Assessing the future uptake of greater than 100kW behind the meter solar in Victoria

Prepared for Victorian Department of Environment Water, Land and Planning

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1.1 About this project

This modelling analysis has been prepared for the Victorian Government's Department of Environment, Water, Land and Planning ('the Department').

The model seeks to estimate likely levels of uptake of solar PV systems in Victoria greater than 100 kilowatts (kW) in capacity that are installed primarily to serve electrical demand on the site in which the system has been installed. Commonly these are referred to as "behind the meter" systems.

This modelling analysis has been prepared within the context that behind-the-meter solar systems in Victoria may be eligible to earn revenue through creating Victorian Energy Efficiency Certificates (VEECs) for the electricity consumed from the system on-site (while exported power would be ineligible for VEECs). This model is designed to assist the Department to understand the potential volume of VEECs that might be created out to 2030 from solar systems greater than 100kW.

The model has been designed to allow the Department to adjust prices over each year to 2050 for:

- Electrical energy (megawatt-hours) according to three set time periods:
    - Peak (Weekdays 3pm – 9pm)
    - Shoulder (Weekdays 7am-3pm and 9pm-10pm; Weekends from 7am to 10pm)
    - Off-peak (all other times)
- Large-Scale Generation Certificates (LGCs); and
- Victorian Energy Efficiency Certificates (VEECs).

Adjustments to these prices then alter the amount of revenue a solar system might earn. This then alters the financial attractiveness of a solar system which is measured in the model by its 'payback period'. As paybacks become shorter the model estimates higher levels of uptake of solar capacity, and likewise, as payback periods become longer, uptake of solar capacity declines.

Accounting for factors influencing the viability and attractiveness of large behind the meter solar systems

A complication, which this model has attempted to take into account, is that customers' sites tend to be subject to a wide degree of variation in characteristics that affect the viability of solar systems.

The model incorporates several generic customer segments which attempt to account for these differences, albeit imperfectly.

Factors that need to be taken into account in evaluating the prospects for 100KW+ systems for each customer type and therefore the overall size of the Victorian market for such large systems include:

- **Suitable space.** Is there enough suitable space for installation of such a system?
- **Premium on wholesale price.** What is the value of electricity that the solar system's generation can displace?
- **Site occupation structure.** Does the host organisation own its premises or must it negotiate with a landlord to agree to installation of the solar system and contribution towards the system's cost? Also, how long into the future does the host organisation feel confident it will continue to operate at its existing premises?

- **Investment time horizon.** What is the organisation's time horizon for its investments and does it value environmental benefits? Some organisations require very high rates of return or short payback periods for potential capital investments and apply the same criteria to solar systems. Other organisations can be willing to accept longer payback periods for investments more generally or solar systems in particular.
- **Alignment of site energy consumption with solar generation profile to maximise self-consumption.** To what degree will the site's electricity consumption be sufficiently high to consume most or all of a large solar system's generation? As a rough rule of thumb a solar system's economics look most attractive when its generation meets but does not exceed a customer's need for electricity on site. This is because customers will usually pay noticeably more for electricity they wish to import from the grid than what a retailer will pay for electricity that the customer may export.

Table 1-1 below provides a traffic light assessment of how the factors driving the propensity to adopt solar apply in the market segments we have identified. Green coloured squares indicate that this factor is favourable to adoption of solar, at least in comparison to how this factor applies to other sectors, while red is unfavourable and amber is in between.

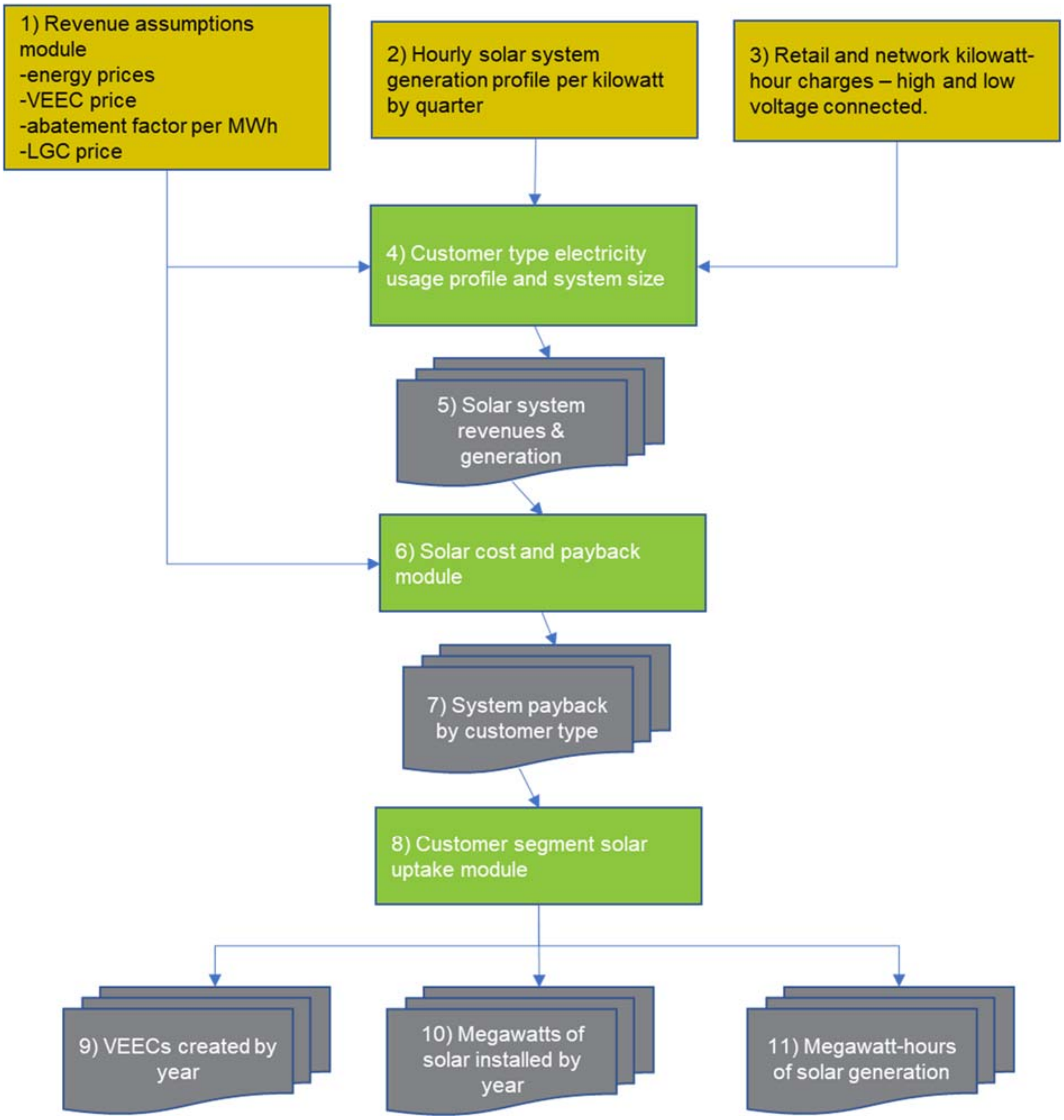
Table 1-1 Traffic light assessment of factors driving propensity to invest in solar by sector

Sector	Suitable space	Premium on wholesale price	Extent of self-consumption	Site occupation structure	Investment time horizon
School	Green	Green	Red	Green	Green
Food processing/Coldstore/Baking	Amber	Green	Green	Green	Amber
Supermarket	Green	Green	Green	Amber	Amber
Shopping centres	Green	Amber	Green	Red	Amber
Heavy Manufacturing	Green	Red	Green	Green	Red
Light manufacturing	Amber	Amber	Green	Amber	Amber
University/TAFE	Green	Amber	Red	Green	Green
Aged Care	Green	Green	Green	Green	Amber
Government-Public Bldgs	Amber	Green	Red	Amber	Amber
Office	Red	Green	Amber	Red	Green
Hospitals	Amber	Amber	Green	Green	Amber
Hotels-Accommodation-Entertainment	Amber	Green	Amber	Amber	Amber

1.2 How the model functions

Figure 1-1 provides an illustrative overview of the model developed to project the uptake of 100kW+ solar systems in Victoria.

Figure 1-1 Diagram of 100kW+ behind-the-meter solar uptake model



Deriving revenue

The revenue assumptions module (box 1) provides the flexibility for the Department to adjust prices as they see fit for energy (with peak, shoulder and off-peak periods catered for), VEECs, and LGCs and also the abatement factor applied per megawatt-hour of electricity saved (which then affects how many VEECs can be created per megawatt-hour of grid imports the solar system's generation has displaced). In addition, there is a generic set of assumptions for the amount of electricity generated per kilowatt of solar capacity by hour for each quarter across the year (box 2). The final set of input assumptions for the revenue equation are the retail and network charges applied per kilowatt-hour of electricity consumed (box 3).

These are then fed into several different customer electricity consumption profiles (box 4) reflective of the customer sectors described in section 3.4 of this report. This then provides an approximation of the revenue and generation profiles for a solar system installed on a site within each sector (outputs box 5). This is divided into generation that is self-consumed by the site and generation which is exported to the grid.

Deriving payback periods

These are then fed into the solar cost and payback module (box 6). This takes these revenue flows and combines them with assumptions about solar system costs over time and also potential revenue from VEECs to determine payback periods for a solar system. These are calculated for each customer segment, with separate results for whether or not the system is able to export generation surplus to on-site consumption (outputs box 7).

