Household energy use: How much and when, now and in the future

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Energy Efficiency and Conservation Authority
20th February 2024
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How much – Of different fuels, relative to national consumption
When – What’s the pattern of time of use? How much does this matter?
Now – (And looking back)
In the future

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Insights from Warmer Kiwi Homes evaluation
Insights on deep retrofit
Future work on life cycle carbon and energy
Part 1
How much – 2022

Let’s start from the top ...

**MBIE Energy in NZ** – Numbers are in PJ

1 kWh = 3.6 MJ
1 MWh = 3.6 GJ
1 GWh = 3.6 TJ
1 TWh = 3.6 PJ

1 house (ex. car) ~ 10,000 kWh = 36 GJ
1 PJ ~ 28,000 houses ~ Taupō / Timaru / Blenheim
2 million houses ~ 72 PJ
## Energy Supply and Demand

### Calendar Year 2022

<table>
<thead>
<tr>
<th>Connectivity Perspectives using Balco-Cabero Rubes</th>
<th>Coal</th>
<th>DIE</th>
<th>Natural Gas</th>
<th>Renewables</th>
<th>Electricity</th>
<th>Waste Heat</th>
<th><strong>TOTAL</strong></th>
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<td><strong>Direct</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>TOTAL</strong></td>
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</tbody>
</table>
How much – 2022

• Indigenous production: **615 PJ** (coal, oil, gas, renewables)
  • Note 1:1 on hydro and wind to electricity, but 205 PJ of geothermal is net heat from fluid.

• Total primary energy supply: **832 PJ**
  • Includes 205 PJ as above. Excludes international transport (27 PJ).

• Total final energy consumption: **543 PJ**
  • What’s used on the demand side. Excludes non-energy use (methanol, ammonia-urea), and after conversion losses in (thermal) electricity generation.

• Residential energy consumption: **84 PJ**
## How much – 2022

<table>
<thead>
<tr>
<th>Fuel</th>
<th>PJ</th>
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<td>Electricity</td>
<td>48.3</td>
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<tr>
<td>Petrol</td>
<td>14.2</td>
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<tr>
<td>Wood</td>
<td>7.4</td>
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<tr>
<td>Natural gas</td>
<td>6.8</td>
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<tr>
<td>LPG</td>
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<tr>
<td>Diesel</td>
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<tr>
<td>Solar</td>
<td>0.4</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.2</td>
</tr>
<tr>
<td>Coal</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>83.9</strong></td>
</tr>
</tbody>
</table>
How much – some notes and caveats

• Petrol and diesel use includes off-road vehicles and recreational marine
  • Informed by EECA report on off-road liquid fuels
  • Probably an over-estimate? (Speaker’s opinion!)
  • EECA EEUD attributes 100% to “mobile motive power”
  • Some diesel will be heating – number unknown, likely small
### How much – 2022

<table>
<thead>
<tr>
<th>Fuel</th>
<th>PJ</th>
</tr>
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<tbody>
<tr>
<td>Electricity</td>
<td>48.3</td>
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<tr>
<td>Wood</td>
<td>7.4</td>
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<tr>
<td>Natural gas</td>
<td>6.8</td>
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<tr>
<td>LPG</td>
<td>3.8</td>
</tr>
<tr>
<td>Solar</td>
<td>0.4</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.2</td>
</tr>
<tr>
<td>Coal</td>
<td>0.1</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>67.0</strong></td>
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</table>

![Pie chart showing energy distribution](chart.png)
## How much – 2022

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Residential [PJ]</th>
<th>Total [PJ]</th>
<th>Residential %</th>
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</thead>
<tbody>
<tr>
<td>All</td>
<td>83.9</td>
<td>543.2</td>
<td>15%</td>
</tr>
<tr>
<td>All (ex. P &amp; D for res)</td>
<td>67.0</td>
<td>543.2</td>
<td>12%</td>
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<tr>
<td>Electricity</td>
<td>48.3</td>
<td>141.9</td>
<td>34%</td>
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<tr>
<td>Natural gas</td>
<td>6.8</td>
<td>63.2</td>
<td>11%</td>
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<tr>
<td>LPG</td>
<td>3.8</td>
<td>9.6</td>
<td>40%</td>
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</table>
How much – Looking back
Residential total, electricity, NG, and LPG

Residential fuel use 2012-2022

Total
Electricity
NG
LPG
How much – Looking back
Residential total, electricity, NG, and LPG

Residential fuel use per dwelling 2012-2022

Data on private dwellings from Stats NZ / Figure.NZ
How much – Looking back
Residential total, electricity, NG, and LPG

<table>
<thead>
<tr>
<th>Year</th>
<th>Total kWh/dwelling</th>
<th>Electricity kWh/dwelling</th>
<th>NG kWh/dwelling</th>
<th>LPG kWh/dwelling</th>
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<tbody>
<tr>
<td>2012</td>
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<td>2013</td>
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</tr>
<tr>
<td>2022</td>
<td></td>
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</tr>
</tbody>
</table>

Data on electricity per ICP from MBIE / Figure.NZ
Data from EECA Energy End Use Database.
When

Source: NZ GREEN Grid Household Electricity Demand Data
When – Estimate of end use loads at peak

Source: eCubed/Concept Consulting/RDT deep retrofit study
“Peak electricity demand growth continues to raise concerns for potential capacity issues during peak demand periods. Six of the highest peaks on record occurred in 2023, with the maximum peak of 7122 MW on 2 August 2023 coming just 7 MW short of the record set on 9 August 2021.

