Modelling peak electricity demand to 2050

Final report and model manual

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Glossary

Abbreviation	Stands for
CBA	Cost benefit analysis
CCC	Climate Change Commission
DER	Distributed energy resources
DR	Demand response
EA	Electricity Authority
EECA	Energy Efficiency and Conservation Authority
EDB	Electricity distribution business
ENA	Electricity Networks Aotearoa
FNF	Future Network Forum
GXP	Grid exit point
GHG	Greenhouse gas
ICP	Installation control point
LCV	Light commercial vehicle
LPV	Light passenger vehicle
NDC	Nationally Determined Contribution
NSP	Network supply point
TOU	Time of use
VKT	Vehicle kilometres travelled

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Executive summary

Electricity distribution businesses (EDBs) will play an important role in decarbonising the energy system and meeting New Zealand's legislated net zero carbon goal. Electrification of transport and industrial heat combined with much greater intermittent renewable electricity supply will put pressure on distribution networks. The nature of the new electricity demand will see higher peaks and, possibly, peaks at different times than currently experienced.

We modelled all electricity end uses for every network supply point (NSP) out to 2050 to see what peaks might look like individually and collectively under three scenarios:

1. Naïve. In this scenario net demand growth is left unchecked by any signals or remote switching.

2. Energy optimised. In this scenario discretionary load control is applied by energy traders (e.g retailers, generators, aggregators) seeking to minimise the cost of purchasing in the wholesale market or simply using load control to optimise revenue opportunities.

3. Network optimised. In this scenario discretionary load control is undertaken by EDBs wishing to minimise the impact of peaks on network capacity requirements.

The idea was that by creating a single national picture with the ability to drill down to individual NSPs the sector could comment on the national implications and EDBs could test their own assumptions by individual NSPs. This report includes the results and insights. It also includes a guide to the model.

We had thought there might be a number of national scenarios that could be used to inform the peak demand assessment, but we needed to be able to robustly disaggregate the national forecast to a local level. Only the Climate Change Commission's (CCC) analysis provided such a basis as its modelling was publicly available and included end use assessments by sector (commercial, residential, industrial, and agricultural). This, and its detailed assumptions about aspects like vehicle kilometres travelled (VKT), gave a basis for comparing to territorial authorities and could also be compared to NSPs. Data provided by the Electricity Authority (EA) on NSPs gives number of connections by size and by sector.

We determined that any credible scenario would involve general management of EV charging from peak to off-peak times. Considering the two key purposes that EV charging management could be applied to (energy trading and network peak reduction), both are generally improved by reducing demand at peak times. However, there is some delinking of peak energy prices from system peaks due to the variable injection of renewables, especially wind. While price pressure still tends to be higher when demand is high, short-term injections or reductions of wind output can move the highest price periods and can sometimes make the peakiest periods relatively cheap.

In the network optimised case EDBs use any reasonable load control (mainly water heating and EV charging) to avoid the national peak as much as can be reasonably expected. The energy optimised case is generally similar to the network optimised case. The key difference is the energy optimised scenario responds to an expected short-term peak in wind generation that energy traders seek to move demand into. In our modelling we have set this peak to occur at the worst time for national peak demand, but the point is that it could occur at the most inconvenient point for any NSP. Another key difference for the wind peak is that, where network peaks could be managed down to the NSP level (subject to transmission constraints) market driven demand peaks will respond to the national market and will have whatever effect on the NSPs that results.

The way we approached the shifting of EV demand was that the energy traders turned on EV charging to match a wind peak. Once the chargers were started, they were allowed to complete their charging cycles, they were not remotely switched off.

Modelling how batteries would be used was challenging when so much demand flattening can be done using EVs and water heating. Given that we are focusing on load profiles by 2050, we used our conclusions from our work on a distributed energy resources (DER) cost benefit analysis (CBA) for the EA. The DER CBA (Reeve, Comendant, & Stevenson, 2021) concluded that, by 2050, the price of rooftop solar with a battery would have fallen to the point that only two value streams would be needed to make them economic, i.e. the combination of self-supply plus some form of local peak avoidance would be enough for an installation to go ahead. Therefore, we made a combined assumption for rooftop solar output where solar output is absorbed by a battery and used to self-supply the (mostly) residential demand focused on the residential peak.

Industrial point loads are single large loads that can be built in the transmission or distribution networks. These loads can be new demand, for example a new coolstore, or the result of electrification, for example a dairy processor converting from coal to electric heat. They are large enough that one load makes a significant difference to an NSP's profile. For the most part, EDBs provided their expectations of industrial load growth. There were some industrial loads that were seen as highly likely but uncertain on timing. Our default approach was to set them to a 2030 connection date.

Results

Figure 1 shows a single NSP profile with all controllable load optimised to minimise impact of network capacity over time.

Figure 2 demonstrates the annual national peak demand for all NSPs aggregated under the three scenarios modelling:

1. No mitigation is applied to new load (naïve case).
2. All of the load is optimised in the energy market (energy optimised).
3. All of the load is optimised for the sole purpose of managing peaks in distribution networks (network optimised).

In reality, demand side management will mitigate the naïve scenario to some degree. It will come from a mix of energy traders and EDBs who will use some mix of remote management and price incentives.

Figure 3 breaks down the intraday load profiles for five NSPs again for each of our three scenarios. Profiles are provided for the years 2022, 2030, 2040 and 2050. In the case of BRY0661 the profiles are the summer profiles. For the other four cases the profiles are winter profiles.

Figure 1 – Single NSP profile under the network optimised scenario

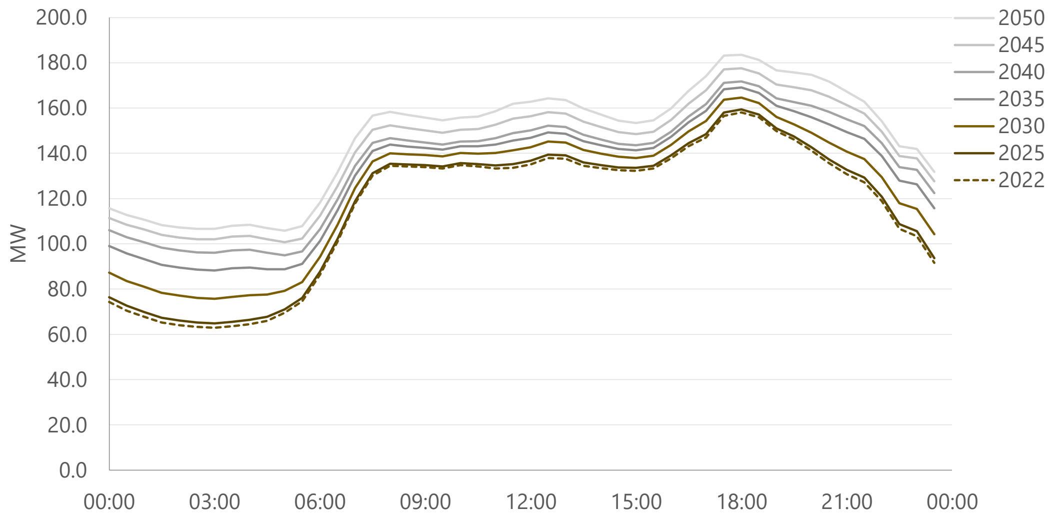


Figure 2 – Aggregated national results for the three peak scenarios based on the CCC modelling

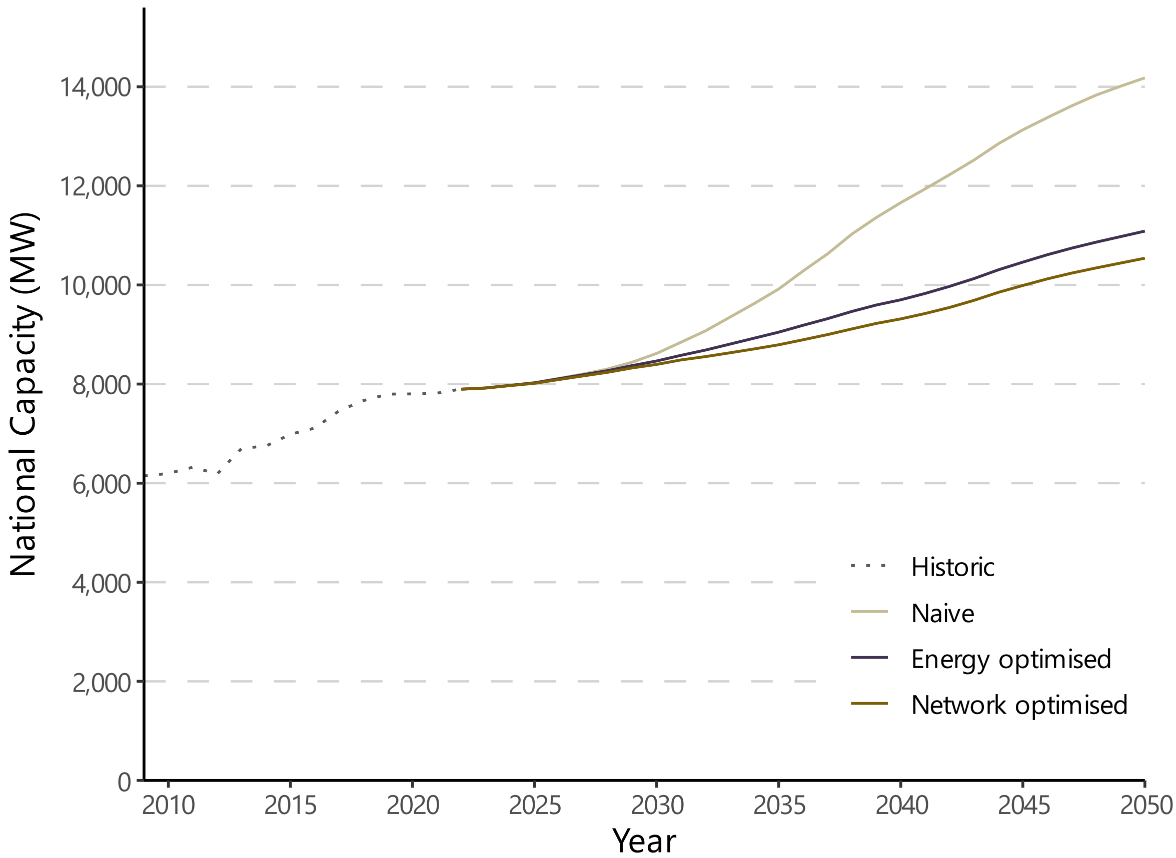
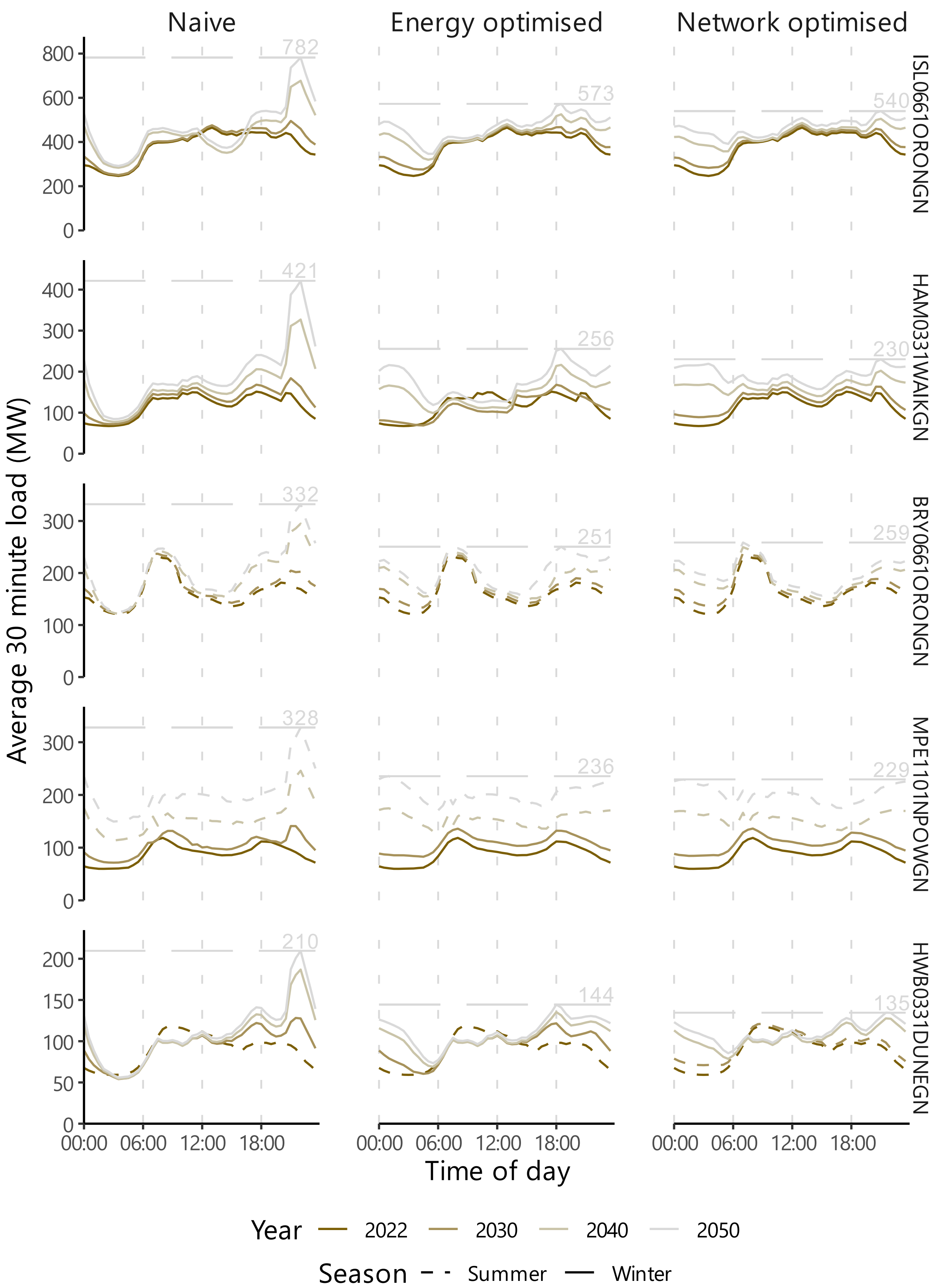


Figure 3 –Five sample NSPs (ordered by max naïve profile load)



Insights

This work is somewhat a first for disaggregating forecast demand to this detail. One of the challenges was a lack of publicly available research into domestic electricity demand behaviour. Individual EDBs have done studies in their own networks, but if there is no publicly available research, demand management practices, modelling and related policy may not evolve as much as possible.

A particular area for further research that is almost essential is into industrial demand. Our survey suggests that a lot of industrial loads may be agriculture-related and might lift summer demand significantly. Our allocation of summer demand lifted 45 of 151 existing NSPs to have summer peaks rather than winter peaks, while only two NSPs shifted in the other direction.

Control/management of discretionary load will take on increasing importance for energy optimisation and network optimisation as load increases. Amongst all of the end uses, effects on network peaks will be dwarfed by managing EV charge demand. In fact, once water heating and EV charging are used to flatten demand, moving any other demand will either simply move the peak or could be just as easily achieved by adjusting EV charging profiles. Significant numbers of EVs are already on overnight charging tariffs. At current levels these tariffs are helping network peaks, but eventually the herding of charging volume into narrowly distributed charging times could actually cause significant peak problems.

Energy optimisation will generally be conducted with a national picture in mind but network optimisation will focus on a more local level. Also, it remains unclear in either case the degree to which operators rely on price incentives or on securing actual control of smart chargers and the like. The best NZ benefits would come from applying EV charging dynamically to find the optimal risk-weighted mix of value streams for the control but historically (i.e. since the 1998 separation of ownership between lines and energy businesses) there has not been a great incidence of collaboration between energy optimisation and network optimisation.

A second stage of work could investigate the implication of the CCC forecasts for capital investment and labour deployment in the distribution networks. This would involve extrapolating the demand peaks deeper into distribution networks probably based on typical network densities, substation and connection statistics and typical construction configurations.

The model

Users need to be quite proficient in Excel to use the model, and even then recalculation times are long. The development version of the model (in R) could be developed further, potentially into a web accessible model with a more intuitive user interface.

Development version (R code)

The version coded in R is much faster to run and was developed to quickly sandbox developments in the model and produce early results.[1] The development model has little in the way of user interface

[1] R is a free software environment for statistical computing and graphics. It has a dedicated user base, and many free and paid modules (add-ins) are available. It is a powerful mathematical coding language but not as well-known as other mathematics languages (such as Matlab) or other coding languages (such as Python).

and can only be used by a competent R coder.

Production version (Excel)

The delivered model is about 340MB of Excel model across many workbooks, with multiple spreadsheets. Many dependencies in the model mean that a series of workbooks must be opened following a change to model parameters/inputs, such as scenario (naïve, network, or energy optimised) in order for the results to refresh.