Estimating total Victoria-wide uptake of solar capacity and VEEC creation

These payback results are then fed into the customer segment solar uptake module (box 8) which calculates the expected amount of megawatts each segment would be likely to install in a given year based on the payback period achieved by a solar system for that segment (outputs box 9). In addition, this then also calculates the amount of VEECs that would be created in each year (outputs box 10) and also the amount of megawatt-hours of electricity produced by these systems (outputs box 11).

Calibration of the model

The uptake levels for each customer segment are calibrated back to paybacks and levels of installations expected in 2019. Uptake sensitivities to paybacks are informed by our analysis of key factors influencing uptake within each customer segment summarised in Table 1-1 and explained in more detail in section 3 of this report.

Based on current available information we estimate that approximately 50 to 70 megawatts will be installed in 2019 in Victoria claiming LGCs – with the range reflecting the degree to which the industry decides obtaining grid export approval is worth the extra costs and effort. This estimate is subject to substantial uncertainty given the rapid change unfolding in the 100kW+ market and its immaturity.

In the model the level of megawatts we expect for 2019 claiming LGCs and associated paybacks estimated for each sector are used as the reference point or baseline against which future levels of uptake are calibrated. If payback periods improve on the 2019 levels (where the system is creating LGCs, not VEECs) then the amount of megawatts installed increases and visa versa.

With the reference point in place the model can evaluate how payback periods might change if VEECs were claimed for self-consumption of the solar system's generation instead of LGCs. The model allows for the price of VEECs in each year to be adjusted by the user but for the purposes of developing and presenting results for this report we have adopted a constant real VEEC price of $18 (close to recent market levels) and a constant abatement factor (also adjustable by the user) set at the current level of 1.095 tonnes of CO_2 per MWh.

The model delivers results for megawatts of uptake creating VEECs and the number of VEECs created according to two alternative situations: systems are allowed to export electricity to the grid; or they aren't allowed. The model will only report megawatts of uptake creating VEECs where VEECs deliver a shorter payback than creating LGCs.

in addition, two spreadsheet versions of the model have been provided. One assumes relatively modest ongoing reductions in the installation cost of solar PV systems declining from a level of $1400 per kilowatt in 2019 by 2.5% per annum in real terms. This might be thought of as a pessimistic scenario. The other version of the model has a linear straight line series of cost reductions from $1400 per kilowatt in 2019 to $900 per kilowatt by 2030 (in 2019 real dollars).

1.3 Example model results for megawatts and VEECs

Figure 1-2 illustrates the model results for megawatts installed each year claiming VEECs under the assumption VEECs are worth $18 throughout the outlook period and all solar systems gain authorisation to export to the grid. It also reflects an assumption energy prices remain unchanged in real terms. This is based on the version of the model involving ongoing significant declines in cost for solar systems. Please note that while the model produces results for 2019, given no one has yet developed processes for claiming VEECs from solar systems these are not expected to eventuate in reality. Also these results are purely provided as an example of what the model might produce. They are not intended to reflect Green Energy Market's expectations about what will actually happen because we have not attempted to project what is the likely future price of electricity or VEECs. Our understanding is that the Department will develop these projections and adjust the model's inputs in line with these projections.

Figure 1-2 Megawatts installed creating VEECs where all systems can export and solar costs continue to fall rapidly

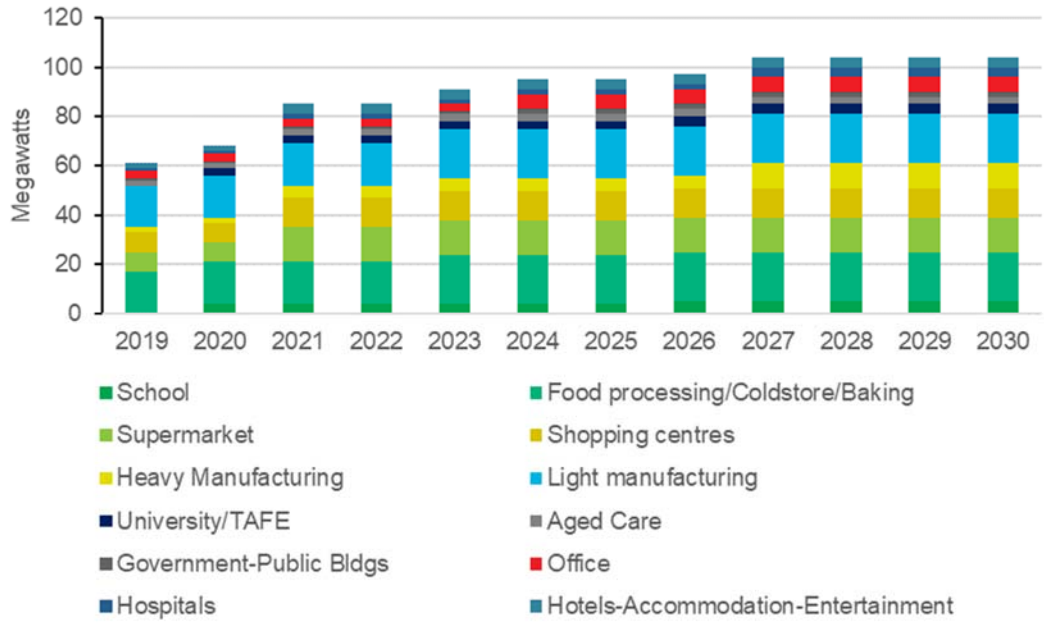
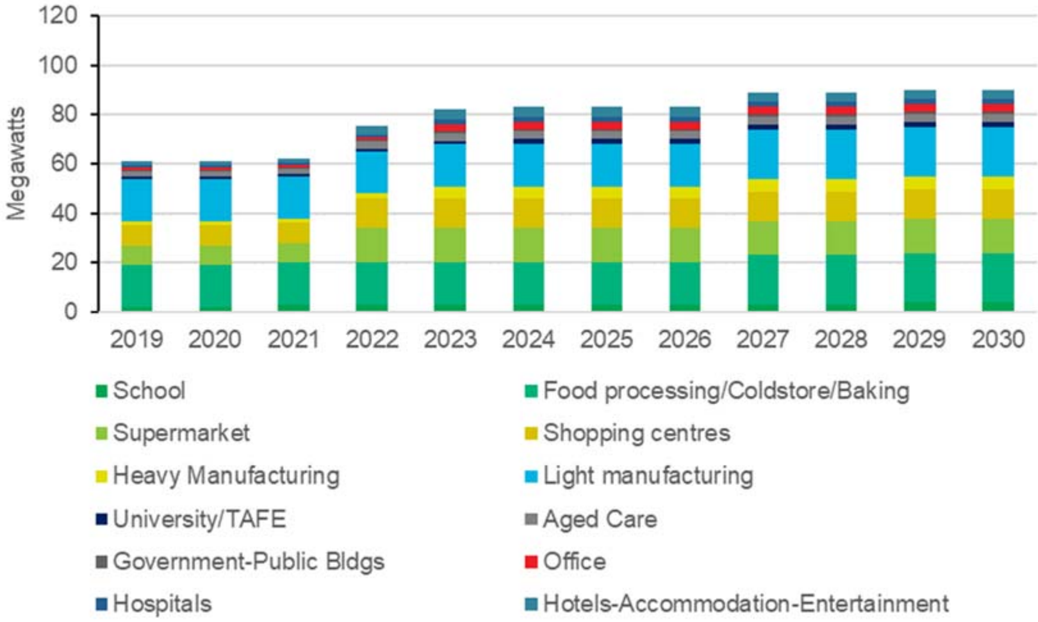


Figure 1-3 below presents the results for megawatts claiming VEECs under a situation where solar systems don't export power off-site and the cost of solar systems falls slowly, while maintaining the other assumptions used in developing the results are detailed in Figure 1-2.

Figure 1-3 Megawatts installed creating VEECs where systems do not export and solar cost reductions are slow



Irrespective of the option chosen, the availability of VEECs delivers equivalent or shorter paybacks than claiming LGCs across all sectors from 2020 onwards.

The number of VEECs created to 2030 from these installs where systems export power and solar costs continue to decline substantially is detailed in Figure 1-4. Note that creation in a given year reflects megawatts of installations in the prior year due to the need to demonstrate a year's performance before VEECs can be claimed.