“Peak demand growth has risen 2% annually on average since 2021, with another increase of 122 MW this winter. This rise in demand can be attributed to the growing electrification of transport, process heat, and space heating. It is also attributed to the removal of RCPD charges, with analysis published by the Electricity Authority confirming that this is associated with a 157 MW increase in average peaks – or 2.2% of national demand.”

Source: Transpower TMH Monitoring Report – October 2023
How much and when – In the future

- Electrification
- Heat pumps
- Hot water cylinders
- EVs
- Solar and batteries
- Energy efficiency (of thermal envelope) – Part 2 of this talk
Heat pumps

• Already (very) high penetration
  • 47% in 2018 census (Main types of heating used)
  • Over 1.1 million units sold in last 5 years (EECA data)
    • Note some will be used for commercial premises
    • Healthy Homes Standards (2021 onwards)
• Potential for demand management through pre-heating
Hot water cylinders

- Smart controls can anticipate usage and optimise temperatures
- Likely potential for greater demand response
  - Investigation into electricity supply interruptions of 9 August 2021
  - “Ripple (hot water) control and replacement technologies are envisaged as being at the heart of a transition to a richer demand side participation in the market over the next decade”
EVs

• Smart controls essential!
Solar

Installed distributed generation trends

<table>
<thead>
<tr>
<th>Date range</th>
<th>Region type</th>
<th>Market segment</th>
<th>Capacity</th>
<th>Fuel type</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Sep 2013 - 31 Jan 2024</td>
<td>New Zealand</td>
<td>All ICPs</td>
<td>All combined</td>
<td>Solar (all)</td>
</tr>
</tbody>
</table>

Source: EA
Solar

- Costs continue to fall in real terms
  - (Flat-ish in nominal over last few years)
- Trend towards larger installations, and larger DC/AC ratio (all scales)
- $2.5/W for 4 kW, down to $2/W for 7 kW
- Cf. *Genesis Lauriston* (Canterbury) at $1.66/W for 62 MW
Batteries

• TBC – Will leave to tomorrow’s speakers!
• Vehicle-to-grid represents huge opportunity to solve winter peaks for low (marginal) cost
Part 2
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Insights on deep retrofit
Future work on life cycle carbon and energy
Insights from Warmer Kiwi Homes evaluation(s)

• Q: What is Warmer Kiwi Homes?
• A: EECA’s grant programme for insulation and heating
  • Targets low-income households (NZDep7-10 and CSC)
  • 80-90% grant funding for insulation
  • 80% grant funding for heating (capped at $3000)
    • Mostly heat pumps
• Since 2009:
  • Around 400,000 insulation retrofits (~ ¼ of pre-2008 houses)
  • Around 75,000 heating retrofits
Insights from Warmer Kiwi Homes evaluation(s)

• Smart meter data analysis by Vector
• Warmer Kiwi Homes Impact Evaluation: Phase 2: Warmer Kiwis Study by Motu
• ... and more on EECA website
Smart meter data analysis by Vector

- Some very clever analysis of 360,000 addresses in EECA database
- Matched to 2510 insulation jobs (and 492 heat pump jobs)
  - Vector Metering dataset + lots (and lots) of data cleaning!
- Key insights (on insulation):
  - Relatively low energy savings of 80-180 kWh (1-2%)
  - Saved more when cold (and at peak demand)
  - Saved more (%) if their electricity usage was higher before
Smart meter data analysis by Vector

**Average % Savings by Baseline Total Load**

**Average % Savings by Baseline Heating Load**
Warmer Kiwis Study by Motu

- Fieldwork study of impact of WKH heat pump retrofits – 164 households
- Key insights (on heat pumps):
  - Households reported increases in warmth, comfort and satisfaction with their home, alongside a reduction in condensation and damp.
  - Living area temperatures increased, with the greatest gains when it was coldest outside, and at breakfast and dinner/evening time.
  - Household electricity use decreased at almost all times of day, and most significantly during the evening peak demand period.
  - Overall electricity use decreased 16% over the winter months.
  - Benefit cost ratios for the programme as a whole are 4.4 on a wellbeing and energy basis, and 1.9 on a health and energy basis.
Warmer Kiwis Study by Motu
Insights on deep retrofit – Provisional subject to final QA

