Transitions, Global Trends & NZ Energy

Basil Sharp
Energy Centre & Department of Economics
February 19th 2018

Support by Energy Education Trust of NZ
Outline

PART A: Global market transitions
  – History
  – Reserves
  – Prices

PART B: Economy-Energy New Zealand
  – NZ Economic indicators – how are we doing?
  – Energy & Economic growth

PART C: NZ energy sector transitions
  – Demand & supply

PART D: Policy
Manure crisis

**LATE 1800s**

Roads became congested and pollution from horses became a problem.

Manure was sold to farmers, but they couldn’t keep up with supply.

20,000 deaths in NY attributed to manure crisis.
A tale of two energy sources

Whale oil was on the way out well before petroleum became society’s fuel of choice.

Coal entered the picture. Scientists discovered how to make kerosene for lighting and whale oil was priced out of the market.

Sources:
Coal - a wonderful resource

Energy conveniently packed in readily accessible deposits

Coal combined with science and engineering catapulted society into the industrial age

Gas was available for cooking...

... and street lighting improved

Coal powered trains

Ships no longer had to rely on wind

6 weeks journey from the UK to US reduced to 7-10 days in a steamship
Oil - a wonderful resource

Demand for oil exploded with the mass production of cars - the manure crisis was solved

Huntington Beach, California 1926

Your cell phone uses the electricity equivalent of 2 modern refrigerators

The global ICT ecosystem uses the combines annual electricity consumed by Japan and Germany
Part A: Global market transitions

- Global energy markets are in transition
  - Growth, higher incomes have led to growth in energy demand, particularly developing economies within Asia as opposed to OECD
  - Drive towards improving energy efficiency
  - Share of renewables in energy supply increasing
  - Net result is that demand grew at ~ 1% over the last 3 years – 10 year average 1.8% pa

- Carbon emissions:
  - All-time high in 2018 37.1bn tonnes. Most contributing to the rise, China +4.7%, US +2.5%, India +6.3%
Primary energy consumption

Shares of global primary energy consumption by fuel

Oil remains the world’s dominant fuel, making up just over a third of all energy consumed. In 2017 oil’s market share declined slightly, following two years of growth. Coal’s market share fell to 27.6%, the lowest level since 2004. Natural gas accounted for a record 23.4% of global primary energy consumption, while renewable power hit a new high of 9.8%.

BP Statistical Review of World Energy June 2018
Oil Markets

- World’s leading fuel – market share increased following 15 years of decline
- Brent oil price averaged US$71.34 (low US$50.57)
- India & China largest increase in consumption
- Production in Middle East increased modestly, increase in US
Drake’s well 1859 & Huntington Beach
Oil Production

Reserves-to-production (R/P) ratios

2017 by region

History

Global proved oil reserves in 2017 fell slightly by 0.5 billion barrels (-0.63%) to 1696.6 billion barrels, which would be sufficient to meet 50.2 years of global production at 2017 levels. Higher reserves in Venezuela (up by 1.4 billion barrels) were outweighed by declines in Canada (-1.8 billion barrels) and smaller declines in a number of other non-OPEC countries. OPEC countries currently hold 71.8% of global proved reserves.

Note: Lags in reporting official data mean that 2017 figures for many countries are not yet available.

BP Statistical Review of World Energy June 2018
Oil production & consumption

World oil production rose by only 0.6 million b/d in 2017, below average for the second consecutive year. Production fell in the Middle East (-250,000 b/d) and South & Central America (-240,000 b/d) but this was outweighed by growth from North America (820,000 b/d) and Africa (390,000 b/d). Global oil consumption growth averaged 1.7 million b/d, above its 10-year average of 1.1 million b/d for the third consecutive year. China (500,000 b/d) and the US (190,000 b/d) were the single largest contributors to growth.
Oil prices

BP Statistical Review of World Energy June 2018
Shale oil

Did You Know?...