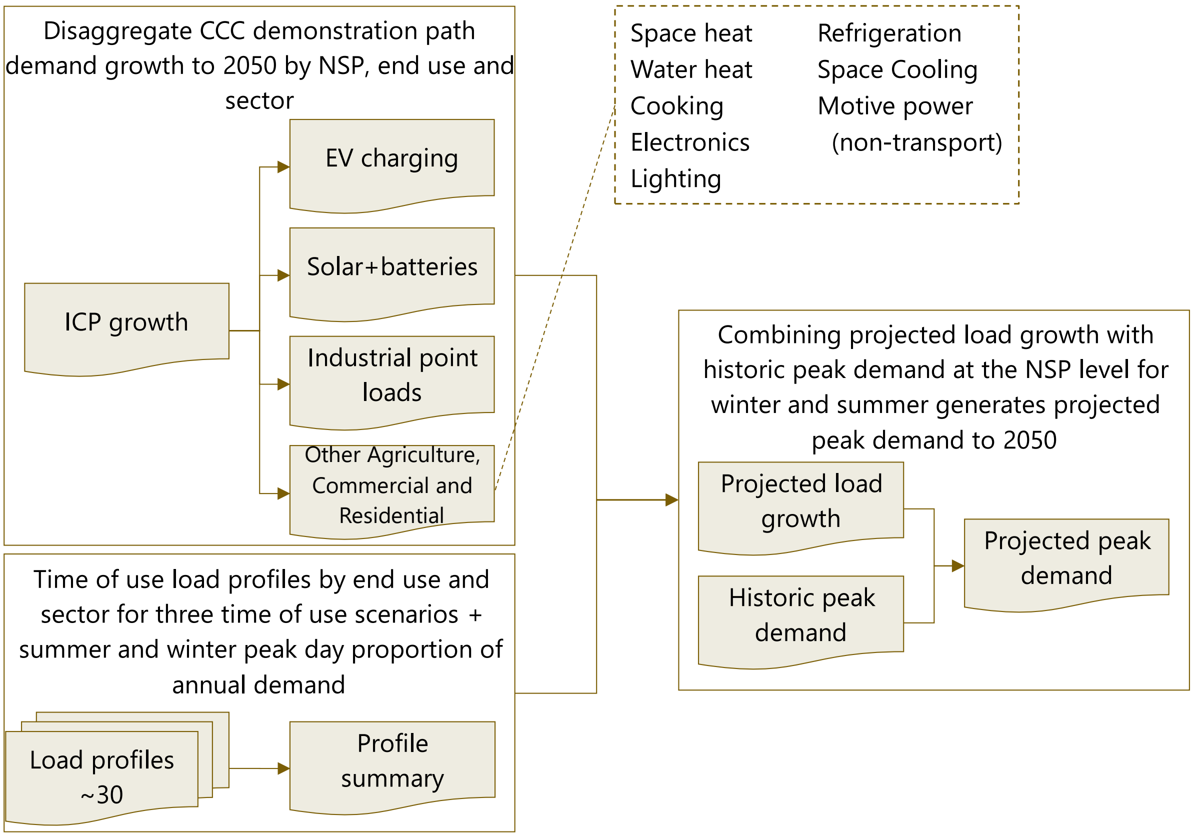
Model structure

There are four main parts to the model:

- Time of use profiles for each sector and end use.
- Disaggregation of CCC's national annual demand forecast to NSP level.
- Current peak day profile.
- Peak demand projection.

The Excel model workbook structure

Figure 4 – Excel model workbook structure



The list of file dependencies is available in the model in the 'File dependencies' workbook – see Appendix C. See also Appendix D 'Workbook descriptions'. Full instructions and a quick use guide can be found in the main body of this report in Section 3, 'The model'.

1. The project and process

1.1 Context

New Zealand's legislated target of net zero greenhouse gas (GHG) emissions by 2050 will drive a significant increase in electricity demand over the next decades. This demand will be required to meet the baseline population and economic growth as communities move away from fossil fuels, but also to substantially electrify transport and industrial sectors.

Consumers responding and adapting to the new energy system will be the main drivers of change to all parts of the electricity industry – generation, transmission, distribution, and retailing.

Electricity distributors are key enablers of this consumer-led change, supporting New Zealand's households and businesses shift away from fossil fuels to low-carbon and renewable energy.

The energy transition will see an increase in generation by solar or wind, which is intermittent. This will create challenges to distributors, requiring them to find new ways to ensure reliability of electricity supply. The role of distributed energy resources is also likely to increase, changing the landscaping that the distributors will have to navigate during the transition.

In this work, we developed potential pathways (or scenarios) for how the distribution network might evolve through to 2050. The distributors' asset management plans provide important staging points along the pathways, but their outcomes are necessarily short-term oriented.

Developing the pathways required assembling robust assumptions on factors driving electricity demand, and on underlying macroeconomic developments. The pathways will be used by ENA members to make decisions and engage with consumers and stakeholders.

1.2 The brief

The project brief required a clear, comparable set of assumptions and modelling to support EDBs across the country to develop their own network-specific scenarios and demand models.

The assumptions were to cover reasonably broad categories that are seen to affect future electricity demand. They must cover key dates, expectations of transition or wait-and-hold points, technology adoption rates, and possible triggering events will assist the sector to picture the most likely directions and end points.

Assumptions can be categorised as follows (list not exhaustive):

- Macro-economic: e.g. economic and population growth, interest rates, net migration, and labour productivity.
- Sectoral electrification: e.g. electrification of public transport; electrification of industrial process heat (in terms of additional GWh demand).
- Technology uptake: e.g. heat pumps; solar PV of different scale; hydrogen technologies; domestic and grid-scale battery storage; EV home charging capacity; vehicle-to-grid technology; public versus residential EV charging; growth of flexibility markets.

- Energy efficiency improvements: e.g. fuel economy of vehicles; energy-efficiency initiatives, including building quality and insulation.
- Security of supply:
    - Peak load control through demand-side management: e.g. hot water control, household batteries, vehicle-to-grid technology, or other forms of load shifting to reduce peak loads; EDB access to DER load management.
    - Power quality / reliability of supply: e.g. factors affecting voltage, harmonics, power factor; low-voltage visibility and advanced metering equipment.
- Behavioural changes: e.g. reduction in distances travelled by car due to changes in consumer preferences.
- Policy and regulatory: e.g. the extent to which the government will stop, start or continue to fund or subsidise electric appliances, solar and battery installations, industrial heat conversion, and electrification of public and private transport.

1.3 Working with the Steering Group

The work was to be delivered in a collaborative way with the Electricity Networks Aotearoa (ENA) members.

It must be informed by the knowledge and expertise of ENA members preparing for the future, including network adaption, technology adoption, forecasting, and regulation. To achieve this, the project would require workshops with members.

The project brief also required engagement with the project's Steering Group, to provide briefing to and ask feedback on the ongoing work. Regular reporting would also be required to the ENA Board.

As well as regular update meetings, workshops were also held with the Steering Group. Advice was sought on the nature of load control potential, checking on key profile assumptions, and what would be useful for the output scenarios.

Individual Steering Group members also answered questions on end uses and provided candid findings on their assessments of future peak loading.

A meeting was also held with Transpower on their approach to peak demand forecasting at grid exit points (GXPs).

1.4 Future Networks Forum

The Future Networks Forum (FNF) provided an excellent opportunity to workshop the project with members and we attended two workshops. We provided initial results at the 19 July meeting and final results on 15 November 2023.

2. Model development and insights

2.1 Initial approach

The initial approach proposed to the Steering Group had the following six stages:

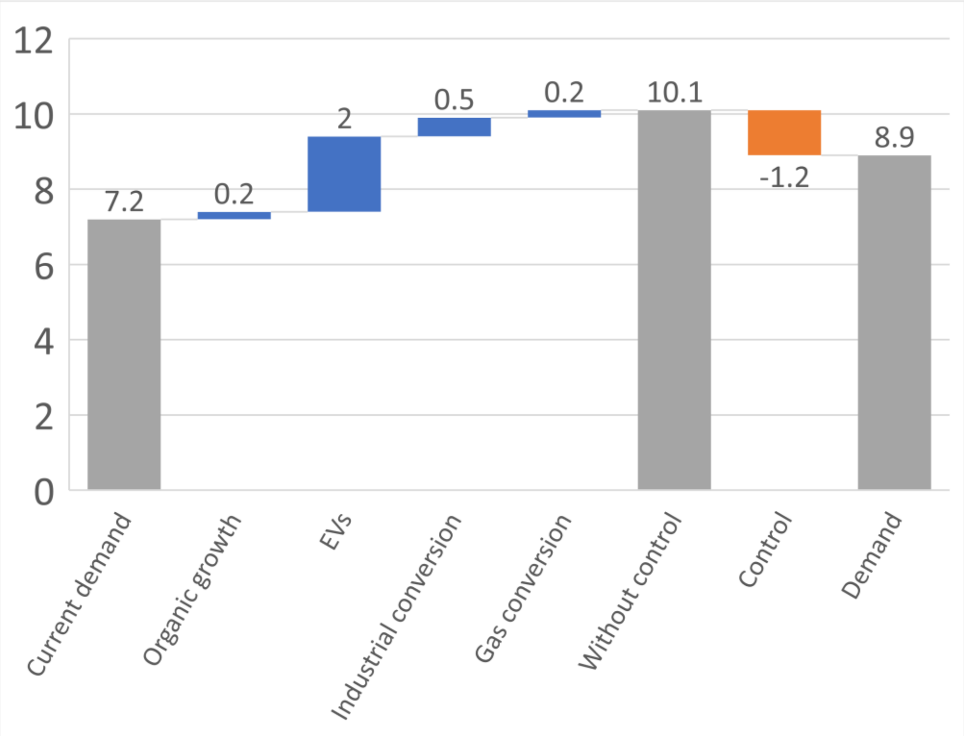
1. Plan project delivery.
2. Collect and analyse information needed to develop assumptions.
3. Develop high-level scenario themes.
4. Develop assumptions.
5. Develop and model detailed scenarios.
6. Prepare reports and submit model.

Our approach was modified somewhat after meeting the EDBs at the FNF above and Transpower. What we found was that EDBs take a consistent approach EDBs building total system maximum demand:

- Add each component of growth.
- Assess the uncontrolled demand.
- Apply component(s) of control.

This is demonstrated in Figure 5.

Figure 5 – Example of components of growth and control



The meeting with Transpower highlighted that modelling the time of use can be important as adding new demand can change the time when peaks occur, and new periods may be higher than previous peaks. Transpower also advised that modelling an entire year is data intensive and to focus on days where the peak is likely to be highest.

2.2 Evaluating national scenarios

Originally it had been envisaged that there might be a number of national scenarios that could be used to inform the peak demand assessment, e.g. Productivity Commission, BusinessNZ Energy Council (BEC), Boston Consulting Group BCG, etc. However, as well as providing a consistent national forecast for demand growth and decarbonisation through electrification, we also needed a basis on which we could robustly disaggregate the global forecast to a local level.

In practice only the Climate Change Commision's (CCC's) analysis provided such a basis as its modelling was publicly available and included end use assessments by sector (commercial, residential, industrial, and agricultural). This, and its detailed assumptions about aspects like VKT, gave a basis for comparing to territorial authorities and could also be compared to NSPs. Data provided by the Electricity Authority (EA) on NSPs gives number of connections by size and by sector.

2.3 CCC demonstration path

The CCC developed economy-wide forecasts for emissions on a demonstration path to show an achievable path for its advice to the Government on New Zealand's Nationally Determined Contribution (NDC). The emissions were primarily based on energy use across the economy for end uses and sectors, including national electricity consumption.

Using the CCC demonstration path, we could determine:

- Future electricity demand and drivers based on CCC scenarios.
- Baseline demand and peaks/time of use based on historic data.

We then needed to develop a time-of-use model for each of the drivers' uncontrolled and controlled contribution to future national peaks. This "control" would include a combination of price signals from EDBs and price signals from the energy market, which could be reinforced in some circumstances through direct switching by EDBs and aggregators/retailers.

The CCC demonstration path would allow us to analyse this in detail, as outlined in Table 1. By comparing this with the EA's data for sector, size, and the number of installation control points (ICPs) by NSP, the NSP level of disaggregation became the most sensible approach.

Table 1 – End use and sectors from CCC demonstration path

Space heat	Agricultural
Water heat	Industrial
Cooking	Commercial
Electronics	Residential
Wash and dry	
Lighting	
Refrigeration	
Space Cooling	
Motive power (non-transport)	
Process heat	
EV charging – a function of no. of EVs and VKT (LPV, LCV, MC, MT, HT, Bus)	
Batteries	
Solar	

The end uses mentioned above could be disaggregated using regional data if it were available. Different methodologies were applied for different demand drivers:

- General end uses, based on:
    - Regional population/economic growth
    - Electrification of space heating, water heating and cooking away from natural gas (NG) and LPG
    - Change in demand of existing ICPs
- EV charging (based on):
    - Uptake curves
    - Regional changes in Vehicle km Travelled
- Distributed solar and batteries based on:
    - Current solar installations from EA
    - ICP growth projections
- Industrial growth based on:
    - Data provided by EDBs

2.3.1 Peakiest day allocation

The above disaggregation determines the annual energy forecast for each NSP by sectoral end use. To convert it into peak demand, the annual energy needs to be allocated to the peakiest day, and a time of use (TOU) profile needs to be applied to that day. However, this process was challenging due to a lack of data or proxy data for daily allocation. Although daily electricity volumes were available, sectoral end use volumes needed to be allocated separately. Some end uses were summer weighted (e.g., agricultural water heating), some were winter weighted (e.g., residential space heating), and others had no seasonal weighting (e.g., EV charging). Ultimately, simple assumptions and averages were found to produce sensible results compared to other methods.

2.3.2 Daily profiles

Again, there was little data available for sectoral end use profiles over a day, although some information on sector daily profiles could be found including in EDBs' asset management plans. Determining sectoral end-use profiles was approached on a 'bottom up' basis. Daily TOU profiles for each sectoral end use were built by a two-step process that first determines the duty cycle and then determines the 'time of start' profile.

A variety of use cases were blended to give average duty cycles. For example, residential space heating would start and run continuously until the space temperature setting is reached and then would cycle as the spaces cool and are reheated. This cycling is not consistent over a day as it is also a function of outside temperatures.

Time of start makes assumptions about when people switch things on. For example, residential space heating could be switched on for the mornings only, for evenings only, for both, or could be left on for 24 hours. In some cases, the duty cycle had to be matched to the time of start. For example, residential heating may also be manually switched off and the time of day (outside temperature) matters. Other uses, such as water heaters, are always on but the time of start triggers an increase in demand which then follows an automatic duty cycle.

Using the time of start distributions to trigger the starting of average duty cycles for each sectoral end use then gives a derived TOU profile. For convenience, initial profiles are developed in nominal MW for an appropriate period. They are then converted to percentage of daily demand per period.

2.4 First results and Steering Group questions

First results were provided to the Steering Group using first assessments of the most important future sectoral end use. This highlighted what was already largely known, that EVs represent the biggest growth in demand across a range of sectors. The two subsets of EVs providing the greatest impetus to demand growth are light passenger vehicles (LPVs) and light commercial vehicles (LCVs). However, heavy transport is also significant, as is commercial and agricultural (non-transport) motive power, which is mostly off-road EVs.

To produce some indicative results for the Steering Group we focused on EVs (mainly LPVs) and space heating. Space heating isn't expected to grow significantly in energy terms but contributes strongly to current peaks.

Our initial assumptions were based on current peaking for space heating and the Energy Efficiency and Conservation Authority's (EECA) report (Electric vehicle charging report - Insights into EV owners' charging habits, and use of public EV charging, 2023) for EVs. The EECA report suggested that EVs are highly price elastic and respond strongly to the increased availability of EV tariffs. Based on this, our first EV TOU profile had a dramatic peak from 9pm. This peak was overstated but was the first attempt and demonstrated the method.

While the peak for EVs was overstated, it did confirm two things. First, that EV charging management is critical. Second, that overly simple tariffs risk 'herding' demand into a more severe peak. The simple tariff incentives that encourage EV demand at 9pm or 10pm create a tight distribution of charging that would actually be less severe if left to natural diversity. However, it will be possible to encourage EV charging demand to follow more beneficial profiles than natural diversity or herding tariffs.

As EVs are obviously critical to assessing peak demand in the future, some Steering Group members forwarded more information and the questionnaires in Appendix A and Appendix B was sent to the Steering Group as well.

2.5 Refining the approach

Following Steering Group feedback, more work was done on expanding the load profiles and the disaggregation.

2.5.1 Peakiest day allocations

Allocating annual energy forecasts to the peakiest day was difficult. There wasn't data available on which to base these assumptions. In the end we used three basic methods.

For many end uses, such as EVs, it was assumed that there was generally even use for every day of the year. For clearly seasonal use, such as space heating, allocations were done over an assumed season length (four months for space heating). For other uses where seasonality was less clear we used MBIE's daily statistics to allocate daily demand according to the end uses sector (commercial, residential, industrial).