Figure 1-4 VEECs created by solar systems where they are capable of exporting and solar costs fall rapidly

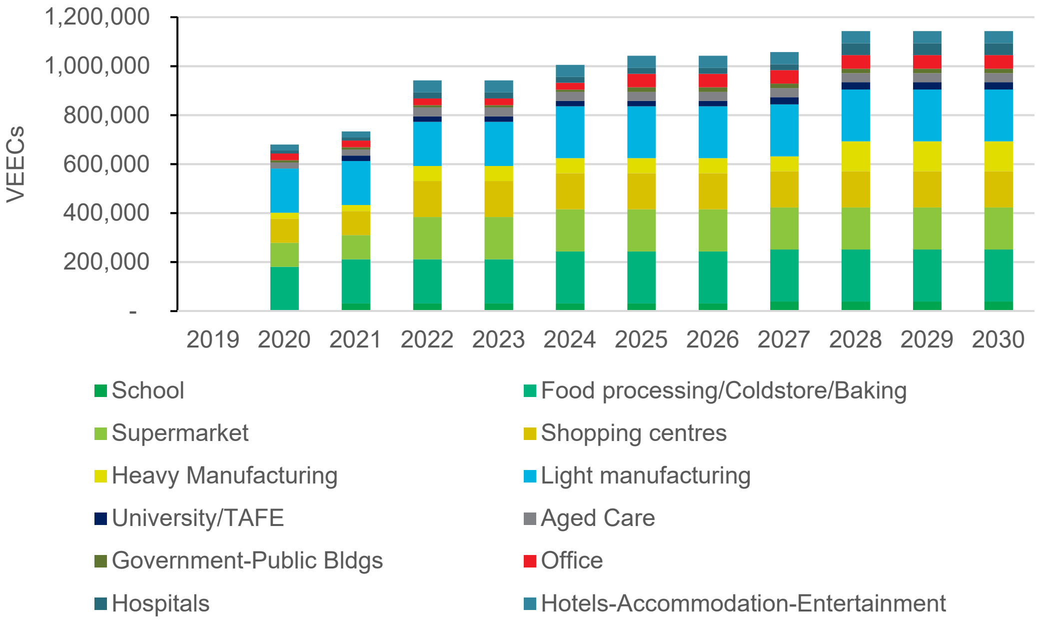
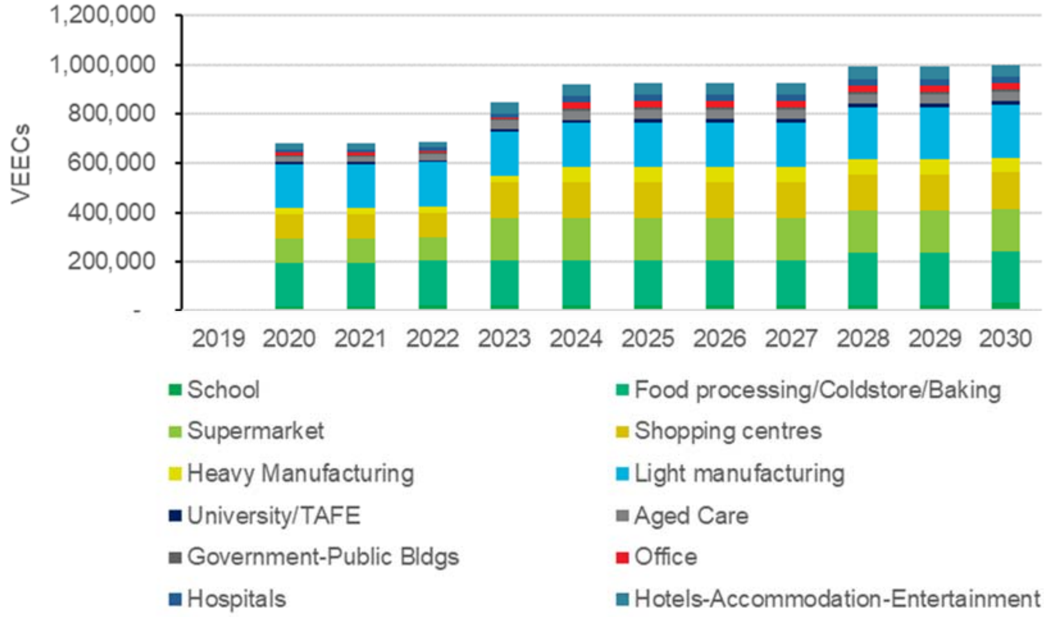


Figure 1-5 provides VEEC creation for the alternative situation where systems are unable to export surplus electricity and solar system costs fall slowly.

Figure 1-5 VEECs created by solar systems where they don't export and solar costs fall slowly



2 Introduction and scope

This modelling analysis has been prepared for the Victorian Government's Department of Environment, Water, Land and Planning ('the Department').

The model seeks to estimate likely levels of uptake of solar PV systems in Victoria greater than 100 kilowatts (kW) in capacity that are installed primarily to serve electrical demand on the site in which the system has been installed. Commonly referred to as "behind the meter" systems, they are intended to reduce the need for businesses to purchase electricity from the grid, rather than generate revenue from producing power sold into the wholesale electricity market. In some circumstances such solar systems will produce electricity surplus to the consumption levels of the site and export this power to the grid, but it is not currently the main driver for installing the system.

This modelling analysis has been prepared within the context that behind-the-meter solar systems in Victoria may be eligible to earn revenue through creating Victorian Energy Efficiency Certificates (VEECs) for the electricity consumed from the system on-site (while exported power would be ineligible for VEECs). To date no solar system has elected to do so, because they have preferred to create Large-scale Generation Certificates (LGCs) instead under the Federal Government's Renewable Energy Target (solar systems are not allowed to create VEECs if they have created LGCs). However, the market price for LGCs has declined markedly in value and is expected to decline to quite low levels from 2022 and beyond due to a substantial oversupply of LGCs relative to demand under the Renewable Energy Target, as well as voluntary carbon offset markets. This model is designed to assist the Department to understand the potential volume of VEECs that might be created out to 2030 from solar systems greater than 100kW. Systems smaller than 100kW have not been considered in this analysis because they are eligible to earn revenue from creating Small-scale Technology Certificates (STCs) under the Federal Government's Small-Scale Renewable Energy Scheme. At least for the next few years these are anticipated to be financially more attractive than creating VEECs.

The model has been designed to allow the Department to adjust prices over each year to 2050 for:

- Electrical energy (megawatt-hours) according to three set time periods:
    - Peak (Weekdays 3pm – 9pm)
    - Shoulder (Weekdays 7am-3pm and 9pm-10pm; Weekends from 7am to 10pm)
    - Off-peak (all other times)
- Large-Scale Generation Certificates (LGCs) which electricity retailers need to obtain to comply with the Federal Government's Large-Scale Renewable Energy Target and avoid a penalty of $65 for each LGC they are short of their share of the Renewable Energy Target (although Green Energy Markets has also provided a recommendation of likely prices for LGCs within the model); and
- Victorian Energy Efficiency Certificates which Victorian electricity retailers need to obtain to comply with greenhouse gas abatement targets set under the Victorian Energy Upgrades Program and avoid a penalty of $50 for each VEEC they are short of their share of the abatement target.

Adjustments to these prices then alter the amount of revenue a solar system might earn. This then alters the financial attractiveness of a solar system which is measured in the model by its 'payback period'. The payback period is the amount of years it takes for the solar system to deliver an amount of revenue that exceeds the cost of installing the solar system. Naturally the sooner a customer can achieve payback on the solar system, the more financially attractive it becomes to install a solar system.

As paybacks become shorter the model estimates higher levels of uptake of solar capacity, and likewise, as payback periods become longer, uptake of solar capacity declines. Payback periods are not the only way businesses might evaluate financial attractiveness of an investment, for example some may employ net present value or internal rate of return financial criteria. However, feedback from interviews with solar PV industry participants indicates that payback period is a common metric for evaluating whether or not to invest in a solar PV system.

For the purposes of this report, we have used energy and certificate prices that are considered to be reasonably reflective of market conditions in 2018/19 (as at January 2019). However these are unlikely to be reflective of conditions throughout the model outlook period to 2030. The model has been designed so that the Department can insert its own estimates of likely energy and certificate prices with the model then estimating the megawatts of large behind the meter solar systems likely to be installed and the flow on effects for creation of Victorian Energy Efficiency Certificates.

A complication, which this model has attempted to take into account, is that customers' sites tend to be subject to a wide degree of variation in the following characteristics that affect the viability of solar systems:

- The premium they pay for retail electrical energy (the megawatt-hours consumed) over and above wholesale market prices. Customers that might consider installing a solar system greater than 100kW in capacity can vary greatly in the type of tariff they face to pay for the transmission and distribution network which delivers power to their site. Also electricity retailers charge varying levels of margins on top of the underlying wholesale and network costs they incur.
- The available space suitable for the installation of a solar system greater than 100kW.
- The amount of electricity consumed on site and the time periods over which the electricity is consumed.

The model incorporates several generic customer segments which attempt to account for these differences, albeit imperfectly.

It is important to recognise that there can be significant differences in the revenue or avoided cost that power from a solar system will generate depending on whether that power is being consumed on-site, or being exported to the grid. Furthermore, there are circumstances where solar systems will not be allowed to export electricity to the grid. In such cases, if the solar system produces more power than can be consumed on site, some of the electricity will be dumped as heat, and provides no financial value to the owner.

In addition, customers can have differing time horizons on what they deem to be an attractive payback for prospective investments. For example, some organisations may reside at a site which they rent and so need to recoup the investment in the solar system quickly given the risk they may move to another premise. Also some businesses may face a reasonable probability of ceasing operations within a few years' time that necessitates short paybacks on investments.

As an example of how these factors can play out let's consider schools. These sites have a range of characteristics that are ideal for solar, except for their electricity consumption profile. The attributes that work in favour of solar in schools are:

- They will often have plenty of available space for a solar system due to the use of low rise buildings and in some cases even spare vacant land.
- They will also typically own their premises (not rent) and be confident they will be operating at the same site for several decades into the future. In addition, many schools have management motivated by non-financial, societal good goals.

These factors mean they are more willing to accept long payback times on a solar system to reduces carbon emissions.

- They will often pay a substantial premium for their electricity over wholesale market values because they are a fed from lower voltage distribution networks and are not a big enough consumer of electricity to negotiate a low retailer margin[1].

