050.

Here: we’d still need to offset the remaining emissions!
Cost of decarbonisation: Impact of discount rate

Cost of mitigation with various discount rates
No RCP

NZD/tCO2

MtCO2 mitigated

-50%  -55%  -60%  -75%

-80%

d=0.05  d=2.5  d=5  d=7.5
Average and marginal cost of decarbonisation

Cost of decarbonisation (5% discount rate)

Reduction in annual emissions from 1990

NZD/tCO2

Average no RCP  Average RCP8.5  Marginal no RCP  Marginal RCP8.5
Fuel shifting: Transport

- Petrol phased out by 2050 in all scenarios.
- Diesel to electricity shift in buses and medium size trucks.
Fuel shifting: Industry

Shift from coal and natural gas to electricity and biomass.
Key insights

• Systems approach needed to understand transitions (fuel, technology, behaviour, etc.)

• Climate change impact on hydro
  • Higher winter availability -> decrease in fossil fuel reliance
  • Lower summer availability -> increase in solar capacity
  • Note: Potential day-to-day or seasonal volatility not taken into account, may have more severe consequences!

• Decarbonisation
  • 80% reduction in energy emissions: 85-90 NZD/tCO2 for last 5%

• New Zealand is well positioned to reach significant emissions’ reductions from techno-economic perspective (e.g. transport sector).

• Energy sector changes slowly – decisions now will have consequences for a long time.
Thank you!