2.5.2 Profile development

Reports from Vector and Powerco, in conjunction with the EECA report, highlighted that most EVs use 'trickle' charging and that most EVs aren't charged every day.[2] This results in longer charge times than we originally modelled but far fewer vehicles herded into the evening peak. However, this still results in a significant peak.

Most of the rest of our profile assumptions were either acceptable or insignificant to the result. There was a problem with water heating. This wasn't a problem for the profile modelling but rather we were unable to discern existing networks that control water heating and those that weren't. We have simply applied our water heating control assumptions to water heating demand growth. There is the potential for greater water heater control than our modelling suggests.

[2] 'Trickle' charging is charging at low current/power. Technically, speaking EV batteries aren't trickle charged but most EVs are charged using mobile connectors plugged into ordinary power points with charging current limited to 10 amps.

Figure 6 – Examples of duty cycles

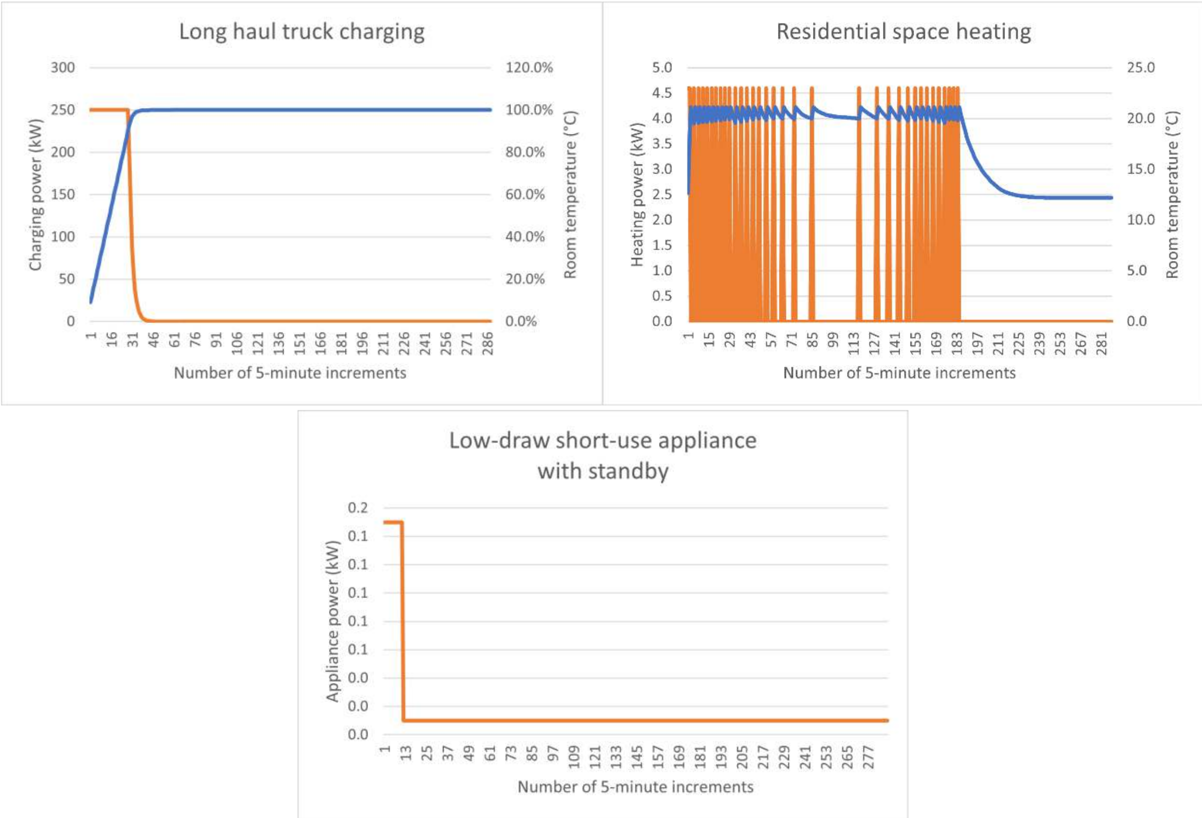


Figure 7 – Examples of time of start profile

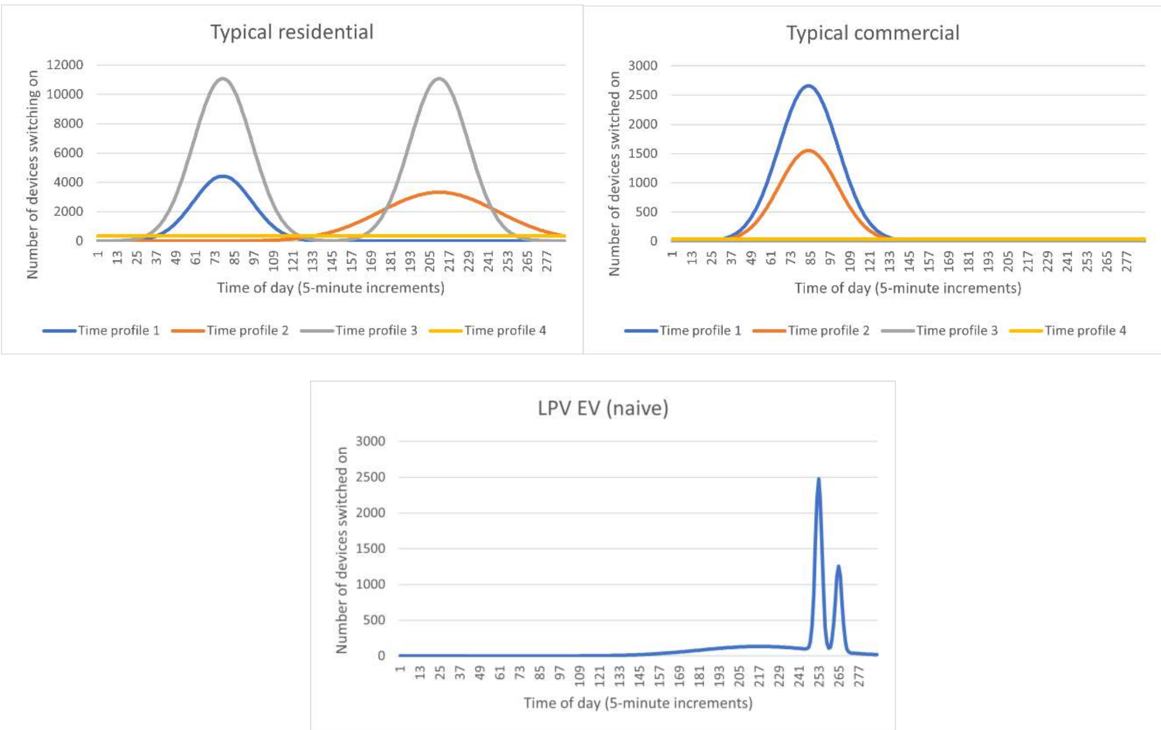
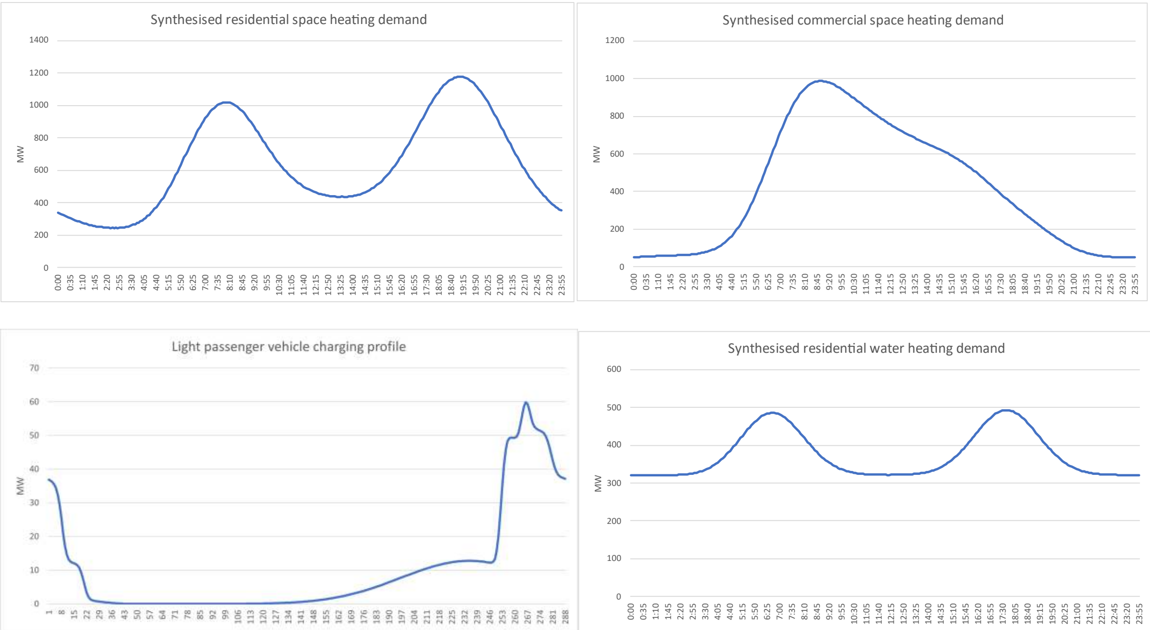


Figure 8 – Examples of sectoral end use profiles



While refining the results reduced the peak the results, still highlight the need to manage EV charging, and the problems with potential herding. Therefore, even though this peak demand forecast is unlikely as both energy traders and network operators would change the EV charging incentives, it is still useful for showing what a herding problem could be. This scenario is called the naïve scenario.

2.5.3 Assessing the new demand peak

Finally, we add the change in peak demand profile to historic profiles.

For the historic profile for each NSP, we took the five days that had the highest peak load trading period from the previous five years for summer and winter separately (five each).

We then added our forecast additional peak day profile to each of these five historic days and selected the one that creates the highest peak for each NSP. These peak days are not necessarily the same day for each NSP. Therefore, the results are not an assessment of national peak demand, but the national peak capacity required to just meet each NSP's expected peak demand. In practice there would also be a security margin on capacity.

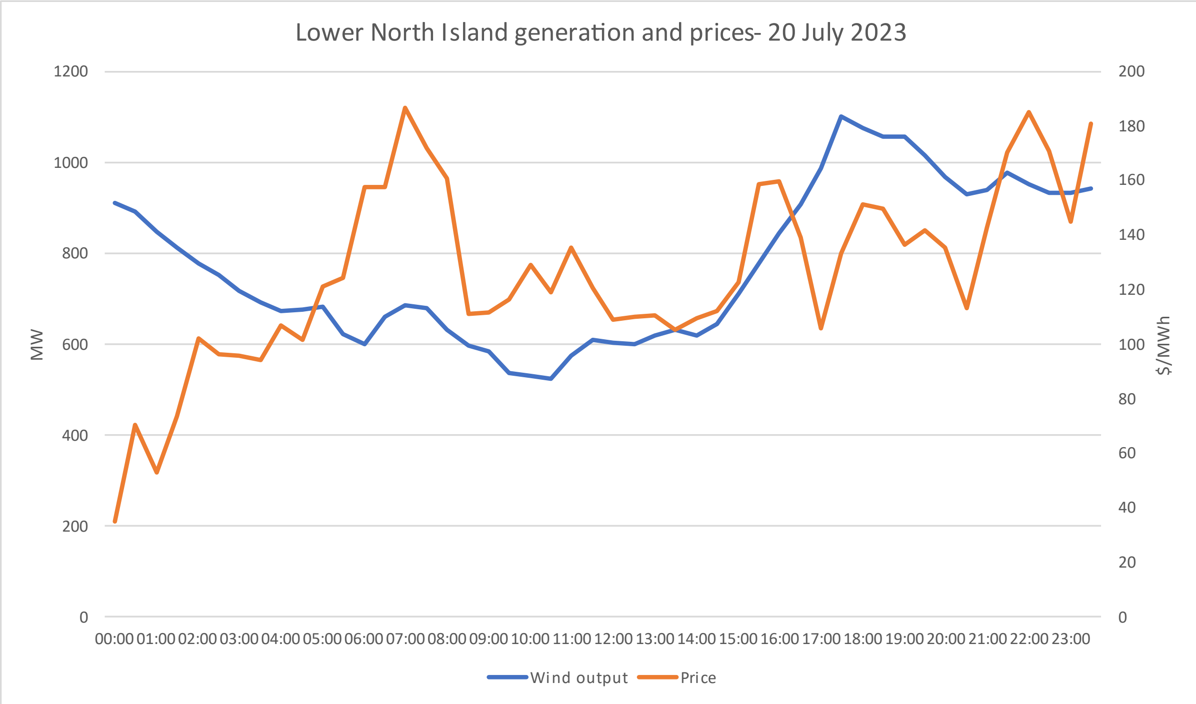
2.6 Identifying the peak demand scenarios

We suggested to the Steering Group that there wasn't a 'baseline' scenario as such. As EV charging has already demonstrated a high degree of flexibility and price responsiveness (with the potential for herding), it is credible that EV charging will be managed under any scenario. The Steering Group was asked about the control scenarios that were to be applied and suggested developing the 'worst' and 'best' credible scenarios from the point of view of the impact on EDB network capacity.

We determined that any credible scenario would involve general management of EV charging from peak to off-peak times. Considering the key two purposes that EV charging management could be applied to (energy arbitrage and network peak reduction), both are generally improved by reducing demand at peak times. However, there is some delinking of peak energy prices from system peaks due to the variable injection of renewables, especially wind. While price pressure still tends to be higher when demand is high, short-term injections or reductions of wind output can move the highest price periods and can sometimes make the peakiest periods relatively cheap.

Figure 9 demonstrates the potential for negative correlation between wholesale market price and wind output. In the example from 20 July, lower wind output assisted in a morning peak price and high prices before and after the evening peak. However, higher wind output helped suppress prices during the evening peak. It should be noted that wind forecasting is not exact, and some price effects are not necessarily driven by wind output but by wind output differing significantly from expectations.

Figure 9 – Lower North Island prices and generation for 20 July 2023



SOURCE: emi.ea.govt.nz

We concluded that the range of credible control scenarios would fall somewhere between demand response (DR) (mainly EVs) being focused on network peak minimisation (the best credible scenario for network capacity) and focused on energy arbitrage only (the worst credible scenario for network capacity).

2.6.1 Network optimised

The network optimised (best case) uses any reasonable load control (mainly water heating and EV charging) to avoid the national peak as much as can be reasonably expected. It is important to note that we only attempted to moderate the peak of each end use at a national level, and so the network optimised approach isn't necessarily the best approach for individual NSPs. We didn't use an algorithmic optimisation but simply trialled controlled time of start profiles to give the best outcome.

Originally, we used water heating to shift the evening peak later and then ramped up EV charging and cycled chargers on well into the night. We then assumed that chargers that weren't available to be charged overnight could be encouraged to charge around midday (for solar). However, with increases in industrial loads, moving all EVs to midday distributions created a day peak, especially with our revised rooftop solar assumptions (see section 2.6.3).

2.6.2 Energy optimised

The energy optimised (worst case) is generally similar to the network optimised case except that less demand is available for demand management. The key difference is the energy optimised scenario responds to a notional short-term peak in wind generation that energy traders seek to move demand into. We have set this peak to occur at the worst time for national peak demand.

It is important to note that such a wind peak could occur at any time, but we have simulated the worst time for the network peak. This won't affect every NSP the same way, but a key point is that a market driven demand response could occur at the most inconvenient point for any NSP. Another key difference for the wind peak is that, where network peaks could be managed down to the NSP level, subject to transmission constraints, market driven demand peaks will respond to the national market and will have whatever effect on the NSPs that results.

The way we approached the shifting of EV demand was that the notional traders switched on a number of EVs to match a wind peak. Once the chargers were started, they were allowed to complete their charging cycles, they were not remotely switched off.

2.6.3 Solar battery optimisation

It became difficult to decide how batteries would be used when so much demand flattening can be done using EVs and water heating. Given that we are focusing on load profiles by 2050 we used our conclusions from our work on a DER CBA for the EA. The DER CBA (Reeve, Comendant, & Stevenson, 2021) concluded that, by 2050, the price of rooftop solar with a battery would have fallen to the point that only two value streams would be needed to make them economic, i.e. the combination of self-supply plus some form of local peak avoidance would be enough for an installation to go ahead. Therefore, we made a combined assumption for rooftop solar output where solar output is absorbed by a battery and used to self-supply the (mostly) residential demand focused on the residential peak.

2.7 Industrial point loads

Industrial point loads are single large loads that can be built in the transmission or distribution networks. For the purposes of assessing EDB peak demand there are three types with different effects:

1. Transmission (or grid) connected – which doesn't affect distribution capacity.
2. Distribution connected directly to a GXP – while technically these loads increase distribution capacity requirements, they have dedicated distribution lines that would be designed when the plant is built/converted. They affect GXP capacity but are more of a problem for transmission planning than distribution.