However, schools' electricity loads tend to vary substantially over time. They have extended holiday periods where their electricity demand is low. Also, their electricity loads are heavily driven by heating and cooling needs. Because of this highly variable electricity consumption profile, a solar system that might be optimally sized to meet their electricity needs during school hours in winter (when air conditioner heating loads are high) will generate substantial amounts of electricity surplus to the needs of the school over holiday periods and weekends. This surplus electricity will usually only be eligible to receive the wholesale value of electricity and in many cases will be spilled as heat at the inverter because a connection to export to the grid imposes significant extra cost and complexity (see section 3.3.1 for further explanation on why this is the case)

A large industrial plant with very large and constant electricity loads by contrast will face no difficulty consuming all the electricity that might be produced from an on-site solar system that might fit on the site. However, their large electricity load also means they face far lower electricity prices. In addition, such sites can often face intense global competition and suffer from narrow profit margins that mean their ongoing viability is uncertain. Consequently, investment in a solar system will only be considered if the payback is very short.

These variations mean that estimating likely solar uptake of systems greater than 100kW is extremely complex and uncertain. This is made even more uncertain by the immaturity of this market segment for solar systems. Prior to 2018 there was a very small number of systems greater than 100kW systems being installed behind the meter. This means there is relatively little market experience and data to draw from in informing our analysis. Many customers in this segment have only shown serious interest in installing solar within the past 12 to 24 months so predicting how they might behave is difficult. The projections we have developed need to be seen within that context and are likely to benefit considerably from being revisited in another 12 months in light of installation activity over 2019.

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[1] Energy consumers connected to the low voltage network pay substantially high kilowatt-hour consumption charges for use of the electricity network than large industrial sites that are connected to the high voltage sub-transmission network. Those connected to the high voltage sub-transmission network in Victoria face cents per kilowatt-hour charges in the realm of 2.2 cents during peak periods and around 0.8 cents during off-peak (they also face demand charges levied on the basis of their shorter-term peak in electricity demand that are independent of overall energy consumption). Meanwhile those on the low voltage network pay closer to 4.4 cents during peak and somewhere between 2 to 3 cents in off-peak periods (on top of demand-charges). In addition, the ACCC identified that large electricity consumers face retailer costs and margins of around 0.5 cents per kWh, while small to medium enterprises face retailer charges of 3.2cents per kWh.

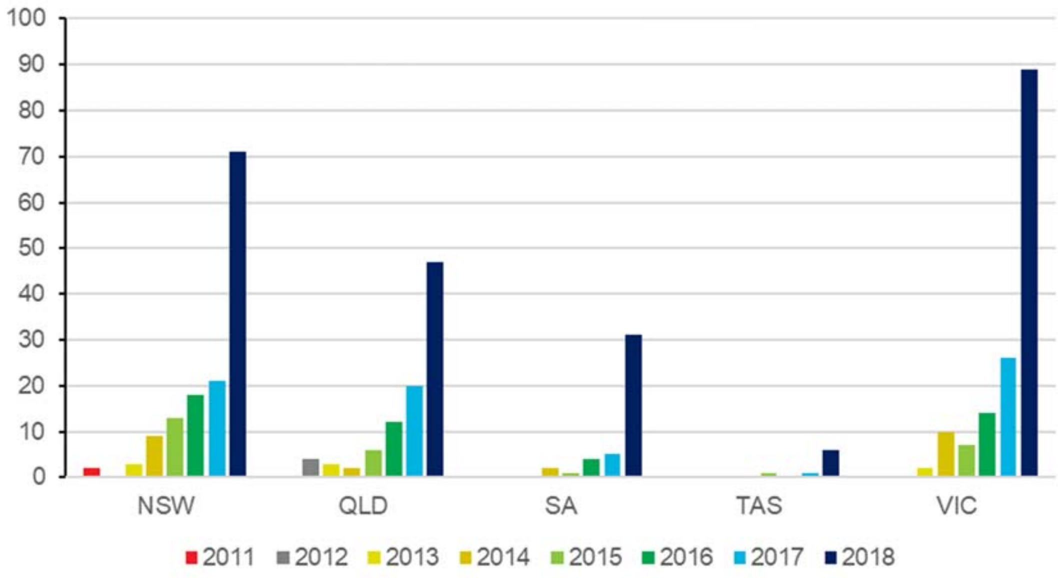
3 Understanding the nature of the 100kW+ behind the meter solar market

3.1 Installation levels

The market for large behind the meter solar systems in Australia has only just recently emerged at a noticeable scale in 2018, with less than 100 systems installed in any year prior to 2018.

Figure 3-1 details the number of behind-the-meter solar systems accredited by the Clean Energy Regulator for LGCs across the states of the National Electricity Market (NEM). It illustrates that the number of systems accredited dramatically increased in 2018 across every state in the NEM.

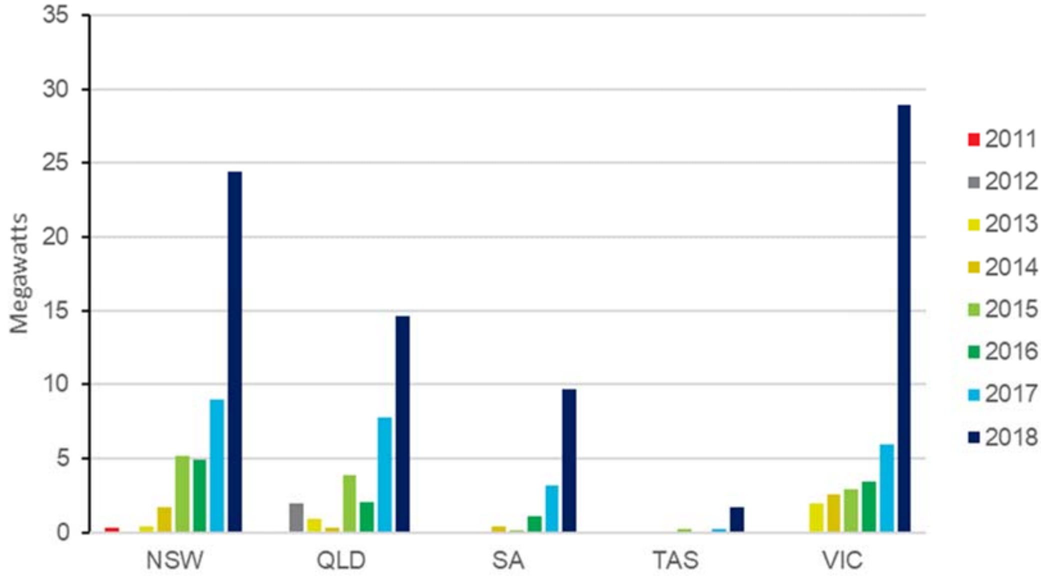
Figure 3-1 Number of behind-the-meter solar systems accredited by year for LGCs 2011-2018



Source: Green Energy Markets analysis of REC registry data

The amount of generating capacity also leapt up in a similar fashion in 2018 across the NEM states, with the jump in Victoria being the most significant (see Figure 3-2).

Figure 3-2 Megawatts of behind-the-meter solar accredited by year for LGCs 2011-2018



Source: Green Energy Markets Analysis of REC registry data

Substantial growth of solar capacity and systems also occurred in 2018 for systems smaller than 100kW that claimed STCs rather than LGCs. However, the rate of growth in capacity for STC systems for 2018 was far smaller than LGC systems - 45% versus more than a tripling in capacity for systems larger than 100kW.

3.2 The types of organisations installing LGC registering systems

Table 3-1 sets out the megawatts installed in Victoria by end customer site type by year of accreditation back to 2016. The details of each host site are detailed in attachment 1.

Table 3-1 Megawatts of Victorian rooftop solar accredited for LGCs by sector type 2016 to 2018

Sector	Megawatts Accredited		
	2016	2017	2018
School	0.00	0.44	1.64
Food processing/Coldstore/Baking	0.00	1.00	7.12
Supermarket	0.00	0.20	0.65
Shopping centres	1.04	0.00	1.98
Manufacturing	0.33	2.21	9.94
University/TAFE	0.00	1.14	1.41
Aged Care	0.97	0.18	0.10
Government-Public Bldgs	0.00	0.12	0.70
Office	0.00	0.00	1.09
Hospitals	0.00	0.26	0.00
Hotels-Accommodation-Entertainment	0.00	0.00	1.61
Warehousing-transport	0.30	0.15	0.28
Unidentified	0.14	0.26	1.51
Data centre	0.40	0.00	0.00
TOTAL	**3.17**	**5.98**	**28.04**

Source: Clean Energy Regulator power station data with sector type determined by Green Energy Markets

While we have not categorised all power stations in states outside of Victoria, our review of the national list sees the same types of sectors registering LGC solar power stations. Although the balance of megawatts being installed between sectors is often different to what has been seen in Victoria.

3.3 Understanding the factors influencing adoption of 100kW+ solar

The sites where behind the meter solar systems larger than 100kW are potentially viable are subject to a range of constraints that complicate attempts to project the likely level of uptake.

Interviews undertaken with several businesses that have extensive experience in the purchasing process for solar systems greater than 100kW provided consistent feedback that this market is subject to substantially greater complexities than the residential solar market.

The residential sector presents less complexities because there is a very large pool of potential customers for which a solar system represents a compelling and relatively simple sales proposition due to.

- the majority of residential dwellings are owner-occupied and so are not subject to split incentive problems;
- payback periods of 6 years or less are readily obtainable for a significant proportion of prospective customers;

- customers are typically happy to make purchasing decisions based on relatively simple rules of thumb and associated calculations, which are assisted by electricity tariff structures that are reasonably simple and consistent across customers;
- system design and grid connection requirements can be satisfied relatively quickly by staff without much engineering expertise; and
- systems installation can be undertaken very quickly using personnel with relatively basic electrical trade and occupational health and safety training.

However as solar systems become larger, the processes around the purchasing decision and the design and installation of these systems becomes more complicated.