Top 10 countries with recoverable shale oil:
1. Russia: 85 bb
2. U.S.A: 50 bb
3. China: 22 bb
4. Argentina: 27 bb
5. Libya: 26 bb
6. Australia: 14 bb
7. Venezuela: 13 bb
8. Mexico: 13 bb
9. Pakistan: 9 bb
10. Canada: 9 bb

Mexico ranks 8th in the world in shale oil reserves.

Chart 15: The highest cost producers in the Permian start to feel the pain by not being able to cover their costs.

US shale oil breakeven prices:
- Granite Wash (oil)
- Bone Spring
- Miss Lime
- Wolfcamp Del
- Bakken South
- Wolfcamp South
- Granite Wash (cond)
- Wolfbone (Vt)
- Barnett Liquefied
- Yeso
- Eagle Ford West (cond)
- Cana Stack
- Cline
- NE Weld
- Wolfcamp North
- Cana Woodford
- Bakken Core
- Permian Central Vt
- Wattenberg Hz
- Utica (cond)
- Eagle Ford East (cond)

Source: BofA Merrill Lynch Global Commodities Research
Oil trade

Major trade movements 2017
Trade flows worldwide (million tonnes)

BP Statistical Review of World Energy June 2018
Gas

Reserves-to-production (R/P) ratios

Years

2017 by region

History

Global proved gas reserves in 2017 rose slightly by 0.4 trillion cubic metres (tcm) or 0.2% to 193.5 tcm. This is sufficient to meet 52.6 years of global production at 2017 levels. Israel was the largest single contributor to growth (0.3 tcm), while the CIS region also added 0.2 tcm to reserves. By region, the Middle East holds the largest proved reserves (79.1 tcm, 40.9% of the global total), followed by CIS (59.2 tcm, a 30.6% share).

Note: Lags in reporting official data mean that 2017 figures for many countries are not yet available.
Gas production, consumption

Global natural gas production increased by 131 billion cubic metres (bcm), or 4%, almost double the 10-year average growth rate of 2.2%. Russian growth was the largest by far at 46 bcm, followed by Iran at 21 bcm, and Australia at 17 bcm. Gas consumption rose by 96 bcm, or 3% – the fastest growth since 2010. Growth was driven by China (31 bcm, or 15.1%), the Middle East (28 bcm) and Europe (26 bcm). Consumption in the US fell by 1.2%, or 11 bcm.

BP Statistical Review of World Energy June 2018
Gas prices

BP Statistical Review of World Energy June 2018
Gas trade

Major trade movements 2017
Trade flows worldwide (billion cubic metres)

Source: Includes data from FGE MENA gas service, IHS.

BP Statistical Review of World Energy June 2018
Gas development – Gorgon field

6000 construction jobs
350 operation
Cost ~A$60 b
Asset specific
Long term contracts
LNG Terminal Japan

Asset specific investment - cost?
Power production
Long term contracts
**Coal**

**Reserves-to-production (R/P) ratios**

### Years

**2017 by region**

- **North America**
- **S. & Cent. America**
- **Europe**
- **CIS**
- **Middle East & Africa**
- **Asia Pacific**

### History

- **North America**
- **S. & Cent. America**
- **Europe**
- **CIS**
- **Middle East & Africa**
- **Asia Pacific**
- **World**

World proved coal reserves are currently sufficient to meet 134 years of global production, much higher than the R/P ratio for oil and gas. By region, Asia Pacific holds the most proved reserves (41% of total), split mainly between Australia, China and India. The US remains the largest single reserve holder (24.2% of total).

BP Statistical Review of World Energy June 2018
Coal

Coal: Production by region
Million tonnes oil equivalent

Coal: Consumption by region
Million tonnes oil equivalent

World coal production increased by 105 million tonnes of oil equivalent or 3.2%, the fastest rate of growth since 2011. Production rose by 56 mtoe in China and 23 mtoe in the US. Global coal consumption grew by 25 mtoe, or 1%, the first growth since 2013. Growth was driven largely by India (18 mtoe), with China consumption also up slightly (4 mtoe) following three successive annual declines during 2014-2016. OECD demand fell for the fourth year in a row (-4 mtoe).