3. Distribution connected – these are large loads embedded within an EDB's distribution network and significantly affect distribution capacity.

These loads can be new demand, for example a new coolstore or entity, or the result of electrification, for example a dairy processor converting from coal to electric heat. They are large enough that one load makes a significant difference to an NSP's profile. The CCC data delineated between transmission connected and distribution connected but the distinction between connection directly to a GXP and distributed loads was less clear.

It became obvious that there was no basis on which to allocate industrial point loads as the industrial loads, while large in size, are low in number. Therefore, statistical allocations don't meet the law of large numbers and are highly unreliable.

The steering group advocated directly polling EDBs and so the questionnaires in Appendix A and Appendix B were sent to all EDBs. There was good response to the questionnaire, but it also became obvious that there was a lot of uncertainty for the EDBs. Many loads had made enquiries about electrification but were considering other options, and some also had multiple decarbonisation pathways. For some loads it wasn't clear what their profile would be.

There were some industrial loads that were seen as highly likely but uncertain on timing. Our default approach was to set them to a 2030 connection date. This creates an unrealistic step change in capacity at 2030, but this should be interpreted as the capacity that is expected to be required by 2030.

2.8 Results

Figure 10 – Aggregated national results for the three peak scenarios based on the CCC modelling

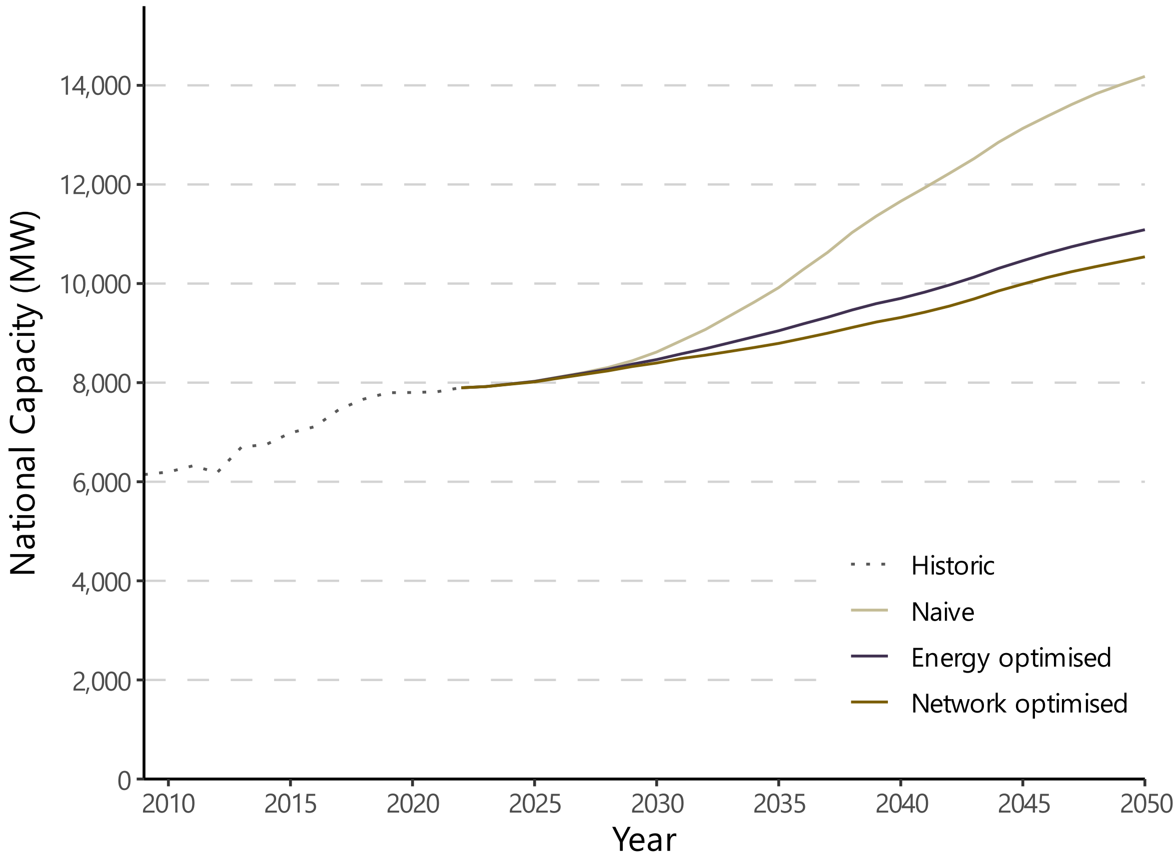


Figure 10 demonstrates the extreme outcomes for aggregated national peaks if either no mitigation is brought to new load (naïve case) or all of the load is optimised in the energy market (energy optimised) or all of the load is managed for the sole purpose of managing peaks in distribution networks (network optimised). In reality, demand side management will mitigate the naïve scenario. It will come from a mix of energy traders and network businesses and will be the result of a mix of remote management and price incentives.

Figure 11 breaks down the intraday load profiles for five NSPs again for each of our three scenarios. Profiles are provided for the years 2022, 2030, 2040 and 2050. In the case of BRY0661 the profiles are the summer profiles. For the other four cases the profiles are winter profiles.

Figure 12 shows how growth in industrial load, vehicle charging and other load (and an indication of the solar effect) add to 2022 profiles by 2050 under the three scenarios.

Figure 11 – Top five NSPs (ordered by max naïve profile load)

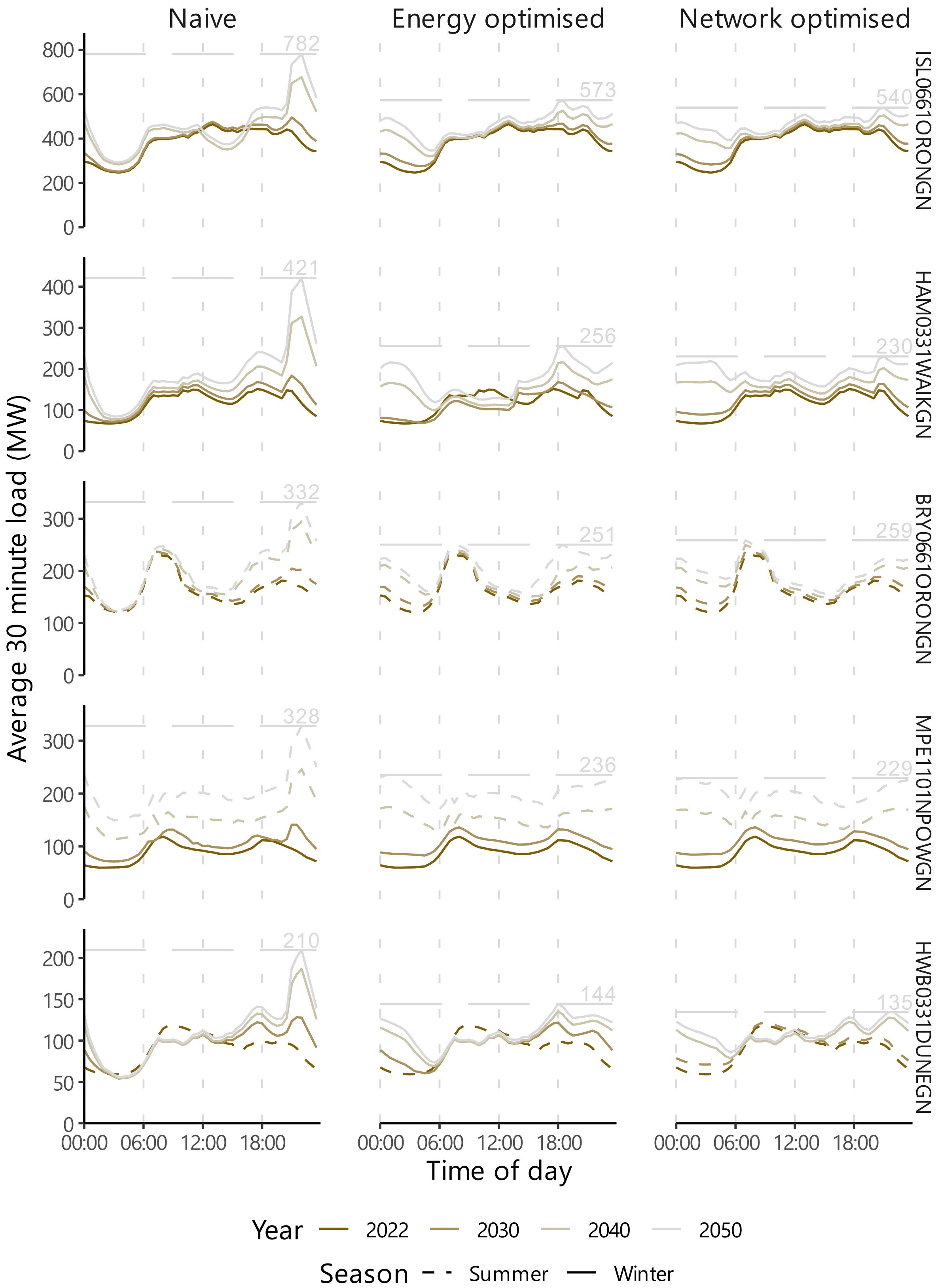
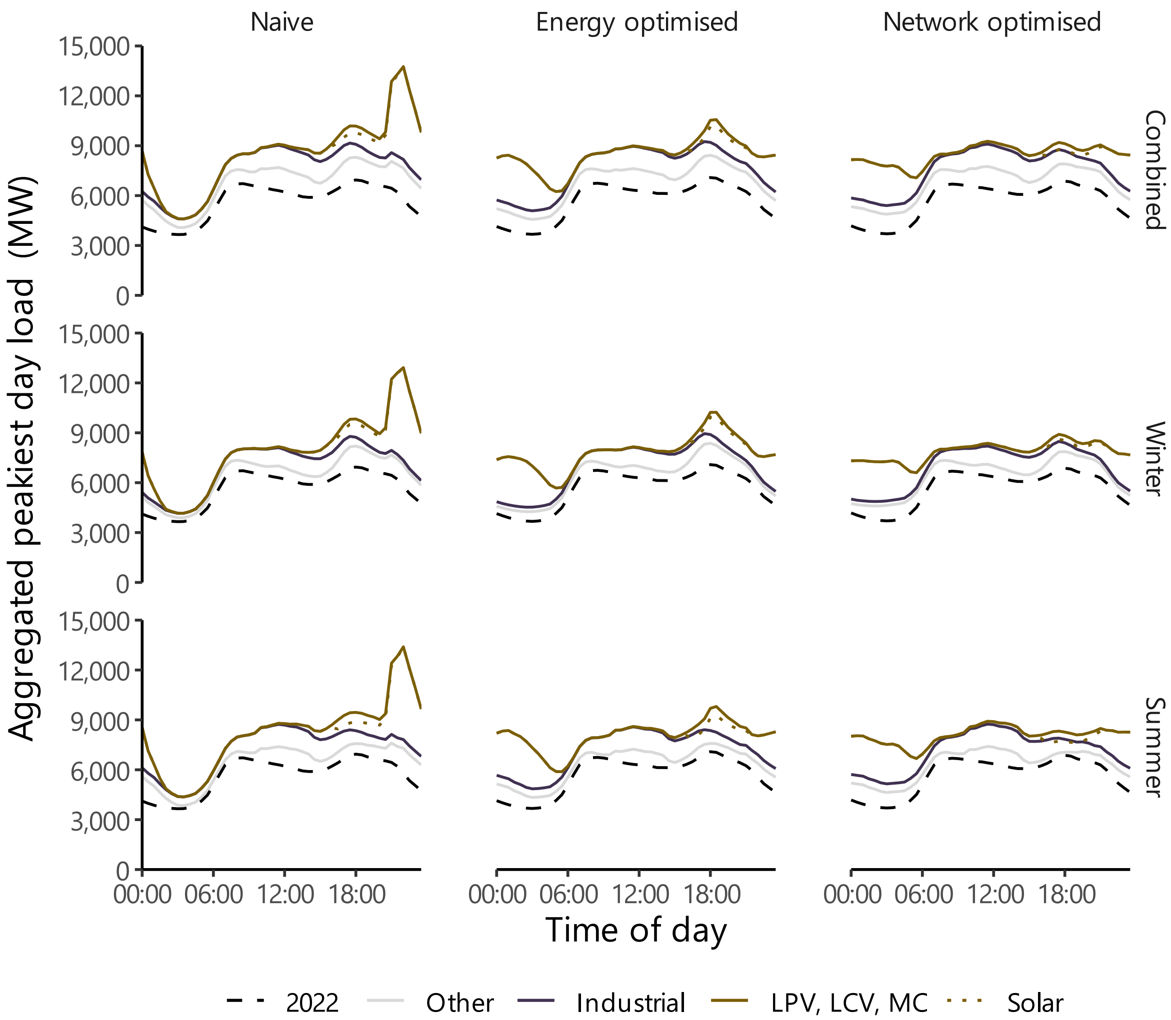


Figure 12 Cumulative contribution from aggregated industrial load, vehicle charging and other load (and an indication of the solar effect) in 2050 compared to 2022.



2.9 Insights

This work is somewhat a first for disaggregating forecast demand to this detail. Doing the work has brought some insight, although it also reinforces some insights that were already known or suspected.

There is a lack of publicly available research into demand behaviour that can be applied across all networks. We note that New Zealand lags behind other power systems when it comes to electricity demand statistics, for example, the US Energy Information Administration (EIA) and its extensive demand surveys. Being able to more closely match sectoral end use from the CCC data to more granular demand data would have improved the modelling significantly.

A particular area for further research that is almost essential is into industrial demand. Our limited survey suggests that a lot of industrial loads may be agriculture-related and might lift summer demand significantly. Our allocation of summer demand lifted 45 of 151 existing NSPs to have summer peaks rather than winter peaks, while only two NSPs shifted in the other direction. This could be of some concern as hotter summers may also limit network capacity.

The other aspect of summer industrial load is that is more diverse than we first thought in terms of TOU. Baseload was less prevalent than expected, and irregular loads seem to be quite common too.

Another aspect worth following up on is that even with a reasonably conservative screening of how likely the EDBs thought their industrial loads would be, the industrial loads surveyed exceeded the CCC's forecast. This would be worth exploring further, perhaps with the CCC.

Control/management of discretionary load will take on increasing importance for energy optimisation and network optimisation as load increases. While there are potentially a number of end uses that might be able to be controlled, their effects on network peaks are dwarfed by managing EV charge demand. In fact, once water heating and EV charging are used to flatten demand, moving any other demand either simply moves the peak or could be just as easily achieved by adjusting EV charging profiles. Therefore, control/management of EV charging will have a large part to play in managing required network capacity. Ironically, EV demand profile would put less pressure on demand than the naïve forecast if it is left to its natural diversity. However, significant numbers of EVs are on overnight charging tariffs. At current levels these tariffs are helping network peaks, but eventually the herding of charging volume into narrowly distributed charging times could cause significant peak problems.

While the dynamic management of EV charging with a national profile provides a large level of benefit for network capacity, there could be further gains if management occurred at a more granular level. EV charging management used for energy trading, though, would be applied nationally subject to transmission constraints. A clear picture is yet to emerge of how control of discretionary load will be accessed and prioritised and the balance of benefits between:

- EDBs
- generator and/or retailers
- aggregators
- consumers
- NZ Inc.

It is likely that the best NZ benefits would be found from maximising the consumer benefit from EVs while applying EV charging dynamically to find the optimal risk-weighted mix of value streams for the control. However, risk will need to be a factor in assessing the value of use of EV charging. Aggregators and energy traders have different risk profiles to EDBs. If mistakes are made, a bad trading day can be expensive but tomorrow is another day. If demand gets herded into a distribution network peak, the resulting damage could be both disruptive and long-term.

While much of the above insight won't be a surprise to EDBs, this work lends itself to public messaging about future discretionary control. The graphical nature of the work and the fact that it is tied to a nationally credible scenario is convincing.

2.10 Potential future development

There are a number of developments that could be progressed from this work.

This work was originally envisaged as being the first stage of two stages of work. The second stage of work could investigate the implication of the CCC forecasts for capital investment and labour deployment in the distribution networks. This would involve extrapolating the demand peaks deeper into distribution networks probably based on typical network densities, substation and connection statistics and typical construction configurations.

As discussed in section 3, the model was made to be somewhat accessible and is delivered in a set of Excel spreadsheets. However, users need to be quite proficient in Excel to use the model, and even then, recalculation times are long. The development version of the model (in R) could be developed further, potentially into a web accessible model with a more intuitive user interface.

Another possible development that could benefit from the more granular locational approach is to investigate whether there is a point where limiting trading flexibility is optimised, on a risk weighted basis, against network investment.

3. The model

Part of the original scope was to make the model available to EDBs if practical. It was almost impractical, but the model is available as a set of Excel spreadsheets. Nevertheless, the Excel model is large, has long recalculation times, needs a relatively high spec PC, and users need to be Excel savvy. Due to the long recalculation times, it became expedient to also build a development model in addition to the production model.