Factors that need to be taken into account in evaluating the prospects for 100KW+ systems for each customer type and therefore the overall size of the Victorian market for such large systems include:

- **Suitable space.** Is there enough suitable space for installation of such a system? Panels common on the market today typically produce from 170 watts to 210 watts per square metre (at peak rated capacity). Therefore a 100kW system will need at least 475 square metres of spare roof or land space reasonably free of shading, and potentially more than 600 square metres.
- **Premium on wholesale price.** What is the value of electricity that the solar system's generation can displace? Sites that have enough available space to host a system greater than 100kW will often have a proportion of the network costs charged on the basis of their peak electrical demand within a short window of time, rather than just the amount of overall kilowatt-hours of electricity they consume. In almost all cases a solar system is not judged as likely to reduce a site's network demand charge, only its charges tied to kilowatt-hours of consumption.
- **Site occupation structure.** Does the host organisation own its premises or must it negotiate with a landlord to agree to installation of the solar system and contribution towards the system's cost? Also, how long into the future does the host organisation feel confident it will continue to operate at its existing premises?
- **Investment time horizon.** What is the organisation's time horizon for its investments and does it value environmental benefits? Some organisations require very high rates of return or short payback periods for potential capital investments and apply the same criteria to solar systems. Other organisations can be willing to accept longer payback periods for investments more generally or solar systems in particular. This may be because the organisation has access to plentiful and low cost capital, or they adjust required paybacks to reflect the specific attributes of solar systems such as their very long operational lifetimes (over 20 years), their environmental benefits and the public relations benefits of being seen to do the right thing, or lower perceived risks of such an investment relative to alternatives.
- **Alignment of site energy consumption with solar generation profile to maximise self-consumption.** To what degree will the site's electricity consumption be sufficiently high to consume most or all of a large solar system's generation? As a rough rule of thumb a solar system's economics look most attractive when its generation meets but does not exceed a customer's need for electricity on site. This is because customers will usually pay noticeably more for electricity they wish to import from the grid than what a retailer will pay for electricity that the customer may export. In addition in order to be able to export power from a 100kW+ system an authorisation has to be obtained from the local distribution network which adds additional costs, time delays and complications to installation of a solar system (see section 3.3.1 below). Many sites that might

have sufficient space to accommodate a system greater than 100kW in size, may not have sufficient steady daytime load to consume the generation from such a large system, and will instead be better off with a sub-100kW system. Warehouses that don't need to maintain steady air temperatures are an example of such sites. This is an important factor in restricting the size of the market for solar systems greater than 100kW.

3.3.1 Why it is common to constrain a system from exporting power to the grid

Under the rules governing the National Electricity Market, electricity customers are required to pay for the network costs associated with transporting electricity from the generators to their site. Generators do not pay any network use of system charges for the service of transporting their power to end consumers. However, generators are obliged to pay for what are known as shallow connection costs. To simplify this - these are the upgrades a network would need to have implemented to safely accommodate any electricity a generator is likely to inject into the network while maintaining reliability of supply to electricity end consumers.

Network businesses have tended to adopt streamlined automatic connection processes for solar systems where their capacity falls below certain thresholds such as 5 kilowatts of inverter capacity. In such cases the network is generally quite confident that injection of power from the solar system into the network will not necessitate significant upgrades of the network to maintain safety and reliability. Such streamlined, approval processes are also typically applied for solar systems where the system is prevented from exporting power into the grid.

However, if a site is looking to install a system above 100kW in size and wishes to export electricity they will be required to pay for engineering studies. These studies will evaluate the likely impact their generator's injection of power may have on the surrounding network's ability to operate safely and reliably. In the case of large behind the meter solar systems such engineering studies can cost several tens of thousands of dollars. This is quite a significant cost in the overall scheme of these projects. For a 200kW solar system it could represent an additional cost equal to 10% of the overall system. At the same time there is no guarantee that these engineering studies deliver an outcome that noticeably improves the economics of the solar system relative to export limiting the system, because the network operator may impose a series of requirements including additional and sometimes costly equipment to manage any impacts such a study might identify, or potentially limit the size of the solar system below what was originally planned.

It can also act to noticeably delay and complicate the purchasing process and the ultimate installation of a solar system. Interviews with solar installers and solar industry consultants indicated that going down the route of seeking export permission was seen as opening a can of worms that can undermine the profitability of the solar project for the supplier or the sale of the system altogether. Customers in evaluating whether to purchase a large solar system can often require significant hand-holding from a solar supplier to effectively evaluate their options and their relative costs and benefits. At the end of what can be quite a significant involvement of time from the solar installers' staff, the payback on the solar system may still fall short of an overwhelmingly compelling investment. Therefore, any delays or changes to the parameters of the system and its costs and benefits that may emerge from seeking network approval to export can put the decision to proceed with the project at risk. A grid export approval will also require the solar installer to incur further staff costs managing the application process. If the client subsequently gets cold feet the supplier will in many cases be unable to recover their costs or may only partially recover their costs (possible where feasibility and design fees are charged separately to installation of the system).

A narrow financial analysis of a range of market segments characterised by large drops in demand over weekends and holiday periods, such as schools, suggests that there are large gains in revenue from gaining approval to export to the grid. Our admittedly relatively simplistic model indicates that systems greater than 200kW would generate an amount of export revenue that would exceed the likely cost of the network engineering study and some extra equipment costs, thereby delivering shorter payback periods. Nonetheless, interviews with solar industry participants suggest that they will usually design the solar system with an expectation of no grid exports or seek to size the system to keep grid exports low.

This probably reflects a combination of factors. The obvious one is that displaced imports from the grid are usually far more valuable per kilowatt-hour than exports that earn the wholesale market price for electricity. and possibly even less. It is also influenced by the commercial incentives faced by the solar supplier to make the purchasing and design process simpler and faster and therefore less costly and risky for the supplier. In addition, it may also reflect the immaturity of this market with a lack of experience across the combination of the solar suppliers, the purchaser and the network companies in connecting 100kW+ solar systems for grid-export. As all these participants gain greater experience in processing grid export approvals, one would expect the approval process to become faster and the additional requirements and costs imposed for allowing export become more predictable.

The model has been designed to provide paybacks and levels of uptake assuming systems either do export or don't export power to the grid with no mixture of the two options. Given the above analysis and feedback from industry participants paybacks and levels of uptake in practice are likely to better represented by the no export scenario, but with considerable uncertainty surrounding the relative balance between these two options.

As an aside, it may be worthwhile for policy makers to consider whether it is sensible that each and every solar system proponent is required to undertake their own separate and costly assessment of the impact on the network if they wish to export surplus power to the grid. Given large solar systems that exceed networks' automatic connection standards for export are becoming increasingly common, it may be worth investigating whether engineering studies could be undertaken more efficiently if they evaluated the overall ability of sections of the network to safely absorb different quantities of exported generation from an aggregate of multiple solar systems.

The projections from our modelling, as well as the work from CSIRO for the Australian Energy Market Operator, suggest that behind the meter systems greater than 100kW could represent quite a significant amount of capacity within the next decade on a national basis. Over time the economic loss from these systems spilling electricity and/or being sub-optimally sized will become increasingly material.

3.4 How the solar adoption factors play out in different sectors

In attempting to evaluate the likely uptake of 100KW+ solar systems we have taken as our starting point the types of industries or site types where LGC registered power stations have historically been located, as shown in Table 3-1. We have then combined this with information gathered from interviews to develop 12 market segments or sectors that provide an approximation of the potential market for 100kW solar systems. These idealised sectors aim to reflect the diversity of likely payback periods and organisations' capacity/willingness to invest in such systems within the Victorian market. Although it's worth noting that even within each of these sectors there will be wide variation. Interviews with industry participants emphasised that often the most important factor driving the decision to purchase a solar system was the presence of individual champions for solar within an organisation rather than the type of organisation.

Table 3-2 below provides a traffic light assessment of how the factors driving the propensity to adopt solar apply in each of these market segments. Green coloured squares indicate that this factor is favourable to adoption of solar, at least in comparison to how this factor applies to other sectors, while red is unfavourable and amber is in between.

Table 3-2 Traffic light assessment of factors driving propensity to invest in solar by sector

Sector	Suitable space	Premium on wholesale price	Extent of self-consumption	Site occupation structure	Investment time horizon
School	Green	Green	Red	Green	Green
Food processing/Coldstore/Baking	Orange	Green	Green	Green	Orange
Supermarket	Green	Green	Green	Orange	Orange
Shopping centres	Green	Orange	Green	Red	Orange
Heavy Manufacturing	Green	Red	Green	Green	Red
Light manufacturing	Orange	Orange	Green	Orange	Orange
University/TAFE	Green	Orange	Red	Green	Green
Aged Care	Green	Green	Green	Green	Orange
Government-Public Bldgs	Orange	Green	Red	Orange	Orange
Office	Red	Green	Orange	Red	Green
Hospitals	Orange	Orange	Green	Green	Orange
Hotels-Accommodation-Entertainment	Orange	Green	Orange	Orange	Orange

The nature of how we have defined these segments and how the various factors apply is explained in further detail under the headings below for each segment.

3.4.1 Schools

Secondary schools represented 1.64 megawatts of LGC registered solar PV systems in Victoria in 2018 which was 5.8% of overall capacity installed in Victoria. These schools were mostly non-government run organisations.

Secondary schools have a range of characteristics that are highly favourable to adoption of solar:

- They will often have plenty of available space for a solar system due to the use of low rise buildings and in some cases even spare vacant land.
- They will also typically own their premises (not rent) and be confident they will be operating at the same site for several decades into the future.
- Many schools have management motivated by non-financial, societal good goals. These factors mean they are willing to accept long payback times on solar investments.
- They will often pay a substantial premium for their electricity over wholesale market values because they are a fed from lower voltage distribution networks and are not a big enough consumer of electricity to negotiate a low retailer margin.