BP Statistical Review of World Energy June 2018
Coal prices

BP Statistical Review of World Energy June 2018
Are gas & coal prices correlated?
Open cut mining Hunter region
Fossil fuel emissions

Primary Pollutants
- CO - Carbon Monoxide
- CO₂ - Carbon Dioxide
- SO₂ - Sulfur
- NOₓ - Nitrogen Dioxide
- N₂O - Nitric Oxide
- VOCs - Volatile Organic Compounds
- HCs - Hydrocarbons

Particulate Matter
- PM₁₀ - Coarse Particles - less than 10 microns
- PM₂·₅ - Fine Particles - less than 2 microns
- NH₃ - Ammonia

Fossil CO₂ emissions

Source: FUTURE EARTH, STRAITS TIMES GRAPHICS
Clean coal

- CCS (carbon capture and storage) aimed at preventing carbon dioxide (CO$_2$) exhaust from entering the atmosphere.
- Kemper Project 582 MW (MI) planned for 2014 @ US $2.4 b; 2017 cost US $7.5 b. Switched to running on gas.
Hydro technology – 1882 Wisconsin

- Technical potential for growth – development limited by politics & poorly developed transmission networks in Asia.
- Lake Benmore; run of river system
Global nuclear generation rose by 5 million tonnes of oil equivalent (mtoe), or 1.1%, above the 10-year average growth rate of -0.7%. Growth in China (8 mtoe) and Japan (3 mtoe) was partially offset by declines in Europe (3 mtoe). World hydroelectric power generation rose by 5 mtoe, just 0.9%, compared with the 10-year average of 2.9%. The US (7 mtoe) provided the largest increment. China’s growth was the slowest since 2011, while European output declined by 10.5% (-16 mtoe).
Fukushima diachi power plant
Fukushima diachi after earthquake
Fukushima recovery

Fukushima No.1 plant

Sea wall

Planned ice wall

Groundwater bypass wells

300 tons of groundwater going into reactor buildings daily

Tanks storing tainted water

SOURCE: Tokyo Electric Power Co.

©Google ©2015 ZENRIN Image
Tomioka township
High level radioactive waste
Low level radioactive waste
PART B: Economy-Energy NZ

- Macroeconomic measure
  - GDP, imports/exports
  - Structure of economy
  - Energy per unit output

- Energy supply/demand
  - Sector demand
  - Transport

- Energy resources
  - Hydro, geothermal, gas, oil, wind, solar
Gross Domestic Product

GDP/Capita 2009/10 prices
Value of Exports & Imports

**Exports $million 2009/10**

- **Dairy**
- **Crude, minerals, gas**
- **Meat products**

**Imports NZ $1,000**

- **Crude oil**
- **Petrol Av gas**
- **Vehicles**
Economy in transition

Sector shares of GDP

- % Agriculture
- % Retail
- % Finance
- % Utilities
Energy & Economic Growth, NZ

\[ R^2 = 0.8036 \]
NZ Primary Energy 2017
Patterns of energy demand 2017

Residential
- Coal: 69%
- Oil: 10%
- Gas: 15%
- Renewables: 0.6%
- Electricity: 1%

Commercial
- Coal: 64%
- Oil: 14%
- Gas: 15%
- Renewables: 5%
- Electricity: 6%

Industrial
- Coal: 26%
- Oil: 9%
- Gas: 29%
- Renewables: 10%
- Electricity: 26%

Agriculture Forestry Fishing
- Coal: 30%
- Oil: 54%
- Gas: 9%
- Renewables: 2%
- Electricity: 3%

Source:
Oil Imports/Exports (PJs)

Price elasticity of demand: in range of [-0.1 to -0.4]
Fleet composition & emissions