3.1 Model versions

3.1.1 Development version (R code)

The version coded in R is much faster to run and was developed to quickly sandbox developments in the model and produce early results.[3] The development model has little in the way of user interface and can only be used by a competent R coder. However, it does have the potential to be further developed with better user interface, including the potential for a web-based application.

It is far faster for experimenting with significant change to the model or inputs.

3.1.2 Production version (Excel)

The delivered model is about 340MB of Excel model across many workbooks, with multiple spreadsheets. Many dependencies in the model mean that a series of workbooks must be opened following a change to model parameters/inputs, such as scenario (naïve, network, or energy optimised) in order for the results to refresh. Each spreadsheet contains large matrices of calculations and so recalculation takes time, even on a high spec machine. Nevertheless, the model can be adapted and reworked by a person suitably familiar with Excel.

The following descriptions are made for the production version (Excel).

3.2 Model structure

There are four main parts to the model:

- Time of use profiles for each sector and end use.
- Disaggregation of CCC's national annual demand forecast to NSP level.
- Current peak day profile.
- Peak demand projection.

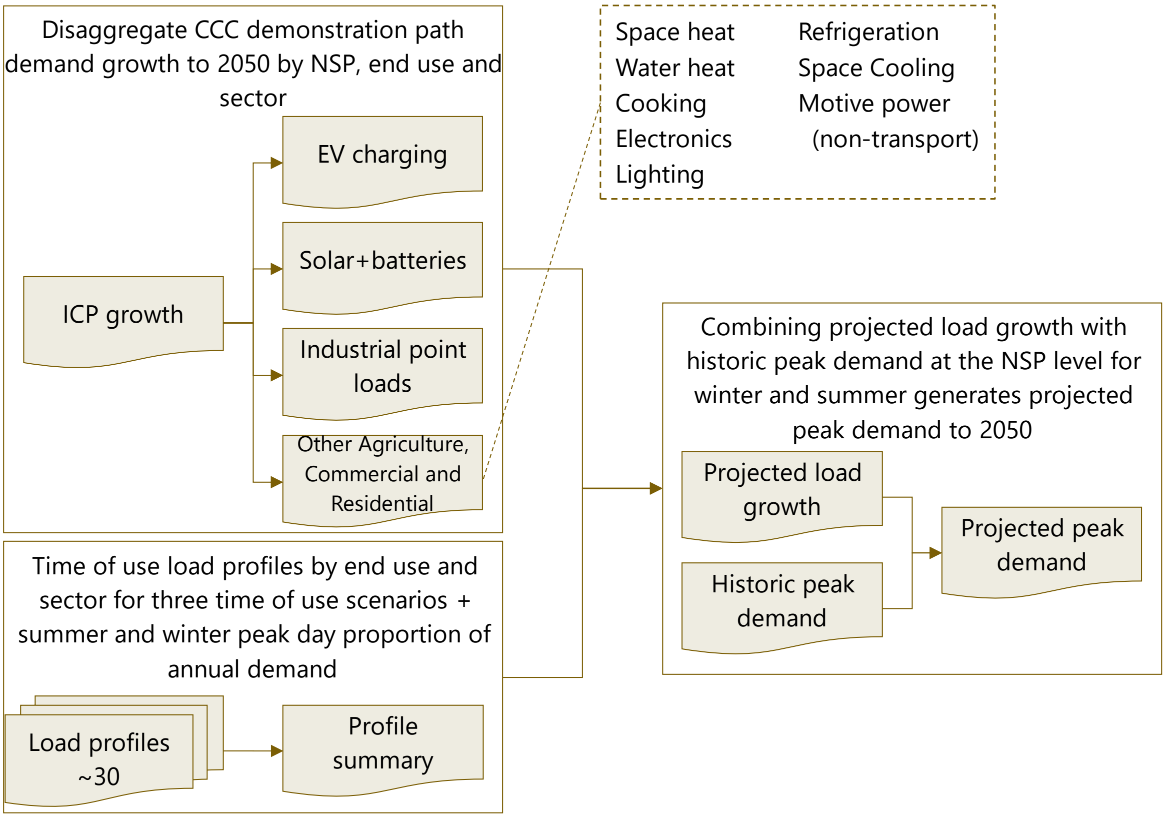
[3] R is a free software environment for statistical computing and graphics. It has a dedicated user base, and many free and paid modules (addins) are available. It is a powerful mathematical coding language but not as well-known as other mathematics languages (such as Matlab) or other coding languages (such as Python).

Each of these parts has a number of workbooks for the model to work. As the model is so data intensive, and has so much matrix arithmetic, the model needed to be spread across many workbooks, and spreadsheets within these.

3.2.1 The Excel model workbook structure

Figure 13 shows the Excel workbooks and how they relate to each other.

Figure 13 – Excel model workbook structure



The list of file dependencies is available in the model in the 'File dependencies' workbook. This is also included in Appendix C. A more itemised description of each workbook is included in the model in the 'Workbook descriptions' workbook, which is also included as Appendix D.

3.3 End use TOU profile module

The TOU profile models are five-minute period models aggregated to half-hours for the main modelling. A five-minute period captures more diversity than a 30-minute period would. However, this creates a large model for each sectoral end-use and needs to be aggregated to 30 minutes for the main model, which would otherwise be impractically large.

Each TOU profile model has two component models, a duty cycle module and a time of start module. The TOU profile results from combining the two.

There are three types of duty cycles modelled:

- EV charging duty cycle.
- Thermal duty cycle.
- Baseload duty model.

The EV charging cycle is based on a variety of battery sizes (loosely based on standard vehicles if known). Different battery charge levels (e.g., 80%), charger sizes and average kms travelled are inputs. The model produces a charging demand for the duration required for battery charging.

The thermal model bases a heating and temperature cycle based on a volume of material (e.g., air for space heating or steel for cooking plates). The thermal model is quite coarse but does cycle the heating to simulate diversity. Generally, the heating is provided for a certain time matched to the time of start profile it uses. A modification of the thermal model is used for water heating where the thermal cycling is over 24 hours, but the time of use is matched to a drop in temperature. The model is also used for space cooling and refrigeration. For space heating and cooling, time of day is important as outdoor temperatures affect the cycling.

The baseload model just switches things on at a constant level for a set duration. It is used for uses such as lighting and appliances. It can also be set to have a low load carry on after the main load is switched off to simulate standby loads.

Each sectoral end use spreadsheet has an 'Assumptions' sheet. This sheet has the input assumptions for the model used and allocates percentages of demand to time of start profiles. For the thermal and baseload models this sheet collates a matrix of inputs and individual assumptions can be selected to view the results. The 'Derived profile' sheet shows the results of the assumptions selected.

Then there are four duty cycle sheets that collate the results of each set of assumptions. These are just single assumptions for EV charging, but for the thermal and baseload models several sets of assumptions can be blended providing they are consistent with the time of start profile to which they will be applied. The thermal and baseload models also have temperature sheets that are part of the thermal modelling. These are not used in the baseload models.

The 'Start charging time' sheet is where the time of start profiles are set. This is usually done through applying one or many normal distributions. The normal distributions can be modified by altering the target average time of start and the standard deviation of time of start. Other time of start profiles can be used, such as an even (random) distribution or a single start time can be used for 24-hour duty cycles. Bespoke time of start profiles are used to manage EV charging demand.

Four sheets are used to calculate each combination of duty cycle and time of start, and a final sheet sums them. The profile models are done in nominal MW and converted in the workbook 'Profile summary'. 'Profile summary' converts the profiles to percentages of daily demand through the day and converts five-minute profiles into 30-minute profiles. Users can also use 'Profile summary' to directly add their own profiles without using the profile models, but care must be taken to ensure the profile is formatted correctly.

3.4 CCC global disaggregation module

The key approaches to disaggregating the CCC data using regional data are:

1. **ICP assumptions**: It is assumed that the individual connection points (ICPs) per capita by sector will remain constant across different regions over time. For example, if one network supply point (NSP) has twice the commercial ICPs per capita compared to another in existing data, this ratio is expected to continue in the future, irrespective of population changes.
2. **New ICPs and electricity demand**: New ICPs in each sector are presumed to demand an average level of electricity per ICP for that sector. This includes the assumption that natural gas and LPG conversions to electricity will occur uniformly across New Zealand. The increase in electricity demand from these ICPs is based on the national average demand per ICP.
3. **Existing ICPs and washup process**: Existing ICPs are utilised to reconcile any differences between the national change in projections (from the Climate Change Commission) and the sum of changes projected by new ICPs and gas conversion calculations.
4. **Electric vehicle (EV) uptake and usage**: The base proportion of EVs by vehicle class is taken from Ministry of Transport (MoT) data. All regions/NSPs are assumed to follow the national EV uptake curve projected by the CCC but start at different points based on the MoT data. Total vehicle kilometres travelled (VKT) for both EVs and internal combustion engine (ICE) vehicles are allocated to NSP levels, assuming that the VKT per capita by vehicle class remains constant over time.
5. **Industrial growth and demand estimates**: Industrial growth is distributed across existing and new NSPs based on data from individual EDBs, as requested by Sapere. Connection point load estimates are converted to annual demand estimates considering baseload (24 hours a day) and dayload (nine hours a day) operations, as well as seasonal variations (summer for seven months, and all year). These annual demands are then reconciled with the CCC's estimates, often resulting in a significantly higher increase in annual demand than the CCC's projections.

3.5 NSP profile forecast module

Together the workbooks 'LoadGrowth', 'Projected_peak', and 'Model Outputs' collate the profile and disaggregation data and find the peakiest day profile for each NSP. LoadGrowth provides the profiles of the increases in sectoral end-use for each NSP and Projected_peak adds this to the five days with the highest winter peak and the five days with the highest summer peak. The day with the highest peak is then selected and presented by 'Model Outputs'.

3.6 Quick use guide

To do any significant model changes in the production model would require an analyst very familiar with Excel. However, it is quite straightforward to have a look at NSP data (by selecting NSPs), national capacity curves, some NSP detail and change scenarios (naive, network optimised, energy optimised). Nevertheless, even just doing these actions means opening and recalculating large Excel workbooks and still needs a reasonable PC. The model also makes use of the relatively recent array functionality and the 'LET' function and so older versions of Excel may not be able to run the model. There are also some quirks of Excel to be aware of. Even with a good PC and current Excel, the recalculation times will create waiting time.

Four of the workbooks need to be opened to change scenario and they are all linked. A problem that can occur when workbooks are first opened is that they open in protected mode. Sometimes, when in protected mode, link updates don't work even if you select 'update'. For this reason, we recommend that the workbooks are opened in a certain order. This shouldn't matter once the model has been up and running once, but it doesn't hurt to follow the order anyway.

Once the model has been extracted, all files will be under a directory 'Model - Release – V2'. In this directory you will see most of the key workbooks. However, the first workbook to open is in a sub-directory. Open the 'Load profiles' sub-directory and then open the workbook 'Profile Summary.xlsx'. If the workbook opens in protected mode, i.e. a yellow banner appears at the top of the opening spreadsheet saying, "SECURITY WARNING". You may be required to 'Enable Editing' and/or 'Enable Content' (if a second security warning comes up). Make sure all security warnings are addressed and the workbook is open and editable before proceeding.

Go back up to the 'Model - Release – V2' directory and open the workbook 'LoadGrowth.xlsx' and address any security warnings before proceeding. Then open workbook 'Projected_peak.xlsx' and address any security warnings before proceeding. Then open workbook 'Model Outputs.xlsx' and address any security warnings.

If at any time you find '#ref' or '#na' errors, then address any security warnings and close the workbook with the errors without saving. Reopen the workbook and see if the problem goes away (you will probably need to wait for recalculation to complete). If the problem still occurs, make sure all four workbooks are open, address all security warnings, and then close them all. Then reopen them in the order:

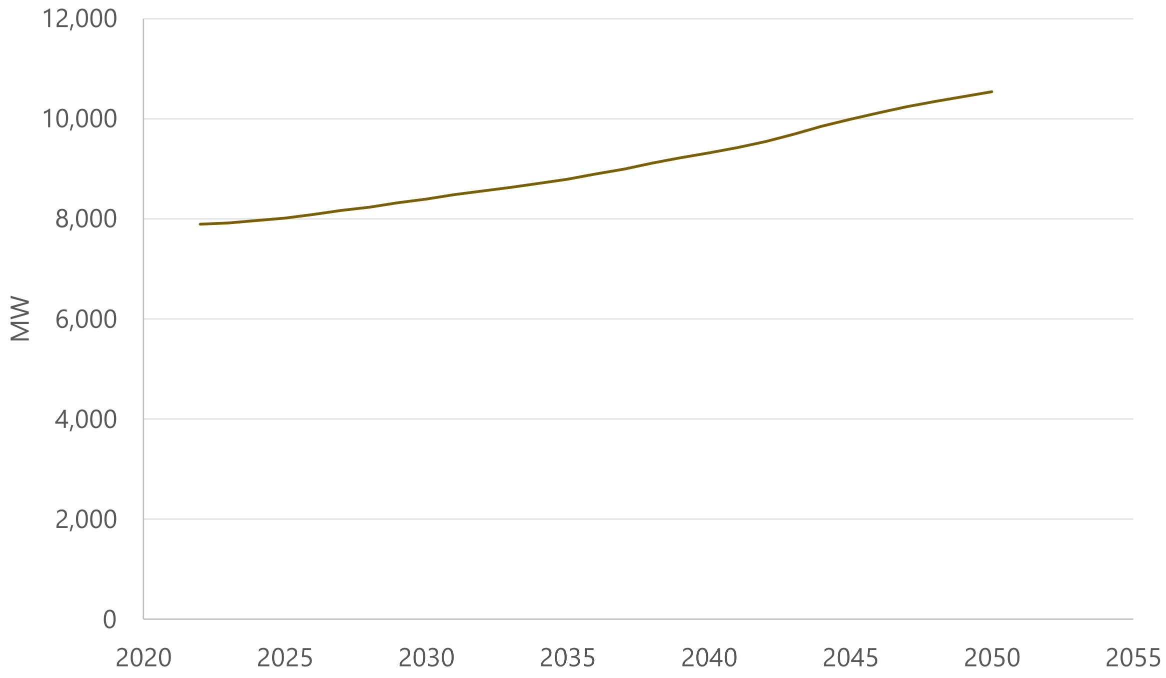
1. Profile Summary.xlsx
2. LoadGrowth.xlsx
3. Projected_peak.xlsx
4. Model Outputs.xlsx

If errors still occur, then please contact the authors.

Once all four workbooks are open, Model Outputs is the workbook with the key results.

The main summary worksheet is 'National growth'. This sheet shows the sum of individual NSP peak demands at the national level for the selected scenario (Figure 14). NB. This is the highest peak for each NSP not a coincident peak.

Figure 14 – National peak capacity – network optimised



To see, and change, the scenario then select workbook ‘Profile Summary.xlsx’. Then select sheet ‘Scenario choice’. The scenario will be listed in cell B2. To change the scenario, select the desired scenario using the drop-down menu in cell B2. Select workbook ‘Model Outputs.xls’ and wait for all recalculation to complete. NB, sometimes Excel will not refresh charts quickly and it can look like a change hasn’t been made. To check this scroll the sheet away from the chart and scroll back again to see if the chart is now refreshed.

To look at the summary data for each NSP select workbook ‘Model Outputs.xlsx’ and sheet ‘Individual NSP’. Scroll down to row 158 and you will see two charts. Figure 15 shows the peakiest day profile for the selected NSP and how it changes over time for the selected scenario.