However, schools' electricity loads tend to vary substantially over time with extended holiday periods with low electricity loads and also electricity loads heavily driven by heating and cooling needs that vary greatly depending on outside temperatures. Because of this electricity consumption profile, solar systems greater than 100kW will typically generate substantial amounts of electricity surplus to the needs of the school. This surplus electricity will usually only be eligible to receive the wholesale value of electricity and in many cases will be dumped because a connection to export to the grid imposes significant extra cost and complexity.

The high proportion of time when demand falls below levels of solar generation substantially hinders solar payback times to around the 8 to 10 year period in cases where grid export is unavailable.

3.4.2 Food processing/Coldstores/Baking

This market segment captures a broad range of businesses with a few common characteristics highly relevant to solar uptake:

- Relatively constant electricity loads throughout the year, driven in many cases by the need for refrigeration to keep food or plant products fresh, and in some cases also mechanical drives. These facilities will tend to operate with full electrical load for at least 6 days per week, with the possible exception of public holidays. Although where refrigeration is involved, such sites may remain operating close to full load without any significant downtime in electrical load.
- Electricity tariffs per kilowatt-hour that still represent a noticeable premium over what is obtained by energy-intensive heavy industry.
- Occupation of warehouse types of buildings that provide sufficient roof-space to support a solar system greater than 100kW.

The table within attachment 1 provides details of the types of businesses that we have categorised under this broad category which have already installed solar systems over 2016 to 2018. These include meat abattoirs, fresh fruit and vegetable suppliers, coldstores for the warehousing of meat and plant products in transit, wineries, bakeries and indoor animal husbandry facilities.

Over 2018 businesses under this category installed 7.1 megawatts of solar capacity in Victoria representing a quarter of overall LGC-registered Victorian solar capacity. These businesses' relatively consistent load and significant roof space makes them an ideal candidate for 100kW+ systems. We estimate that these sites could realise paybacks within the range of 5 to 8 years.

Also, in addition to paying higher electricity tariffs than heavy industry manufacturers these businesses can in many cases afford to adopt longer investment time horizons than heavy industry due to less uncertainty about their long-term viability as a result of:

- operating in sectors that are less exposed to international trade competition; or
- Australian agriculture possessing a significant competitive advantage that flows through to businesses downstream in the supply chain.

3.4.3 Supermarkets

To date supermarkets have represented a small proportion of capacity, with only 650 kilowatts installed in Victoria on these sites in 2018, representing 2.3% of registered capacity that year.

Supermarkets tend to have substantial consistent loads throughout much of the year due to large amounts of refrigeration and operating hours that extend across almost every day of the year. This should make them well suited to maximising self-consumption from a large solar system.

However, premises have usually been leased rather than owned. This has led to difficulties due to split incentives between landlords who own and typically make investments in significant fixed equipment and the tenant who saves money from reduced energy costs.

Nonetheless, the three companies that represent the vast majority of supermarket floor space in Australia – Coles, Woolworths and Aldi - tend to be long-term and highly sought after tenants that are capable of exerting considerable influence over their suppliers. Furthermore, the supermarket chains are now often developers of the properties they occupy which they then later sell with long-term leases attached to property investors. This suggests they should be capable of working with landlords to resolve such split incentive challenges if they are seriously motivated to have solar installed on their premises.

Also, while these supermarkets have large purchasing power that allows them to negotiate low retail margins over wholesale energy market rates, they will face reasonably significant network charges given their connection at the low voltage distribution network.

While uptake of LGC registered systems on supermarket sites in Victoria has so far been small, our understanding is that Coles, Woolworths and Aldi all have plans for roll-out of solar across many of their stores. While these supermarkets are yet to register LGC systems in Victoria, since June last year Woolworths alone registered nine LGC systems with a combined capacity of 2.2MW. Aldi has also announced a 4.6MW roll-out of solar across its sites in NSW and QLD. We expect that roll-outs will ultimately extend to Victorian stores where paybacks appear to lie somewhere around 6 to 7 years.

3.4.4 Shopping centres

Shopping centres installed 1.98MW of capacity in Victoria last year representing 7.1% of all behind the meter capacity registered for LGCs in Victoria in 2018.

Shopping centres tendency to operate throughout the year with few days of downtime, as well as their often large cooling and heating loads, supplemented by daytime lighting and large roof-space make them well suited to 100kW+ solar systems.

Historically the landlord-tenant split incentive problem has hindered energy efficiency upgrades and consequently also solar. However, at least in some of the larger shopping centres owned by large property investment firms, dedicated effort has been put into establishing embedded networks as a business opportunity in itself, rather than simply a non-core administrative function to the side of property development and management. The more professionalised management of embedded networks are more capable of appreciating how solar can lower their energy procurement costs, which they can then capture as increased profits.

We estimate that solar payback periods for this segment will be similar to those seen by supermarkets.

3.4.5 Manufacturing

Manufacturing businesses represented the largest category for capacity installed in Victoria over 2018, with close to 10MW registered for LGCs in 2018 representing 35.4% of all capacity registered.

In developing our market segments it became evident that the manufacturing sector should be considered as two very different sectors:

- Heavy manufacturing – these are industrial facilities with very large electricity loads that are typically engaged in the transformation of raw materials from minerals extraction into intermediate industrial products. This includes such activities as metal smelting, oil refining, pulp & paper and industrial chemicals. In many cases these businesses will be categorised as emissions-intensive, trade exposed industries commonly exempted from having to comply with emission reduction policies such as Victorian Energy Upgrades program or the Renewable Energy Target. We would also list under this category firms such as major water processing entities and data centres that while they aren't engaged in manufacturing, have similar characteristics to industrial plants that are important to the payback periods and suitability of solar.

- Light manufacturing – These are typically far smaller operations that produce less energy-intensive products.

Heavy Manufacturing

Over 2018 there were no LGC systems registered in what would typically be considered emissions-intensive, trade exposed facilities, although there was 1.27MW registered within water treatment facilities that we classify under this category. There were also a number of manufacturing facilities registering systems in 2018 that, while they aren't classified as Emissions Intensive and Trade Exposed, may potentially have sufficiently large loads that they would share power price and stable consumption characteristics of such plants (but without the exemption from emission reduction obligations).

While heavy manufacturing certainly have very large electricity loads capable of easily consuming all the generation that might be feasibly produced from solar systems that could fit on these sites, they face very low electricity prices. Their very large and relative stable electricity loads mean they are highly sought-after customers by large electricity generators and in many cases can negotiate rates for bulk energy supply at discounts to what some power retailers or very large commercial businesses might face on the wholesale spot market over daytime periods. In cases where they might engage the services of a power retailer rather than deal direct in the wholesale market any retail margin would be extremely low per megawatt-hour. They are also often exempted from the costs associated with complying with emission reduction policies. And because they are connected at the sub-transmission network level any network costs linked to kilowatt-watt hours of consumption are comparatively low.

For these reasons payback periods on solar systems are thought to lie close to 9 years, which for many of these firms is outside their acceptable investment time horizons.

The notable exception to this though is the water treatment facilities. They face slightly higher energy prices and because they are regulated-rate-of-return businesses with access to low cost capital, even a payback period of 9 years on a system with a 20 year operational life can represent a worthwhile investment. Furthermore, these businesses often have ambitious voluntary carbon emission reduction commitments that further enhance the attractiveness of such investments.

In addition, there are a number of manufacturers (some near the borderline of EITE eligibility thresholds) that have entered into long-term power purchase agreements (PPAs) with utility-scale solar and wind projects. We expect that behind the meter solar plants would offer a similar financial benefit to these firms and we know of a number of firms that are well advanced in pursuing such projects. Consequently, we expect some modest level of solar uptake within this sector in the future beyond just water treatment facilities.

Light manufacturing

Most of the systems being installed within the manufacturing sector are in facilities that are not producing highly energy intensive primary products. Nonetheless such facilities can be operating for 6 or 7 days per week and have quite consistent electricity loads that will absorb most, or all of the generation that might be produced from a large rooftop solar system. In addition, these businesses will often operate in warehouse-style buildingwith sufficient roof space to support the installation of a solar system greater than 100kW in size.

The key characteristic that makes solar more appealing to these facilities over those categorised under heavy manufacturing, is that they pay noticeably higher electricity prices. Such facilities will be connected at the low voltage distribution network, which involves significantly higher network costs. They will also have to pay noticeable retailer premiums and higher costs for complying with emission reduction policies.

A number of these facilities are either family-owned businesses or Australian owned. This can lead to a greater preparedness to consider investments with longer-term paybacks. In some cases it canalso mean greater value is placed on environmental benefits than what is evident in very large internationally-owned heavy manufacturing plants, which often don't have a residential consumer-facing brand.

Because these businesses face much higher electricity prices than industrial facilities paybacks are shorter at around 7 to 8 years, and can be as low as 6 years where the facility faces higher electricity prices.

3.4.6 Universities and TAFE

Victorian University and TAFE facilities registered 1.41MW of solar systems for LGCs in 2018 representing 5% of behind the meter capacity registered that year.

The biggest hinderance to solar in this market segment is that these facilities have extended holiday periods with low electricity demand. This can push out payback periods beyond 10 years if the system is sized beyond load during the low load holiday periods and there is not the capability to export generation.