Figure 1.1: Fleet composition

- Light passenger
- Light commercial
- MCycle
- Trucks
- Bus

Figure 1.10: 2015 CO₂ emissions

- Heavy fleet: 21.5%
- Light passenger fleet: 64.8%
- Light commercial: 15.1%

Source: VFEM (Vehicle Fleet Emissions Model) 2

Figure 1.5a: Light fleet ownership per 1000 population

http://www.transport.govt.nz/research/newzealandvehiclefleetstatistics/#annual
Tonnes of CO$_2$ from transport per US$10^6$
C: NZ energy sector transitions

- NZ transitioned from economy dominated by large government departments to an economy in which markets play a key role in resource allocation subject to regulations & government oversight.

- In the case of electricity: progression was from centralised production and price setting to a more competitive framework within a regulatory framework.
New Zealand Electricity Market

Consumers
230 volts for residential and business

Distribution
11, 33 or 66kV

Transmission
typically 110 or 220kV

Generation
11–16kV
NZ Electricity

Electricity generation GWh
# Price elasticity: electricity

\[
\frac{\% \Delta Q}{\% \Delta P}
\]

<table>
<thead>
<tr>
<th></th>
<th>Proportion</th>
<th>Short-run</th>
<th>Long-run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>45%</td>
<td>-0.06</td>
<td>-0.28</td>
</tr>
<tr>
<td>Commercial</td>
<td>22%</td>
<td>-0.06</td>
<td>-0.28</td>
</tr>
<tr>
<td>Residential</td>
<td>33%</td>
<td>-0.08</td>
<td>-0.21</td>
</tr>
<tr>
<td>Weighted Av.</td>
<td></td>
<td>-0.07</td>
<td>-0.26</td>
</tr>
</tbody>
</table>

**Source:** MED

Demand is price inelastic:

In short run, increase price to residential by 10%, demand falls by 0.8%
External Cost of Electricity Generation

Source: COVEC (2006)
Assumption: new plant under high cost scenario
C.1: Hydro

- Currently around 5,300 MW of installed capacity (89 stations). Most sites for large-scale hydro developed. Some prospect for irrigation/hydro, high load factor.
- NIWA (2009) estimates potential of 66,820 MW but >45% are small and in remote areas.
- Storage: Taupo holds 93% of water stored in Waikato system.
- Competition for water.
- Limited storage ~ 60 days.
C.2: Geothermal resource

- Deep faults -> water to source of heat -> ascending hot water forms geothermal reservoir temperatures of 350°C
- Systems >150°C can be used for electricity
- Renewability
  - Continual replenishment by up flow
  - Re-injection of fluids
  - Continual monitoring
  - Stop extraction: temperature & pressure increase
Pacific Continental Plate

- Eurasian Plate
- North American Plate
- Pacific Plate
- Philippine Plate
- Caribbean Plate
- African Plate
- Nazca Plate
- South American Plate
- Antarctic Plate

Ring of Fire

Map showing the location of New Zealand with key points like Auckland, Wellington, Christchurch, Dunedin, Hikurangi Trench, Alpine Fault, and Low Temperature Geothermal Resources in New Zealand.
Electricity Generation
Cascading use
Unsustainable use

- Rotorua New Zealand
  - Open access 1970s-1980s
  - Home heating, relatively inexpensive
  - Pressure dropped, subsidence & damage to tourist attractions
  - Entry closed

- Ohaaki plant
  - Commissioned capacity of 114MW
  - Production reduced to 30MW
  - Subsidence & flooding
C.3: Wind Generation

First wind farm 1993 – 225kW
2014: 19 wind farms
623 MW installed
Load factor: ~30-50%
West Wind Farm

Wind patterns
Node price & wind generation

(a) High wind generation

(b) Low wind generation

Source: Electricity Authority (EA), Centralised Dataset.
Consenting Issues

• Access to land
  – Site
  – Lines
  – Contract access

• Resource Management Act 1991
  – Consent to construct & operate
  – Evidence before local tribunal