Figure 15 – Single NSP profile over time

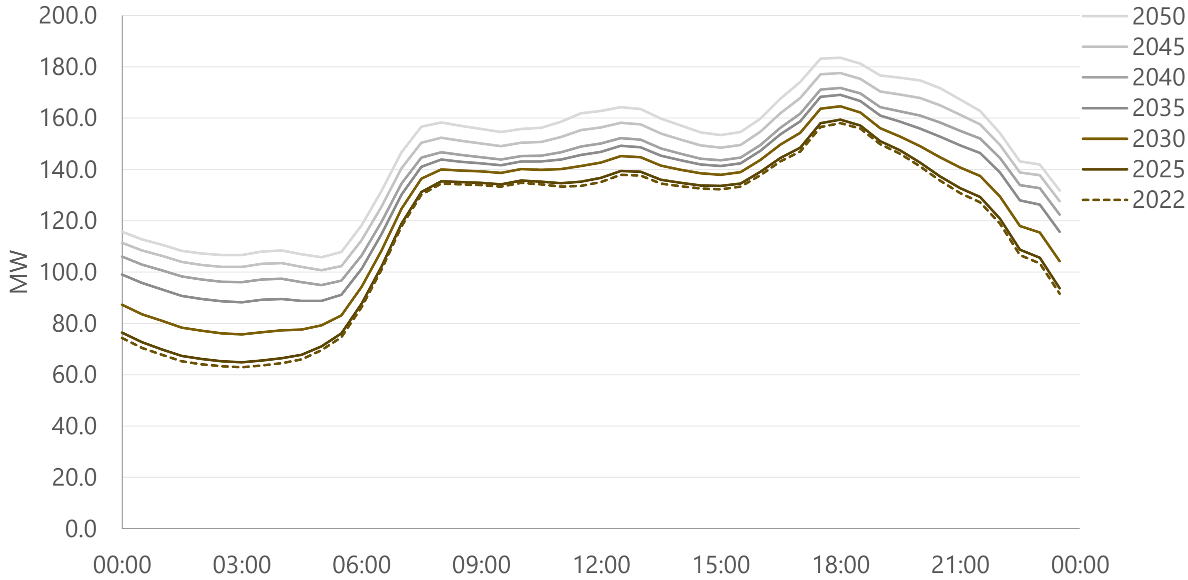


Figure 16 – Selected NSP peak demand

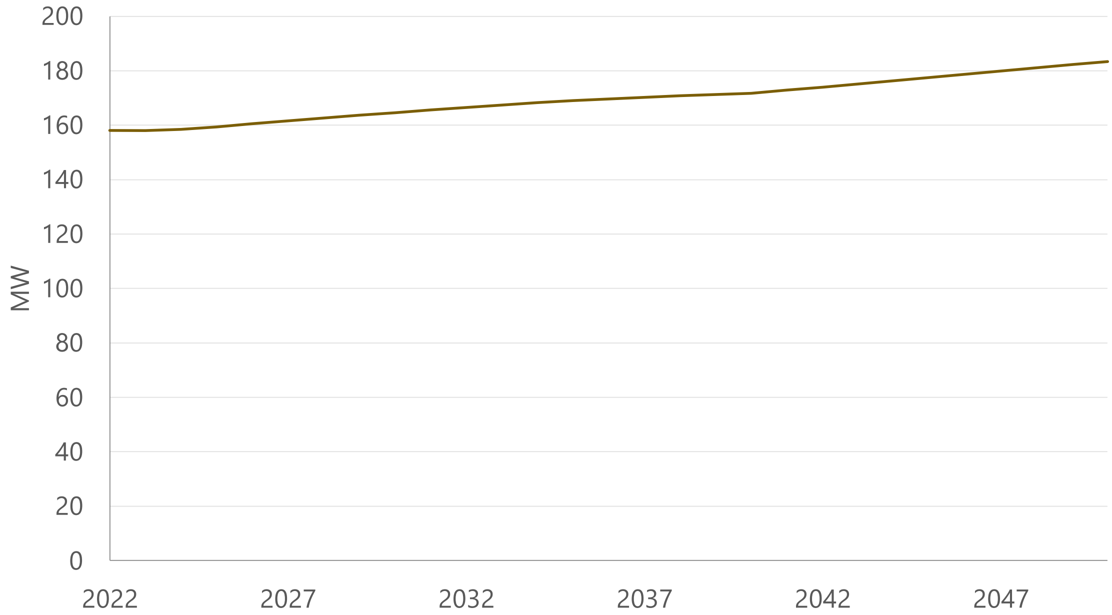


Figure 16 shows the peak demand for the selected NSP over time. Cells F157 to L157 indicate whether the peak in the year shown is a winter peak (w) or a summer peak (s). The data for the charts is also on this sheet.

To select another NSP the NSP name needs to be typed into cell C154. The list of valid NSP names is given in cells C1 to C153. If you start typing the name of an NSP from the list, Excel's autocomplete functionality should give you the desired NSP. Enter this NSP and wait for the recalculation and the data and charts for the newly selected NSP for the chosen scenario will be displayed. Although, the charts may need to be scrolled to refresh as above.

3.6.1 Extra for more detail

For more detail and more options for grouping data select sheet 'Detailed NSP'. This sheet allows one or more NSPs to be grouped or disaggregated in more detail (data only, no charts).

Detailed NSPs can be filtered by winter/summer, network region ID, network reporting region, root NSP, region, sector, end use, and time. To select one or more NSPs to investigate the NSP name(s) need to be listed in row 1 in B1 for one NSP, and in separate cells from B1 to the right for more than one NSP. Each NSP name needs to be in a separate cell and there cannot be empty cells between NSP names. NB, the sheet will recalculate every time a cell is populated so it may pay to turn off automatic calculation until all NSPs are listed (if you are entering a few), and the recalculate the workbook. Bear in mind that each NSP added significant increases the calculation time required.

The detailed NSP data can be filtered by winter/summer by using the drop-down list in cell B2. Network region ID, network reporting region, root NSP, region, sector, end use, and time can be filtered by using the drop-down lists along row 4.

To get the correct summary for a network region ID, network reporting region, or region then you will need to have every NSP in that region listed along row 1 from cell B1. Again, bear in mind that every NSP added will significantly increase the calculation time.

Pick scenario from drop down in cell B2 of the `Scenario choice` sheet in the `Profile Summary` workbook. Once refreshed, this workbook can be closed. Open LoadGrowth, `Projected_peak` and Model Outputs and wait for recalc (could be a few minutes). Type the NSP in Model Outputs to select a different NSP.

References

EECA. (2023). *Electric vehicle charging report - Insights into EV owners' charging habits, and use of public EV charging.* EECA.

Reeve, D., Comendant, C., & Stevenson, T. (2021). *Cost-benefit analysis of distributed energy resources in New Zealand.* Sapere Research Group.

Appendix A Sectoral end use questionnaire

Information request to Steering Group

End uses	Sectors	Description	Growth by 2050 (GWh)	Winter/Summer/Both	Duty cycle	TOU distribution	Reference material	Questions for EDBs	Critical Input for EDB	EDB Comment
Space Heat	Agriculture	Heating of sheds but not process heat	62	Winter only	Same as commercial	Same as commercial	n/a	No questions proposed, this category is small in forecast growth		
	Commercial	Heating of buildings - office blocks, offices, shops, workshops, supermarkets, and malls	212	Winter only	Heating cycles based on outdoor temps for UNI, LNI and SI variety of insulation and building types	1. Normal distribution around 8.30am start and running for 9 hours 2. Normal distribution around 8.30am start and running for 11 hours 3. 24 hour running	Categories and insulation standards based on residential assumptions	LOW priority (relatively small) 1. Have we missed any commercial building types? 2. Are there any other significant TOU patterns for commercial space heating? 3. Any data on the proportions of businesses with normal business hours, extended business hours, or 24 hour operation?		
	Residential	Heating of homes	-116	Winter only	Heating cycles based on outdoor temps for UNI, LNI and SI and variety of insulation	1. Normal distribution around 6.30am start and running for 3 hours 2. Normal distribution around 5.30pm start and running for 5 hours 3. Two normal distributions starting at 6.30am and 5.30pm and running for 4 hours 4. 24 hour running	Categories and insulation standards based on healthy homes standards Further research being done on housing stock Outside temperatures based on MfE temp records	LOW priority (relatively small) 1. Are there any other significant TOU patterns? 2. What is the proportion of morning space heating to evening? 3. What proportion of households work at home? 4. What proportion of households are 24 hour heating (mainly young families and older people)?		
Water Heat	Agriculture	Heating of water	-99	Summer only	Heating cycles based on cylinder size, temp setting and insulation	1. Normal distribution around 5am and 4pm starts for 2 hours	Based on typical water heater specs Usage timings aligned generally with milking sessions	LOW priority (relatively small) 1. Is agricultural water heating primarily dairy? 2. Are there other significant agriculture hot water users?		
	Commercial	Heating of water	240	Both (all year)	Heating cycles based on cylinder size, temp setting and insulation	24 hour cycling with periods of drawdown: 1. Normal distribution around 8.30am drawdown and then random for 9 hours 2. Normal distribution around 8.30am drawdown and then random for 11 hours 3. Random drawdown over 24 hours	Based on typical water heater specs Usage timings aligned with electricity peaks	LOW priority (relatively small) 1. Are there any other significant TOU patterns for commercial water heating? 2. Any data on the proportions of businesses with normal business hours, extended business hours, or 24 hour operation?		

	Residential	Heating of water	2413	Both (all year)	Heating cycles based on cylinder size, temp setting and insulation	24 hour cycling with periods of drawdown: 1. Normal distribution around 7.00am drawdown 2. Normal distribution around 5.30pm drawdown 3. Normal distribution over both peaks 4. Random drawdown over 24 hours	Based on typical water heater specs Usage timings aligned with electricity peaks	1. How much water heating is still routinely used for peak load control? 2. Any data on the proportions of households with morning, evening, or 24 hour hot water usage?		
Cooking	Commercial	Cooking and baking of food for sale	962	Both (all year)	Heating cycles based on typical frying/grilling, roasting, boiling and baking times	1. Normal distribution around 11.30am start 2. Normal distribution around 5.00pm start 3. Normal distribution starting at 7.00am 4. Bakers normal distribution starting at 3.00am	Based on typical commercial cooking facilities	1. Are there any other significant TOU patterns for commercial cooking or baking? 2. Any data on the proportions of businesses operating for breakfast, lunch and/or dinners? 3. How significant is commercial baking in overnight demand?		
	Residential	Cooking and baking of food for home consumption	287	Both (all year)	Heating cycles based on continuous usage for frying/grilling, roasting, boiling and commercial baking	1. Normal distribution around 6.30am start 2. Normal distribution around 5.30pm start 3. Two normal distributions starting at 6.30am and 5.30pm starts 4. 24 hour running	Based on typical domestic cooking appliances	LOW priority (relatively small) 1. Any data on proportion of households are work at home or stay at home?		
Electronics and appliances	Agriculture	All electronics, devices, and appliances (does not include motors except those that are a component of an appliance)	0	Both (all year)	n/a	n/a	n/a	No questions proposed, this category is small in forecast growth		
	Commercial	All electronics, devices, and appliances (does not include motors except those that are a component of an appliance)	240	Both (all year)	Devices on at rated capacity for business hours. When shutdown a proportion of devices can be given standby load	1. Normal distribution around 8.30am start and running for 9 hours 2. Normal distribution around 8.30am start and running for 11 hours 3. 24 hour running	Rough estimates of number of DC chargers/power supplies and larger appliances a proportion of which have standby loads	LOW priority (relatively small) 1. Any data on proportion of small devices (e.g. chargers, DC power supplies) to larger devices/appliances (TVs, computers, washing machines)? (not including fridges, cookers, water heaters, or heaters)		
	Residential	All electronics, devices, and appliances (does not include motors except those that are a component of an appliance)	142	Both (all year)	Devices on at rated capacity for usage hours. When shutdown a proportion of devices can be given standby load	1. Normal distribution around 6.30am start and running for 3 hours 2. Normal distribution around 5.30pm start and running for 5 hours 3. Two normal distributions starting at 6.30am and 5.30pm and running for 4 hours 4. 24 hour running	Rough estimates of number of DC chargers/power supplies and larger appliances a proportion of which have standby loads	LOW priority (relatively small) 1. Any data on proportion of small devices (e.g. chargers, DC power supplies) to larger devices/appliances (TVs, computers, washing machines)? (not including fridges, cookers, water heaters, or heaters)		
Lighting	Agriculture	Lighting	-22	Both (all year)	Devices on at rated capacity for usage hours.	Same as commercial	n/a	No questions proposed, this category is small in forecast growth		

	Commercial	Lighting including streetlighting	-138	Two profiles Winter and Summer	Devices on at rated capacity for usage hours.	1. Normal distribution around 8.30am start and running for 9 hours 2. Normal distribution around 8.30am start and running for 11 hours 3. 24 hour running 4. Streetlights - normal distribution around 5.30pm and running for 13 hours SUMMER - same except streetlights normally distributed around 8.30pm start and run for 9 hours	Rough estimates of number of lights and ratio of CFLs, LEDs, and legacy incandescent and fluorescent lighting	LOW priority (relatively small) 1. Any data on size of lighting baseload and peak, security lighting load, and streetlighting load? 2. Any information on take up of CFLs and LEDs?		
	Residential	Lighting	-129	Two profiles Winter and Summer	Devices on at rated capacity for usage hours.	1. Normal distribution around 6.30am start and running for 3 hours 2. Normal distribution around 5.30pm start and running for 5 hours 3. Two normal distributions starting at 6.30am and 5.30pm and running for 4 hours 4. 24 hour running SUMMER - less morning load and evening distributed around 8.30pm	Rough estimates of number of lights and ratio of CFLs, LEDs, and legacy incandescent and fluorescent lighting	LOW priority (relatively small) 1. Any data on size of lighting baseload and peak, and security lighting load? 2. Any information on take up of CFLs and LEDs?		
Refrigeration	Agriculture	Refrigeration including appliances, cool stores, and chillers.	30	Summer only	Duty cycles assuming horticulture cool stores and dairy shed chillers	1. Normal distribution around 5am and running for 7 hours 2. Normal distribution around 4pm start and running for 13 hours 3. 24 hour running	n/a	No questions proposed, this category is small in forecast growth		
	Commercial	Refrigeration including appliances, fridge & freezer cabinets, cool stores, and chillers.	346	Both (all year)	24 hour duty cycles assuming appliances, commercial cabinets, and cool stores. With cold air loss on usage	24 hour cycling with periods of drawdown: 1. Normal distribution around 8.30am drawdown and then random for 9 hours 2. Normal distribution around 8.30am drawdown and then random for 11 hours 3. Random drawdown over 24 hours	Rough estimates of fridge and cooling sizes and typical specifications	LOW priority (relatively small) 1. Any data on size of lighting baseload and peak?		
	Residential	Refrigeration including appliances.	197	Both (all year)	24 hour duty cycles assuming appliances with cold air loss on usage	24 hour cycling with periods of drawdown: 1. Normal distribution around 7.00am drawdown 2. Normal distribution around 5.30pm drawdown 3. Normal distribution over both peaks 4. Random drawdown over 24 hours	Rough estimates of fridge sizes and typical specifications	LOW priority (relatively small) 1. Any data on size of refrigeration baseload and peak?		
Space Cooling	Agriculture	Cooling of sheds but not to refrigeration levels.	0	Summer only	Same as commercial	Same as commercial	n/a	No questions proposed, this category is small in forecast growth		
	Commercial	Cooling of buildings but not to refrigeration levels.	401	Summer only	Heating cycles based on outdoor temps for UNI, LNI and SI variety of insulation and building types	1. Normal distribution around 8.30am start and running for 9 hours 2. Normal distribution around 8.30am start and running for 11 hours 3. 24 hour running	Based on space heating data	LOW priority (relatively small) 1. Have we missed any commercial building types? 2. Are there any other significant TOU patterns for commercial space cooling? 3. Any data on the proportions of businesses		

								with normal business hours, extended business hours, or 24 hour operation?		
	Residential	Cooling of homes but not to refrigeration levels.	62	Summer only	Heating cycles based on outdoor temps for UNI, LNI and SI and variety of insulation	1. Normal distribution around 6.30am start and running for 3 hours 2. Normal distribution around 5.30pm start and running for 5 hours 3. Two normal distributions starting at 6.30am and 5.30pm and running for 4 hours 4. 24 hour running	Based on space heating data	No questions proposed, this category is small in forecast growth		
Motive power (non-transport)	Agriculture	Use of electric motors for within premise logistics (e.g. lifts, elevators, travelators, conveyors, tractors and other machinery)	1568	Two profiles Winter and Summer	Assume that the bulk of growth is on-farm EVs (particularly tractors) - charging cycle based on typical batteries	1. Wide distribution around charging starting at 5.30pm 2. Tight distribution starting around 9pm energy tariff 3. Tight distribution starting around 10pm energy tariff SUMMER - add regular day charging of heavy tractors (same as linehaul trucks)	Normal spec based on New Holland T4 Etractor Heavy tractor based on Volvo heavy truck Assume as price responsive as LPV	1. Have any connection agreements been struck for on-farm EV charging? 2. Are there any tariffs for on-farm EV charging?		
	Commercial	Use of electric motors for within premise logistics (e.g. lifts, elevators, travelators, conveyors, forklifts and other machinery)	426	Both (all year)	Assume that the bulk of growth is on premise EVs (particularly forklifts)	1. Distribution around 5.00pm to start charging 2. Distribution around 8.00pm to start charging 3. Distribution starting around 6.30am with 3 further 4 hourly charges/batt swaps	Based on samples of forklifts and loaders from Etrucks Assume avoidance of billed capacity, i.e. try to start after business hours	1. Have any connection agreements been struck for commercial on premise EV charging? 2. Are there any tariffs for on-premise EV charging?		
	Residential	Use of electric motors for within premise logistics (e.g. lifts)	14	Both (all year)	Same as commercial	n/a	n/a	No questions proposed, this category is small in forecast growth		
EVs	Light Passenger Vehicle	Passenger vehicle for private use	5987	Both (all year)	Charging cycle based on typical batteries and MoT average VKT	1. Wide distribution around charging starting at 5.30pm 2. Tight distribution starting around 9pm energy tariff 3. Tight distribution starting around 10pm energy tariff	Battery specs based on Nissan, Hyundai, Tesla, and a generic other. Price response based on EECA EV charging survey	1. Any data available on actual demand data from EV charging		
	Light Commercial Vehicle	Light delivery vehicle (<3.5t)	2074	Both (all year)	Charging cycle based on typical batteries and MoT average VKT	1. Wide distribution around charging starting at 5.30pm 2. Tight distribution starting around 9pm energy tariff 3. Tight distribution starting around 10pm energy tariff	Specs based on sample of electric vans (including Mercedes, Ford, BYD) Assume as price responsive as LPV	1. Any data available on actual demand data from EV charging		
	Medium Commercial	Light trucks (3.5-10t)	27	Both (all year)	Charging cycle based on typical batteries and MoT average VKT	1. Wide distribution around charging starting at 5.30pm 2. Tight distribution starting around 9pm energy tariff 3. Tight distribution starting around 10pm energy tariff	Specs based on Volvo Etrucks Assume as price responsive as LPV	1. Any data available on actual demand data from EV charging 2. Have any connection agreements been struck for commercial EV charging?		