However, to date universities across not just Victoria but also other states have shown themselves to be enthusiastic adopters of solar. Feedback from our interviews with industry participants is that universities place value on the environmental benefits of solar systems, their ability to incorporate them within their teaching and research activities, and the perception that solar represents the leading edge of technology which universities wish to be associated with. Universities also have confidence about their ongoing operation at their existing sites for several decades and at least historically have had access to substantial amounts of money for capital works programs (although the abolition of the Education Investment Fund may make funds harder to come by).

Also, universities are large sites and while their overall load can vary noticeably over the year, there are usually a number of loads that are constant throughout the year. Sizing solar systems for such loads can then deliver paybacks closer to 7 years, although many universities' ambitions have extended beyond these loads.

The question mark hanging over universities though is the degree of further expansion they might pursue given several have signed on to long-term power purchase agreements with large-scale utility solar and wind farms to cover their energy consumption needs. Monash University has stated this was necessary due to limitations on the potential to further expand on-site generation to meet its goal of being 100% powered by renewable energy. Meanwhile Deakin University is in the process of constructing a 7.25MW microgrid incorporating very large ground mount system at their Waurn Ponds campus.

TAFEs are not so well resourced, nor as secure about their ongoing operation at the given site, and are much smaller operations. This makes solar at a scale greater than 100kW a more marginal proposition.

We anticipate uptake at current market prices will not grow markedly from 2018 levels (with the exception of Deakin's already committed 7.25MW micro-grid project which is not incorporated within our projections due to it being already under construction). This is due to the prospect that several Universities may be approaching limits in their appetite to install further on site solar now they have entered into PPAs covering their full load, while solar presents a more challenging investment proposition for TAFEs.

3.4.7 Aged care

Aged care facilities in Victoria only registered 100kW of LGC capacity in 2018, however 2016 saw almost a megawatt installed with the sector representing the second largest installer of solar after shopping centres.

An analysis of this sectors' characteristics suggests solar should represent an appealing investment proposition in the future and that installs should rise above 2018 levels.

According to data from the Australian Institute of Health and Welfare there are 53,277 residential aged care facilities in Victoria with more than 40,000 of them housing 60 or more residents.

We expect a substantial proportion of these facilities housing 60 or more residents are likely to have sufficient roof space to accommodate solar systems greater than 100kW in size.

While such facilities probably aren't very large energy consumers, we expect they would have a reasonably consistent daytime load given residents will occupy the facility throughout the entire year, and it will need to be conditioned over this time to maintain comfortable temperatures. In many cases these greater than 60 resident facilities should be capable of consuming most of the output from a system of 150kW in size, with this rising in line with resident numbers. Importantly for solar paybacks, aged care facilities are likely to face significant network charges and probably also retailer premiums above the wholesale value of electricity. We therefore expect paybacks similar to those in the retail sector are achievable of around 6 to 7 years.

3.4.8 Government and public buildings

Victorian government and public buildings registered 0.7MW of solar for LGCs in 2018 representing 2.5% of total behind the meter capacity that year.

Based on current prices we do not anticipate that installations will increase that much above these levels. Solar investments face a number of challenges in this segment that act to inhibit installations in spite of the fact that one would expect governments would wish to display leadership in emission abatement efforts. The first is that these buildings tend to be characterised by relatively modest electricity loads in many cases with low loads over weekends, public holidays and the Christmas-New Year period. Constrained roof space and the fact some premises are rented also work against uptake. While governments often express strong aspirations to reduce emissions, decision making around procurement can be driven by very short-term budgeting imperatives in spite of governments being able to raise capital at very low interest rates.

3.4.9 Offices

Office buildings registered 1.09MW of LGC solar capacity in 2018 representing 3.9% of total registered Victorian capacity.

Office buildings represent the largest amount of floor area of any commercial building type across Victoria and are a major consumer of electricity, equivalent in scale to shopping centres or supermarkets. However, we expect more modest uptake of solar within this segment because they lack the consistency of load that characterises shopping centres and supermarkets due to scaled back operation over weekends, public holidays and the Christmas and New Year period. Also a large proportion of office building floor space is concentrated in high-rise buildings within the Melbourne CBD which substantially constrains the suitable roofspace for solar. Lastly, there are likely to be greater difficulties in overcoming the tenant-landlord split incentive problem than in supermarkets (where major tenants can dictate terms) or large shopping centres (where professionalised embedded network operators have clearer incentives to roll-out solar).

Our analysis suggests that paybacks for offices can be as short as 7 years if exports are allowed or the entire generation from the solar system can be consumed on-site but this can blow out to 9 years where the system generates lots of excess power over nonoperating days such as weekend which cannot be exported. At such paybacks we still believe that uptake of large solar systems will grow above 2018 levels. This is because a number of large property investors appear to place significant value on the environmental ratings awarded to their commercial office buildings. In addition, occupants of office buildings see environmental performance of their premises as valuable for enhancing staff commitment levels and projecting a positive brand image.

3.4.10 Hospitals

There were no solar systems registered for LGCs located at Victorian hospitals last year nor in 2016, while just 0.26MW was registered in 2017. Nonetheless modest levels of installations in the range of a megawatt or two into the future seem likely.

Hospitals have large and consistent electricity loads. While their roof space is not plentiful relative to their loads, for many hospitals it should be sufficient to accommodate systems greater than 100kW. While few systems have been registered for LGCs in Victoria, there are 2.6MW of solar installed on Victorian health facilities once we incorporate sub-100kW systems according to the Department of Health. This suggests these systems represent an attractive option for many sites relative to purchasing power from the grid. According to the Victorian Department of Health a further 40 solar arrays, with an aggregate of 4.9 megawatts, have either been funded or procured but not yet installed (as at July 2018). This suggests an average size per system of 122 kilowatts. So the absence of any LGC registered systems in 2018 and 2016 does not appear to be indicative of future trends. Indeed, it may suggest our current model projections could be too conservative. Although we suspect that a significant proportion of the 4.9 megawatts planned will lie below the 100kW threshold, and that it will be progressively installed over more than one year.

3.4.11 Hotels, Accommodation and Entertainment Facilities

This category attempts to capture a broad array of facilities that fall outside the segments identified above but represent a significant stock of buildings that have sufficient load and space to host systems larger than 100kW. It includes hotels, resorts, stadiums and sporting/leisure centres, large sporting clubs which have significant hospitality and entertainment operations, and also apartment buildings with significant roof space.

1.61MW of capacity was registered in Victoria in 2018 within this miscellaneous category representing 5.7% of total capacity.

A common characteristic across this sector is that they are likely to be paying noticeable price premiums for network services and also retail margins over wholesale energy costs. Another characteristic is that their overall loads will tend to be quite variable over the space of the year complicating the process of appropriately sizing the solar system and possibly making the investment case for a large solar system greater than 100kW more complicated. In some cases, such as sports stadiums and large sporting and entertainment clubs there will plenty of available space to host a large solar system but electrical load to consume the system's output will be the limiting factor. In other cases, such as large hotels or apartments, there may be plenty of daytime load, but roof space is a constraining factor.

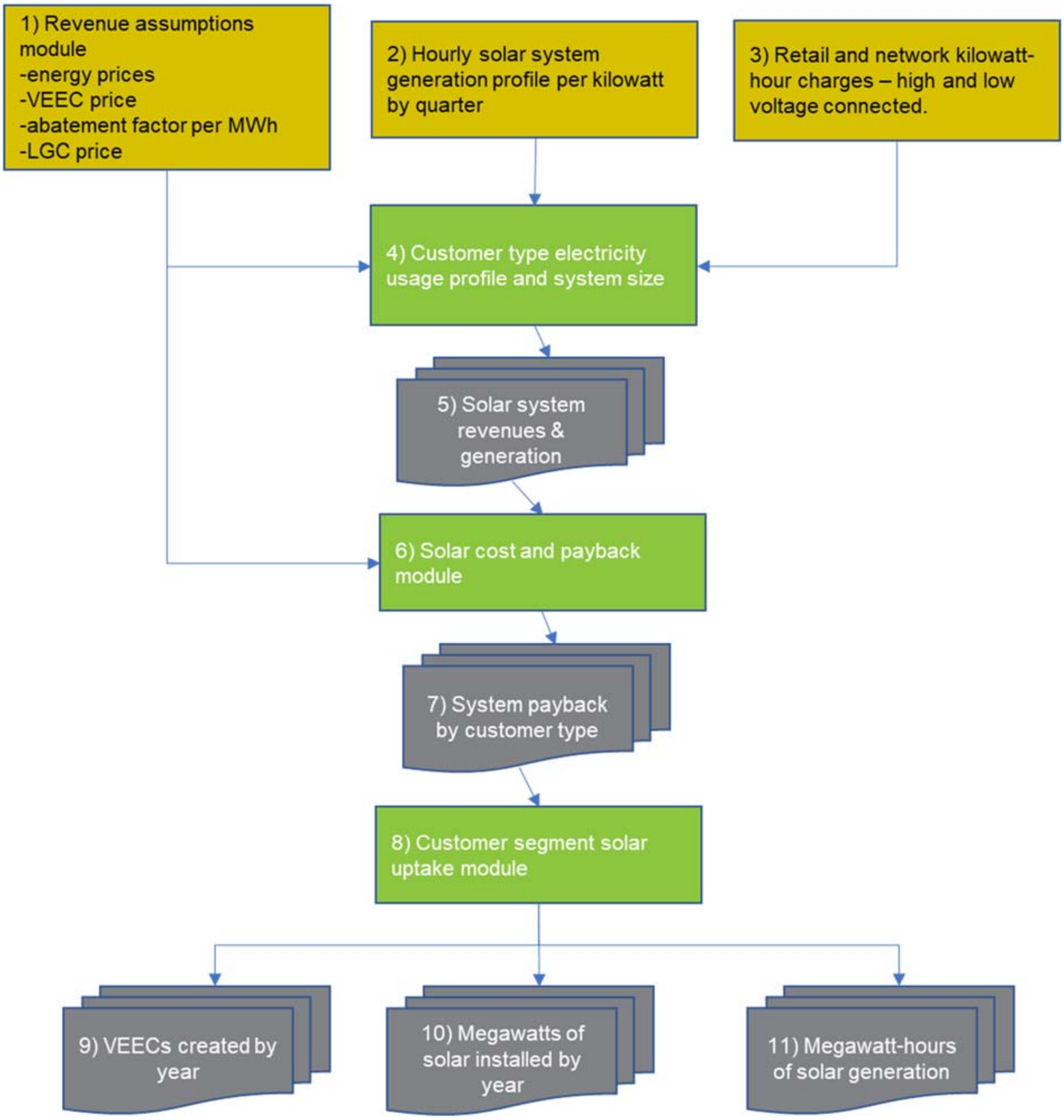
While this presents a very diverse set of customers whose likely behaviour is difficult to predict, the amount of available roof space and electricity load they represent is sufficiently large that they need to be considered in any forecast of 100kW + system uptake. Also, in spite of their diversity we suspect that the solar investment proposition may nonetheless not look all that different to that of a retail operation. As a rule of thumb, systems can be sized to be no greater than that required to service the base level of consistent demand on the site. Or in cases where the available unutilised space is insufficient to host that capacity, the system will be sized to whatever suitable space is available. Such a solar system will minimise spilled generation or exports delivering paybacks in the realm of 6 to 7 years. Although not all sites that have sufficient space for a 100kW system will be able to achieve such paybacks and these may be left untapped, or they will opt for solar systems below 100kW.