• Study commissioned by NZ Green Building Council and EECA
• Conducted by eCubed, Concept Consulting, and RDT
• Thermal modelling of 192 scenarios:
  • 4 typologies (specific buildings representing 4 eras)
  • 4 climates (Akl, Wgtn, ChCh, Qt)
  • 4 thermal envelope standards (baseline, H1, Homestar 6, EnerPhit)
  • 3 heating schedules
• Retrofit requirements determined by least-cost optimisation (additional to above 192)
• Full cost and carbon analysis
Insights on deep retrofit – Heating schedules

• Heating schedules significantly influence economics

• ‘Realistic’
  • Living areas: 20°C morning + evening + daytime at weekend
  • Bedrooms: 18°C morning + evening

• ‘Idealistic’
  • As realistic + bedrooms 16°C overnight

• ‘Underheated’
  • As realistic but 16°C for living areas and 14°C for bedrooms

• 24/7 20°C when determining retrofit requirements to H1, Homestar 6 and EnerPhit standards
Insights on deep retrofit - Optimisation

Auckland - Villa Retrofit Options

- Optimal Design
- No Retrofit to Wall
- Other Combination of Retrofit
- New H1
- Homestar 6
- Enerphit
## Table 9 – Total retrofit cost, embodied carbon, and annual heating electricity use for each combination of typology, climate, and performance standard.

<table>
<thead>
<tr>
<th>Typology</th>
<th>Location</th>
<th>Standard</th>
<th>Cost $NZD</th>
<th>Minimum Embodied Carbon Range (kg CO2 eq)</th>
<th>Average Embodied Carbon (kg CO2 eq)</th>
<th>Maximum Embodied Carbon Range (kg CO2 eq)</th>
<th>Annual Heating Load/Demand “Realistic Schedule” kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auckland</td>
<td>New H1</td>
<td>$25,900</td>
<td>2,280</td>
<td>2,320</td>
<td>2,350</td>
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<td></td>
<td>Homestar 6</td>
<td>$50,800</td>
<td>8,380</td>
<td>8,930</td>
<td>9,400</td>
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<td>291</td>
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<td>EnerPHit</td>
<td>$50,100</td>
<td>3,060</td>
<td>3,570</td>
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<td>285</td>
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<tr>
<td>Wellington</td>
<td>New H1</td>
<td>$25,900</td>
<td>2,280</td>
<td>2,320</td>
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<td>1871</td>
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<td>Homestar 6</td>
<td>$69,400</td>
<td>10,070</td>
<td>10,680</td>
<td>11,200</td>
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<td>EnerPHit</td>
<td>$73,400</td>
<td>9,180</td>
<td>10,190</td>
<td>11,220</td>
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<td>New H1</td>
<td>$27,900</td>
<td>2,400</td>
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<td>Homestar 6</td>
<td>$88,900</td>
<td>10,050</td>
<td>10,570</td>
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<td>EnerPHit</td>
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<td>9,310</td>
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<td>New H1</td>
<td>$27,900</td>
<td>2,400</td>
<td>2,490</td>
<td>2,550</td>
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<td>Homestar 6</td>
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<td>EnerPHit</td>
<td>$154,200</td>
<td>15,150</td>
<td>23,860</td>
<td>31,920</td>
<td></td>
<td>490</td>
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</tbody>
</table>
Insights on deep retrofit – Cost/benefit

• $ cost/saving for:
  • H1 retrofit standard
  • 4 climates
  • 4 heating schedules
  • 2 house typologies
• Note ‘Mid-underheated’ and ‘underheated’ assume takeback
Insights on deep retrofit – Carbon

- Carbon cost/saving for:
  - H1 retrofit standard
  - 4 climates
  - 4 heating schedules
  - 2 house typologies
- Note ‘Mid-underheated’ and ‘underheated’ assume takeback
Insights on deep retrofit – Time of use

• “An unexpected result is that, on average across New Zealand houses, the idealistic heating schedule has almost exactly the same space-heating-driven electricity supply costs as the realistic schedule, despite resulting in almost 40% more electricity consumption.”

• Reminder: Idealistic was realistic + bedrooms 16 °C overnight
Future work on life cycle carbon and energy

- Heat pumps + less grid or ...
- ... resistance heaters + more grid

Example in a nutshell is
- Solar panels + hot water heat pump
- More solar panels + resistance heater (element)
Conclusions

• Is the residential sector a ‘big player’ in NZ’s energy system?
  • Not ‘huge’ in overall PJs …
  • … but largest driver of peak electricity demand
  • … and generally lots of infrastructure with low(ish) capacity factor

• What can we do about it?
  • ‘Shallow’ retrofit cost-effective – Job mostly done?
  • Deep retrofit has big price range
    • Will likely be driven by general renovation cycle?
    • Can have net lifetime carbon cost depending on products