	Medium Truck	Medium trucks (10-20t)	1371	Both (all year)	Charging cycle based on typical batteries and MoT average VKT	1. Wide distribution around charging starting at 5.30pm 2. Tight distribution starting around 9pm energy tariff 3. Tight distribution starting around 10pm energy tariff	Specs based on Volvo Etrucks Assume as price responsive as LPV	1. Any data available on actual demand data from EV charging 2. Have any connection agreements been struck for commercial EV charging?		
	Heavy Truck	Heavy truck (20+t)	734	Both (all year)	Charging cycle based on typical batteries and MoT average VKT	1. Wide distribution around charging starting at 5.30pm 2. Tight distribution starting around 9pm energy tariff 3. Tight distribution starting around 10pm energy tariff 4. Distribution starting around 6.30am with 3 further 4 hourly charges/batt swaps	Specs based on Volvo Etrucks and Etrucks Assume as price responsive as LPV, except for linehaul	1. Any data available on actual demand data from EV charging 2. Have any connection agreements been struck for commercial EV charging?		
	Bus	Range of buses from minibus to coaches	511	Both (all year)	Charging cycle based on typical batteries and MoT average VKT	1. Wide distribution around charging starting at 5.30pm 2. Tight distribution starting around 9pm energy tariff 3. Tight distribution starting around 10pm energy tariff 4. Distribution starting around 6.30am with 3 further 4 hourly charges/batt swaps	Specs based on Volvo Etrucks and Etrucks Assume as price responsive as LPV, except for coaches	1. Any data available on actual demand data from EV charging 2. Have any connection agreements been struck for commercial EV charging?		
All categories	All use types						All uses will be reconciled back to CCC demonstration path assumptions			

Links

Healthy Homes standards

MfE temperature data

EECA EV charging survey

New Holland eTractor

Volvo eTrucks

ETrucks

Appendix B Questionnaire on industrial point loads

Information request to EDBs

Memorandum

25 September 2023

To:	Electricity Distribution Businesses
From:	David Reeve, Mike Young, Toby Stevenson
Re:	Information request on electrification of industrial loads

Introduction

Sapere is developing a model for disaggregating a consistent national consumption scenario, and scenario variations to the peak demand scenarios at the network supply point (NSP) level. The purpose is to provide a forecast of network peak demand at the NSP level with a nationally consistent set of assumptions.

We have chosen to base our scenarios around the Climate Change Commission's (CCC) demonstration path and disaggregate to NSP because the CCC path has the most disaggregation of energy use (e.g. space heating, water heating, EVs, etc. by residential, commercial, industrial, and agricultural) and NSPs have the greatest granularity of types and sizes of customers. We can most easily cross-reference this data to regional growth, population, and transport statistics.

For most energy uses statistical allocations are going to be relatively reliable but for larger industrial conversions from fossil fuel to electricity the small numbers make statistical methods far less reliable.

The purpose of this information request is to seek any information EDBs have on these point industrial loads and how we should treat them.

Grid connected, GXP distribution connected, and embedded distribution connected

The nature of the connection of industrial loads becomes important. Obviously, grid connected industrial, which is the large majority of industrial by volume, is not a concern for our forecasting. Of distribution connected we think there is another important distinction that is relevant. Our thinking is that the larger of the distribution connected industrial loads are likely to be connected to sub-transmission networks or have their own lines to a GXP. While these loads are still a planning concern, they are likely to always require a bespoke planning approach. These point loads are also going to be hard to forecast in a way that can be disaggregated from the CCC path or made consistent with it.

Our suggestion is that the electrification loads that become embedded in EDB's existing distribution network are a bigger concern for EDBs as they will need to be generally planned for.

CCC disaggregation of industrial load

The CCC has made estimates of industrial load allocation by connection. It has delineated industrial load by grid connected, HV distribution, and LV distribution. Technically, LV would mean only 230/400 volt but the CCC delineation is more aligned with a clearly large or clearly smaller definition than an accurate assessment of connection voltage. Therefore, we assume that the LV allocation could also include 11kV and that HV would be at least 22kV and would align with our GXP distribution connection designation.

The CCC demonstration path only has two industrial categories with LV connection – mining, quarrying & construction, and other industry. In both these cases the increase in demand primarily comes from the electrification of liquid fuel consumption and would predominantly relate to diggers, loaders, and other mobile construction equipment.

This consumption does lend itself to our disaggregation method and we would treat it like commercial – non-transport – motive power.

Proposed approach

We don't have a statistically reliable method for disaggregating the CCC's HV distribution point loads and we assume that they will mostly be new NSPs, or new connections to the sub-transmission level of existing NSPs and will require bespoke planning. We will disaggregate the CCC's LV distribution loads (liquid fuel conversions to electricity) similarly to commercial – non-transport – motive power.

There will be some significant point loads that will be embedded deeper into the distribution network that we simply cannot forecast. However, we can capture any point loads that EDBs are able to disclose. Therefore, we have attached a list format so that EDBs can let us know of any point loads they are anticipating in their networks, which we will explicitly consider.

We appreciate that potential new loads will have a range of uncertainties, and we are considering the potential range of outcomes. Therefore, we also ask that EDBs assess the likelihood of the point load disclosed on a simple binary probable/possible basis.

List of point loads

NSP (NEW or existing for embedded load, e.g. PEN0331)	Size of load (MW)	Shape of load (e.g. baseload/dayload/evening peak/morning peak/offpeak	Connection date (calendar year)	Direct connect to GXP/subtransmission or Embedded	Probable/Possible

Appendix C File dependencies

File	Dependencies
ICP Growth.xlsx	Electricity growth.xlsx
Electricity growth.xlsx	Other reference/Gas geographical distribution.xlsx ICP Growth.xlsx
EV Projections.xlsx	ICP Growth.xlsx
IndustrialGrowth.xlsx	Load profiles/Profile Summary.xlsx Other reference/List of Point Loads.xlsx
Solar growth.xlsx	Other reference/DGbyNSP_20231002.xlsx ICP Growth.xlsx
Load profiles/Profile Summary.xlsx	Load profiles/Cooking/Commercial cooking profile.xlsx Load profiles/Cooking/Residential cooking profile.xlsx Load profiles/Electric vehicles/Bus EV profile.xlsx Load profiles/Electric vehicles/LCV EV profile - energy optimised.xlsx Load profiles/Electric vehicles/LCV EV profile - network optimised.xlsx Load profiles/Electric vehicles/LCV EV profile.xlsx Load profiles/Electric vehicles/LPV EV profile - network optimised.xlsx Load profiles/Electric vehicles/LPV EV profile - worst case energy only optimisation.xlsx Load profiles/Electric vehicles/LPV EV profile.xlsx Load profiles/Electric vehicles/Truck EV profile - energy optimised.xlsx Load profiles/Electric vehicles/Truck EV profile - network optimised.xlsx Load profiles/Electric vehicles/Truck EV profile.xlsx Load profiles/Electronics and appliances/Commercial electronics & appliances profile.xlsx Load profiles/Electronics and appliances/Residential electronics & appliances profile.xlsx Load profiles/Lighting/Commercial lighting profile.xlsx Load profiles/Lighting/Residential lighting profile.xlsx Load profiles/Non-transport motive power/Agricultural non-transport motive power - Summer only.xlsx Load profiles/Non-transport motive power/Commercial non-transport motive power.xlsx Load profiles/Refrigeration/Commercial refrigeration profile.xlsx Load profiles/Refrigeration/Residential refrigeration profile.xlsx Load profiles/Solar battery/Solar battery profile.xlsx

	Load profiles/Space heating/Commercial space heating profile.xlsx Load profiles/Space heating/Residential space heating profile.xlsx Load profiles/Water heating/Agricultural water heating profile - Summer only.xlsx Load profiles/Water heating/Commercial water heating profile.xlsx Load profiles/Water heating/Residential water heating profile - network optimised.xlsx Load profiles/Water heating/Residential water heating profile.xlsx
LoadGrowth.xlsx	Electricity growth.xlsx EV Projections.xlsx Solar growth.xlsx IndustrialGrowth.xlsx Load profiles/Profile Summary.xlsx
Projected_peak.xlsx	LoadGrowth.xlsx
Model Outputs.xlsx	LoadGrowth.xlsx Load profiles/Profile Summary.xlsx Projected_peak.xlsx

Appendix D Workbook descriptions

<table>
<tr><th>File name</th><th>File Description</th><th>Sheet name</th><th>Sheet description</th></tr>
<tr><td rowspan="5">ICP Growth.xlsx</td><td rowspan="5">Assumes that the relative ICPs per capita by sector remain constant across different regions over time. E.g. if NSP x has twice the commercial ICPs per capita as NSP y in the data from EMI, it will continue to have twice the ICPs per capita into the future, regardless of population change.</td><td>20230430_MeterCategoryByLevel1A</td><td>Source data is from EMI. This sheet aggregates the Level 1 ANZSIC codes to the higher grouped level of Agriculture, Commercial, Industrial and Residential, aligning with the CCC modelling. It also generates a consistent 'base' data set for NSPs by sector</td></tr>
<tr><td>CCC proj</td><td>Extract of CCC projection of ICPs</td></tr>
<tr><td>ICP_by_sector</td><td>Helper sheet</td></tr>
<tr><td>Population_proj</td><td>Population projection from Stats NZ</td></tr>
<tr><td>ICP_proj</td><td>Final result of workbook - projection of ICPs by sector and NSP</td></tr>
<tr><td rowspan="11">Electricity growth.xlsx</td><td rowspan="11">Assumes that 'new' ICPs in each sector demand the average per ICP level of electricity by end use for that sector.
Natural gas and LPG conversions to electricity are assumed to occur at the same rate across New Zealand, and the increase in demand for electricity from these ICPs are assumed to be the same (based on the national average demand per ICP).
'Existing' ICPs are used to 'washup' the difference remaining from the national change in the CCC projection and the sum of the changes projected by the new ICPs and gas conversion calculations.</td><td>ICP_proj</td><td>Import of data from <ICP Growth.xlsx></td></tr>
<tr><td>CCC proj</td><td>Extract of CCC projection of electricity demand (excluding EVs, solar, and industrial)</td></tr>
<tr><td>gas_to_ele</td><td>Using CCC projection, estimates increase in electricity demand by sector and end use due to electrification of natural gas and LPG ICPs</td></tr>
<tr><td>Ele adjustors</td><td>Two tables from CCC: The first one determines the contribution of ICP growth to electricity demand growth. The second enables adjustment of the CCC projection to account for national demand that occurs 'above' the NSP level (not currently used)</td></tr>
<tr><td>new_ICP_ele</td><td>Projection year-on-year (YoY) of electricity demand growth (decline) by NSP due to ICP growth (decline)</td></tr>
<tr><td>ng_conversion</td><td>Projection of YoY electricity demand growth due to natural gas customers electrifying</td></tr>
<tr><td>lpg_conversion</td><td>Projection of YoY electricity demand growth due to LPG customers electrifying</td></tr>
<tr><td>existing_ICP</td><td>Projection of YoY electricity demand growth from existing ICPs (excluding gas conversions). Acts as a washup for electricity demand not accounted for by new ICPs and gas conversions (previous 3 sheets)</td></tr>
<tr><td>yoy_change</td><td>Aggregation of the YoY electricity demand growth from new ICPs, gas conversions and existing ICPs (previous 4 sheets)</td></tr>
<tr><td>ele_proj</td><td>Final result of workbook - projection of electricity demand growth by NSP, sector and end use, relative to 2022</td></tr>
<tr><td colspan="2" style="display:none"></td></tr>
<tr><td rowspan="14">EV Projections.xlsx</td><td rowspan="14">The base proportion of EVs by vehicle class are taken from the Ministry of Transport fleet data. It is assumed that all regions/NSPs follow the same uptake curve (which is the national uptake curve projected by the CCC), but start at different places on the curve, based on the aforementioned MoT fleet data. Total vehicle kilometres travelled (VKT) (both EV and ICE) are apportioned to NSP level on the assumption that the relative VKT per capita by vehicle class remains the same over time (similar to the ICP growth assumptions).</td><td>CCC</td><td>Extract of CCC projection of EV demand - electricity demand for charging, vehicle kilometres travelled (VKT), proportion of VKT travelled by EVs</td></tr>
<tr><td>Vehicle class map</td><td>Provides mapping between the vehicle classes from Ministry of Transport data and the CCC model</td></tr>
<tr><td>Motive power map</td><td>Provides mapping between the motive power classes from the Ministry of Transport data and the CCC model</td></tr>
<tr><td>NSP TLA map</td><td>Provides a mapping between the NSPs and the Territorial Local Authorities (TLA) that they service</td></tr>
<tr><td>Region map</td><td>Provides a mapping between TLAs and Ministry of Transport regions</td></tr>
<tr><td>Existing fleet</td><td>Data extract from Ministry of Transport vehicle fleet statistics</td></tr>
<tr><td>Population_proj</td><td>Population projection from Stats NZ</td></tr>
<tr><td>ICP projection</td><td>Import of data from <ICP Growth.xlsx></td></tr>
<tr><td>Regional vkt</td><td>Projected Vkt by region from Ministry of Transport</td></tr>
<tr><td>TLA vkt</td><td>Projection of Vkt by TLA</td></tr>
<tr><td>NSP_vkt_millions</td><td>Projection of Vkt by NSP</td></tr>
<tr><td>EV_NSP_vkt_millions</td><td>Projection of EV Vkt by NSP</td></tr>
<tr><td>EV_gwh_demand</td><td>Final result of workbook - projection of EV charging demand by NSP</td></tr>
<tr><td colspan="2" style="display:none"></td></tr>
<tr><td rowspan="5">IndustrialGrowth.xlsx</td><td rowspan="5">Industrial growth is apportioned across existing and new NSPs based on the data provided to us by individual EDBs following Sapere's data request. Connection point load estimates are converted to annual demand estimates based on:
'Baseload' runs 24 hours a day, while 'Dayload' runs 9 hours a day
'Summer' runs for 7 months of the year, while "All year" runs everyday
These converted annual demands are washed up to the CCC estimate. We note that this results in a significantly higher increase in annual demand than the CCC estimates.</td><td>CCC</td><td>Extract of CCC projection of electricity demand for the Industrial sector</td></tr>
<tr><td>TOU</td><td>Conversion factors to map between load in MW and annual electricity demand</td></tr>
<tr><td>Source</td><td>Formatted source data (provided by EDBs)</td></tr>
<tr><td>Provided_point_loads</td><td>Projected load growth by NSP</td></tr>
<tr><td>Industrial_growth</td><td>Final result of workbook - projection of electricity demand growth by NSP</td></tr>
</table>