• Example: Project Hayes; 630MW 176 turbines, electricity for 278,000 homes, estimated cost $2b, carbon savings
C.4: Solar – location matters
Auckland: application using LiDAR data

LiDAR (Light Detection And Ranging) uses laser light to sample the surface of the earth.
Mt Eden vs Pukekohe West

Comparing ratings for best 14m²
LCOE as Guide to Investment

• Careful use data from existing or recent plants to base investment decisions
  – Technological progress, economies of scale, experience tends to lower cost of the marginal plant relative to the average of recent additions
  – Scarcity of locations, access etc. tends to increase the cost of the marginal plant relative to the average
C.5: Gas Production

Annual Gross Gas Production by Field

Source: Ministry of Business, Innovation and Employment
D. NZ policy

- Market incentives & regulatory framework to support investment
- No direct subsidies, no opportunity to export
- Requires national benefits of renewables to be fully considered in the consenting process
- NZ’s ETS prices carbon
  - Energy emissions:
    - Transport 44%
    - Generation 19%
    - Manufacturing industries 16%
Government policy

Figure 1 The Strategy in the wider government context

- Climate change commitments and policies
  - Climate change target: 30 per cent below 2005 emissions levels by 2030
  - New Zealand Emissions Trading Scheme

- New Zealand Energy Strategy 2011-2021
  - Energy Efficiency and Conservation Act 2000

- Business Growth Agenda
  - Action area: Improve energy efficiency and use of renewable energy to raise productivity, reduce carbon emissions and promote consumer choice.

- Resource Management Framework
  - Resource Management Act 1991
  - National Policy Statements:
    - Renewable Electricity Generation
    - Electricity Transmission
    - Freshwater Management
    - National Planning Standards
    - New Zealand Coastal Policy Statement


- Transport policies
  - Electric Vehicles Programme
  - Government Policy Statement on Land Transport

- EECA’s work programme

- Government Policy Statement on Gas Governance
GOVERNMENT POLICY

**Priority Areas**
Where will we focus?

- Renewable and efficient use of *process heat*
- Efficient and low-emissions *transport*
- Innovative and efficient use of *electricity*

**Targets**
How will we measure success?

- Decrease in industrial emissions intensity of at least *one per cent* per annum on average between 2017 and 2022
- Electric vehicles make up *two per cent* of the vehicle fleet by the end of 2021
- 90 per cent of electricity will be generated from renewable sources by 2025
Net-carbon zero

NZ GHG Emissions

Global GHG Emissions
Metric matters

![Pie chart showing the distribution of metric matters globally.]

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Tonnes CO2-eq per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Australia</td>
<td>23.964</td>
</tr>
<tr>
<td>2</td>
<td>Luxembourg</td>
<td>22.557</td>
</tr>
<tr>
<td>3</td>
<td>United States of America</td>
<td>20.403</td>
</tr>
<tr>
<td>4</td>
<td>Canada</td>
<td>20.029</td>
</tr>
<tr>
<td>5</td>
<td>New Zealand</td>
<td>17.155</td>
</tr>
<tr>
<td>6</td>
<td>Russian Federation</td>
<td>16.043</td>
</tr>
<tr>
<td>7</td>
<td>Estonia</td>
<td>14.323</td>
</tr>
<tr>
<td>8</td>
<td>Iceland</td>
<td>13.930</td>
</tr>
<tr>
<td>9</td>
<td>Ireland</td>
<td>12.772</td>
</tr>
<tr>
<td>10</td>
<td>Czech Republic</td>
<td>12.508</td>
</tr>
</tbody>
</table>
Looking forward?

• Global
  – Coal, gas as primary source in many developing economies
  – Inaction on global emissions
  – Likely slow down in economic growth
  – Geopolitics

• NZ low carbon economy
  – Supply: hydro, geothermal, wind, solar, gas
  – Demand: growth, electrification of transport, hydrogen
  – Technology: smart grids, batteries, digital management
  – Uncertainties: impact of climate change, population growth