Load profiles/Cooking/Commercial cooking profile.xlsx	Heating and cooking profiles use thermal models to heat a defined volume of material to a target temperature and then cycle near that temperature for a defined duration. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Cooking/Residential cooking profile.xlsx	Heating and cooking profiles use thermal models to heat a defined volume of material to a target temperature and then cycle near that temperature for a defined duration. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Electric vehicles/Bus EV profile.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Small bus charging	Calculates the profile for a single EV (duty cycle)
		Medium bus charging	Calculates the profile for a single EV (duty cycle)
		Large bus charging	Calculates the profile for a single EV (duty cycle)
		Coach charging	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Small charge demand	Applies the time of start distribution to the profile to give the demand profile
		Medium charge demand	Applies the time of start distribution to the profile to give the demand profile
		Large charge demand	Applies the time of start distribution to the profile to give the demand profile
		Coach charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Electric vehicles/LCV EV	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles

profile - energy optimised.xlsx	5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Energy optimised generally follows the same control distribution as network optimised but 'moves' EV demand into network peak times in response to a peak in cheap wind generation.	Small van charging	Calculates the profile for a single EV (duty cycle)
		Medium van charging	Calculates the profile for a single EV (duty cycle)
		Large van charging	Calculates the profile for a single EV (duty cycle)
		NA	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Small charge demand	Applies the time of start distribution to the profile to give the demand profile
		Medium charge demand	Applies the time of start distribution to the profile to give the demand profile
		Large charge demand	Applies the time of start distribution to the profile to give the demand profile
		na charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Electric vehicles/LCV EV profile - network optimised.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Network optimised uses a manual optimisation to move charging out of the evening peak and ramp it up from late evening and cycles heavily overnight, plus moves daytime charging to midday.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Small van charging	Calculates the profile for a single EV (duty cycle)
		Medium van charging	Calculates the profile for a single EV (duty cycle)
		Large van charging	Calculates the profile for a single EV (duty cycle)
		NA	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Small charge demand	Applies the time of start distribution to the profile to give the demand profile
		Medium charge demand	Applies the time of start distribution to the profile to give the demand profile
		Large charge demand	Applies the time of start distribution to the profile to give the demand profile
		na charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Electric vehicles/LCV EV profile.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Naive profile.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Small van charging	Calculates the profile for a single EV (duty cycle)
		Medium van charging	Calculates the profile for a single EV (duty cycle)
		Large van charging	Calculates the profile for a single EV (duty cycle)
		NA	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Small charge demand	Applies the time of start distribution to the profile to give the demand profile
		Medium charge demand	Applies the time of start distribution to the profile to give the demand profile
		Large charge demand	Applies the time of start distribution to the profile to give the demand profile
		na charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Electric vehicles/LPV EV profile - network optimised.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Network optimised uses a manual optimisation to move charging out of the evening peak and ramp it up from late evening and cycles heavily overnight.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Nissan charging	Calculates the profile for a single EV (duty cycle)
		Tesla charging	Calculates the profile for a single EV (duty cycle)
		Hyundai charging	Calculates the profile for a single EV (duty cycle)
		Other charging	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Nissan charge demand	Applies the time of start distribution to the profile to give the demand profile
		Tesla charge demand	Applies the time of start distribution to the profile to give the demand profile
		Hyundai charge demand	Applies the time of start distribution to the profile to give the demand profile
		Other charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile

Load profiles/Electric vehicles/LPV EV profile - worst case energy only optimised.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Energy optimised generally follows the same control distribution as network optimised but 'moves' EV demand into network peak times in response to a peak in cheap wind generation.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Nissan charging	Calculates the profile for a single EV (duty cycle)
		Tesla charging	Calculates the profile for a single EV (duty cycle)
		Hyundai charging	Calculates the profile for a single EV (duty cycle)
		Other charging	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Nissan charge demand	Applies the time of start distribution to the profile to give the demand profile
		Tesla charge demand	Applies the time of start distribution to the profile to give the demand profile
		Hyundai charge demand	Applies the time of start distribution to the profile to give the demand profile
		Other charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Electric vehicles/LPV EV profile.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Naive profile.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Nissan charging	Calculates the profile for a single EV (duty cycle)
		Tesla charging	Calculates the profile for a single EV (duty cycle)
		Hyundai charging	Calculates the profile for a single EV (duty cycle)
		Other charging	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Nissan charge demand	Applies the time of start distribution to the profile to give the demand profile
		Tesla charge demand	Applies the time of start distribution to the profile to give the demand profile
		Hyundai charge demand	Applies the time of start distribution to the profile to give the demand profile
		Other charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Electric vehicles/Truck EV profile - energy optimised.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Energy optimised generally follows the same control distribution as network optimised but 'moves' EV demand into network peak times in response to a peak in cheap wind generation.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Small truck charging	Calculates the profile for a single EV (duty cycle)
		Medium truck charging	Calculates the profile for a single EV (duty cycle)
		Heavy truck charging	Calculates the profile for a single EV (duty cycle)
		Line haul charging	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Small charge demand	Applies the time of start distribution to the profile to give the demand profile
		Medium charge demand	Applies the time of start distribution to the profile to give the demand profile
		Heavy charge demand	Applies the time of start distribution to the profile to give the demand profile
		Linehaul charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Electric vehicles/Truck EV profile - network optimised.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Small truck charging	Calculates the profile for a single EV (duty cycle)
		Medium truck charging	Calculates the profile for a single EV (duty cycle)
		Heavy truck charging	Calculates the profile for a single EV (duty cycle)
		Line haul charging	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Small charge demand	Applies the time of start distribution to the profile to give the demand profile
		Medium charge demand	Applies the time of start distribution to the profile to give the demand profile
		Heavy charge demand	Applies the time of start distribution to the profile to give the demand profile

	Network optimised uses a manual optimisation to move charging out of the evening peak and ramp it up from late evening and cycles heavily overnight.	Linehaul charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Electric vehicles/Truck EV profile.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Naive profile.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Small truck charging	Calculates the profile for a single EV (duty cycle)
		Medium truck charging	Calculates the profile for a single EV (duty cycle)
		Heavy truck charging	Calculates the profile for a single EV (duty cycle)
		Line haul charging	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Small charge demand	Applies the time of start distribution to the profile to give the demand profile
		Medium charge demand	Applies the time of start distribution to the profile to give the demand profile
		Heavy charge demand	Applies the time of start distribution to the profile to give the demand profile
		Linehaul charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Electronics and appliances/Commercial electronics & appliances profile.xlsx	Lighting and appliance profiles use the heating and cooking models but the thermal model is locked to give constant usage for a defined duration. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation - locked on
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation - locked on
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation - locked on
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation - locked on
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Electronics and appliances/Residential electronics & appliances profile.xlsx	Lighting and appliance profiles use the heating and cooking models but the thermal model is locked to give constant usage for a defined duration. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation - locked on
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation - locked on
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation - locked on
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation - locked on
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile

Load profiles/Industrial/Industrial profile.xlsx	Industrial profiles use the heating and cooking models but the thermal model is locked to give constant usage for a defined duration. Used to create a baseload industrial and daytime industrial demand. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation - locked on
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation - locked on
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation - locked on
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation - locked on
		Start charging time	Sets the time of start distributions
		Baseload industrial demand	Applies the time of start distribution to the profile to give the demand profile
		Daytime industrial demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Lighting/Commercial lighting profile.xlsx	Lighting and appliance profiles use the heating and cooking models but the thermal model is locked to give constant usage for a defined duration. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation - locked on
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation - locked on
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation - locked on
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation - locked on
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Lighting/Residential lighting profile.xlsx	Lighting and appliance profiles use the heating and cooking models but the thermal model is locked to give constant usage for a defined duration. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation - locked on
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation - locked on
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation - locked on
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation - locked on
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile

		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Non-transport motive power/Agricultural non-transport motive power - Summer only.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Naive profile.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Daytime charging	Calculates the profile for a single EV (duty cycle)
		Night 1 charging	Calculates the profile for a single EV (duty cycle)
		Night 2 charging	Calculates the profile for a single EV (duty cycle)
		Line haul charging	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Small charge demand	Applies the time of start distribution to the profile to give the demand profile
		Medium charge demand	Applies the time of start distribution to the profile to give the demand profile
		Heavy charge demand	Applies the time of start distribution to the profile to give the demand profile
		Linehaul charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Non-transport motive power/Commercial non-transport motive power.xlsx	EV profiles use charging models to charge batteries for a variety of specifications, including target charge level. 5 minute periods are used, which can be a bit coarse but does capture tail off in charging if a battery approaches 100%. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. Naive profile.	Charging assumptions	The inputs for a given battery specification
		Derived charging profile	Calculates the assumptions outlined in Charging assumptions to be copied to profiles
		Daytime charging	Calculates the profile for a single EV (duty cycle)
		Night 1 charging	Calculates the profile for a single EV (duty cycle)
		Night 2 charging	Calculates the profile for a single EV (duty cycle)
		Line haul charging	Calculates the profile for a single EV (duty cycle)
		Start charging time	Sets a combined time of start for EV charging
		Small charge demand	Applies the time of start distribution to the profile to give the demand profile
		Medium charge demand	Applies the time of start distribution to the profile to give the demand profile
		Heavy charge demand	Applies the time of start distribution to the profile to give the demand profile
		Linehaul charge demand	Applies the time of start distribution to the profile to give the demand profile
		Total charge demand	Totals all demand profiles to give the combined profile
Load profiles/Profile Summary.xlsx	Summarises the various load profiles into one workbook. Also converts the 5 minute resolution to 30 minutes and provides a conversion factor to convert annual demand to demand for the peakiest day by sector and end use	Scenario choice	
		Chosen Scenario	
		Peakiest day allocation	
		Naive - 5min	
		Naive - 30min	
		Energy optimised - 5min	
		Energy optimised - 30min	
		Network optimised - 5min	
		Network optimised - 30min	
Load profiles/Refrigeration /Commercial refrigeration profile.xlsx	Refrigeration profiles use thermal models to heat a defined volume of material to a target temperature and then cycle near that temperature for a defined duration. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions

		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Refrigeration /Residential refrigeration profile.xlsx	Refrigeration profiles use thermal models to heat a defined volume of material to a target temperature and then cycle near that temperature for a defined duration. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Solar battery/Solar battery profile.xlsx	By 2050 we assume that rooftop solar is installed with batteries. These batteries primarily self-cover. NIWA data is used to determine the energy production for the peakiest day which is then applied to residential peak	Solar Battery profile	
		Solar data from NIWA	
Load profiles/Space cooling/Commercial space cooling profile - summer only.xlsx	Refrigeration profiles use thermal models to heat a defined volume of material to a target temperature and then cycle near that temperature for a defined duration. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Space cooling/Residential space cooling profile - summer only.xlsx	Refrigeration profiles use thermal models to heat a defined volume of material to a target temperature and then cycle near that temperature for a defined duration. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation

	Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Space heating/Commercial space heating profile.xlsx	Heating and cooking profiles use thermal models to heat a defined volume of material to a target temperature and then cycle near that temperature for a defined duration. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Space heating/Residential space heating profile.xlsx	Heating and cooking profiles use thermal models to heat a defined volume of material to a target temperature and then cycle near that temperature for a defined duration. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Water heating/Agricultural water heating profile - Summer only.xlsx	Water heating profiles use thermal models to keep a defined volume of water at a target temperature and then cycle near that temperature. Water heating cycles for the entire day.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation

	5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. For water heating, time of start isn't when water heaters are started but when there is a sudden drop in cylinder temperature through the draw down of hot water. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Water heating/Commercial water heating profile.xlsx	Water heating profiles use thermal models to keep a defined volume of water at a target temperature and then cycle near that temperature. Water heating cycles for the entire day. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. For water heating, time of start isn't when water heaters are started but when there is a sudden drop in cylinder temperature through the draw down of hot water. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Water heating/Residential water heating profile - network optimised.xlsx	Water heating profiles use thermal models to keep a defined volume of water at a target temperature and then cycle near that temperature. Water heating cycles for the entire day. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. For water heating, time of start isn't when water heaters are started but when there is a sudden drop in cylinder temperature through the draw down of hot water. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined. For network optimised the time of start is suppressed to delay water heating recharge until after peaks.	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario
		Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
Load profiles/Water heating/Residential	Water heating profiles use thermal models to keep a defined volume of water at a target temperature and then cycle near that temperature. Water heating cycles for the entire	Heating assumptions	Tabulated input assumptions and a selected scenario can be demonstrated
		Derived heating profile	Demonstrates the output of a selected input scenario

water heating profile.xlsx	day. 5 minute periods are used, which can be a bit coarse but does capture some cycling to allow for some natural diversity. Time profiles (duty cycles) are grouped by time of start. Each group is then delimited by differing input assumptions. For water heating, time of start isn't when water heaters are started but when there is a sudden drop in cylinder temperature through the draw down of hot water. Time of start profiles are applied to give the individual time profile demand sequences, which are the totalled. Time of use are usually normal distributions with defined average times and standard deviations, often around morning or evening peak. Distributions can also be randomly distributed or combined.	Time profile 1	Groups and calculates a set of input scenarios by common time of start
		Temp profile 1	Supports the profile calculation
		Time profile 2	Groups and calculates a set of input scenarios by common time of start
		Temp profile 2	Supports the profile calculation
		Time profile 3	Groups and calculates a set of input scenarios by common time of start
		Temp profile 3	Supports the profile calculation
		Time profile 4	Groups and calculates a set of input scenarios by common time of start
		Temp profile 4	Supports the profile calculation
		Start charging time	Sets the time of start distributions
		Time Profile 1 demand	Applies the time of start distribution to the profile to give the demand profile
		Time Profile 2 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 3 demand	Applies the time of start distribution to the profile to give the demand profile
		Time profile 4 demand	Applies the time of start distribution to the profile to give the demand profile
		Total profile demand	Totals all demand profiles to give the combined profile
LoadGrowth.xlsx	Combines the various growth workbooks with the relevant peak day demand factor and time of use profiles	Base_growth	Import of data from <Electricity Growth.xlsx>
		EV	Import of data from <EV Projections.xlsx>
		Solar_battery	Import of data from <Solar Growth.xlsx>
		Industrial	Import of data from <IndustrialGrowth.xlsx>
		ToU profiles - import	Import of data from <Profile Summary.xlsx>
		ToU profiles - winter	Winter ToU profiles formatted for model use
		ToU profiles - summer	Summer ToU profiles formatted for model use
		load_growth_existing_nsp_w	Projected load growth by NSP for winter for existing NSPs
		load_growth_new_nsp_w	Projected load growth by NSP for winter for new NSPs (from industrial point loads)
		load_growth_w	Projected load growth by NSP for winter (combination of previous 2 sheets)
		load_growth_by_EU_w	Projected load growth by end use for winter
		load_growth_existing_nsp_s	Projected load growth by NSP for summer for existing NSPs
		load_growth_new_nsp_s	Projected load growth by NSP for summer for new NSPs (from industrial point loads)
		load_growth_s	Projected load growth by NSP for summer (combination of previous 2 sheets)
		load_growth_by_EU_s	Projected load growth by end use for summer
Model Outputs.xlsx	Model outputs	Individual NSP	Extract of peak day profile and peak demand by year
		National growth	National aggregation of peak demand at each NSP by year
		Detailed NSP	Detailed extract of daily profile for each end use and sector for a select NSP
Other reference/Gas geographical distribution.xlsx	Geographical distribution of LPG and Natural Gas today	GIC TLA	Natural gas geographical information provided by GIC
		NSP to TLA Map	Mapping between NSP and TLA
		LPG	LPG geographical information provided by Gas NZ
Other reference/List of Point Loads.xlsx	Industrial point load information provided by EDBs	Raw data	
		Winter peak day	
		Summer peak day	
		Winter Peak Day - Industrial	
		Summer Peak Day - Industrial	
Projected_peak.xlsx	Combines the peakiest day load growth with the 5 days with the highest peak loads in the previous 5 years by NSP, for each of summer and winter. The model then selects the one that generates the highest peak for each year projected	Historic_load_w	Data extract from EMI - 5 winter (May - Sep) days from 2018-2022 which had the highest peak values
		Projected_load_growth_w	Import of winter data from <LoadGrowth.xlsx>
		Combined_top5_w	Winter historic data joint with projected load growth
		Peak_values_w	Highest projected winter peak value by NSP (chosen from previous sheet)

		Peak_hist_date_w	Dates that provide the historic profiles that generate the highest peak values by NSP for winter
		Peak_day_load_w	Projected load for the peakiest winter day by NSP
		Historic_load_s	Data extract from EMI - 5 summer (Oct - Apr) days from 2018-2022 which had the highest peak values
		Projected_load_growth_s	Import of summer data from <LoadGrowth.xlsx>
		Combined_top5_s	Summer historic data joint with projected load growth
		Peak_values_s	Highest projected summer peak value by NSP (chosen from previous sheet)
		Peak_hist_date_s	Dates that provide the historic profiles that generate the highest peak values by NSP for summer
		Peak_day_load_s	Projected load for the peakiest summer day by NSP
		Peak_day_season	Season that generates the highest peak value by NSP
		Peak_day_load_combined	Projected load for the peakiest day by NSP
Solar growth.xlsx	Using data from the Electricity Authority for distributed generation, we assume that growth in solar uptake by NSP occurs in such a way that the relative proportion of ICPs with solar remains constant across NSPs over time (similar to ICP growth assumptions)	CCC	Extract of CCC projection of DG solar uptake
		ICP_proj	Import of data from <ICP Growth.xlsx>
		Solar_proj	Projection of DG solar generation
		Solar_growth	Final result of workbook - projection of DG solar generation growth by NSP

About Sapere

Sapere is one of the largest expert consulting firms in Australasia, and a leader in the provision of independent economic, forensic accounting and public policy services. We provide independent expert testimony, strategic advisory services, data analytics and other advice to Australasia's private sector corporate clients, major law firms, government agencies, and regulatory bodies.

'Sapere' comes from Latin (to be wise) and the phrase 'sapere aude' (dare to be wise). The phrase is associated with German philosopher Immanuel Kant, who promoted the use of reason as a tool of thought; an approach that underpins all Sapere's practice groups.

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