4 Projecting future uptake of solar and VEEC creation

4.1 Overview of the model

Figure 4-1 provides an illustrative overview of the model developed to project the uptake of 100kW+ solar systems in Victoria.

Figure 4-1 Diagram of 100kW+ behind-the-meter solar uptake model



Deriving revenue

The revenue assumptions module (box 1) provides the flexibility for the Department to adjust prices as they see fit for energy (with peak, shoulder and off-peak periods catered for), VEECs, and LGCs and also the abatement factor applied per megawatt-hour of electricity saved (which then affects how many VEECs can be created per megawatt-hour of grid imports the solar system's generation has displaced). In addition, there is a generic set of assumptions for the amount of electricity generated per kilowatt of solar capacity by hour for each quarter across the year (box 2). The final set of input assumptions for the revenue equation are the retail and network charges applied per kilowatt-hour of electricity consumed (box 3).

These are then fed into several different customer electricity consumption profiles (box 4) reflective of the customer sectors described in section 3.4 of this report. This then provides an approximation of the revenue and generation profiles for a solar system installed on a site within each sector (outputs box 5). This is divided into generation that is self-consumed by the site and generation which is exported to the grid.

Deriving payback periods

These are then fed into the solar cost and payback module (box 6). This takes these revenue flows and combines them with assumptions about solar system costs over time and also potential revenue from VEECs to determine payback periods for a solar system. These are calculated for each customer segment, with separate results for whether or not the system is able to export generation surplus to on-site consumption (outputs box 7).

Estimating total Victoria-wide uptake of solar capacity and VEEC creation

These payback results are then fed into the customer segment solar uptake module (box 8) which calculates the expected amount of megawatts each segment would be likely to install in a given year based on the payback period achieved by a solar system for that segment (outputs box 9). In addition, this then also calculates the amount of VEECs that would be created in each year (outputs box 10) and also the amount of megawatt-hours of electricity produced by these systems (outputs box 11).

4.2 Calibrating the model with 2019 installation levels as a reference point

As is starkly illustrated several pages earlier in Figure 3-1 and Figure 3-2, the dramatic jump upwards in installed capacity and number of systems registering for LGCs in 2018 illustrates that the behind the meter 100kW systems have only just recently hit a point of wide market appeal. In Victoria the market grew in capacity registered by 188% between 2016 and 2017 and then by 468% in 2018. Given this great flux, historical data provides a weak guide to the future. However we consider it highly improbable that the quadrupling of capacity installed in Victoria in 2018 will be repeated, based on a combination of:

- feedback from industry participants;
- a review of likely payback periods across different sectors; and
- the fact that the large rises in wholesale power prices since the closure of Hazelwood have stabilised.

Nonetheless, we are also confident that the level of capacity installations will grow substantially in 2019. We are confident that installations will grow substantially relative to 2018 because the large-scale solar market is still to work through noticeable lags in the process of businesses acting to install solar to mitigate the large price rises that unfolded over 2017 in the wholesale power market:

The spark that drove the sudden surge in the market for 100kW + systems was the leap in wholesale energy contract prices that unfolded from October 2016 and continued over much of 2017 (caused by the announced closure of Hazelwood power station and tripling in gas prices post LNG plants commencing operation). As a result of these large rises, large solar systems suddenly became a competitive option compared with conventional grid supply for a large range of significant electricity consuming sites on demand-based network tariffs.

Yet for many commercial and industrial electricity consumers their electricity prices tend to be fixed under 3 year contracts. Consequently, many of these businesses have only relatively recently seen their electricity prices rise substantially to reflect what unfolded over 2017.

Lastly, feedback from industry participants is that the process for deciding to purchase and then install a 100kW+ solar systems can regularly extend over a year.

Given this information we'd suggest the surge in 2018 was reflective of the first wave of early movers responding to the spike in wholesale contract prices over 2017. Taking into account the lags affecting this segment we therefore expect the full impact on solar system adoption of the 2017 spike in wholesale energy prices will unfold this year.

After this we anticipate more of a steady state market. This is because of the following factors:

- System prices are expected to remain steady this year due to a combination of stable international module prices and local labour constraints;
- The large fall in LGC prices that has unfolded over the last 12 months reduces the financial attractiveness of large solar systems;
- A number of analysts are predicting wholesale energy prices to fall in the next two years in response to an influx of wind and solar capacity. This expectation of falling power prices will act to reduce the sense of urgency to contain energy costs which businesses have experienced in recent times, even if power prices remain high. This is expected to lead to delays in solar purchasing decisions or even cancellations from those who have begun the process of evaluating solar. It will also probably result in a decline in interest from new prospective purchasers.

Based on current available information we estimate that approximately 50 to 70 megawatts will be installed in 2019 in Victoria claiming LGCs – with the range reflecting the degree to which the industry decides obtaining grid export approval is worth the extra costs and effort. This estimate is subject to substantial uncertainty given the rapid change unfolding in the 100kW+ market and its immaturity.

In the model the level of megawatts we expect for 2019 claiming LGCs and associated paybacks estimated for each sector are used as the reference point or baseline against which future levels of uptake are calibrated. If payback periods improve on the 2019 levels (where the system is creating LGCs, not VEECs) then the amount of megawatts installed increases and visa versa. Paybacks reflect:

- an assumed wholesale energy price structure of $150/MWh for peak, $80/MWh for shoulder and $50 for off-peak that is constant in real terms. The off-peak and shoulder rates are similar to those estimated by ACIL-Allen in their report for the Essential Services Commission – *Victorian Feed-In Tariff Estimate of the Energy Value* (ACIL Allen estimate $46/MWh for off-peak and $78/MWh for shoulder). We have moderated the peak rate to a level noticeably below the ACIL-Allen value of $264/MWh. This is because this very high value estimated by ACIL-Allen covered a period that extended well beyond the time that solar systems are likely to be generating power (peak period covers 3pm until 9pm). As ACIL-Allen's report notes, solar capacity has reached such a large amount of scale that it is likely to depress power prices over the time that it is generating, but when it drops away in the early evening wholesale prices are projected to spike upwards. Given Green Energy Market's solar uptake model focusses only on what a solar system might be able to capture it was considered appropriate to discount the peak value closer to prices that have prevailed in the Victorian wholesale market over 3pm to 6pm in 2018 (which were about $135/MWh after accounting for losses of 6.8%). While these wholesale energy prices are likely to decline over time, it is common practice for solar retailers and their customers to assume constant or even rising prices over time in financial evaluations of solar systems, hence the assumption of holding these prices constant in real terms.

- a system installation cost of $1400 per kilowatt and LGC prices of $38 in 2019 declining to $24 in 2020, $15 in 2021 and then dropping to $10 until 2024 and $5 until 2030.

Table 4-1 provides a break down on the amount of megawatts expected in 2019 by sector and the associated payback periods faced by those electing to install solar in this year assuming a 50-50 balance across exporting and non-exporting systems.

Table 4-1 Details of 2019 reference point for megawatts installed and paybacks by sector (LGCs created)

Sector	Megawatts	Payback period (years)
School	3.0	9.3
Food processing/Coldstore/Baking	14.5	7.5
Supermarket	8.0	6.8
Shopping centres	8.0	6.8
Heavy Manufacturing	2.0	9.3
Light manufacturing	14.5	7.5
University/TAFE	2.0	9.7
Aged Care	2.0	6.8
Government-Public Bldgs	0.8	8.2
Office	2.0	8.2
Hospitals	1.0	9.3
Hotels-Accommodation-Entertainment	2.0	6.8

4.3 Example projections of model results for megawatts and VEECs

With the reference point in place the model can evaluate how payback periods might change if VEECs were claimed for self-consumption of the solar system's generation instead of LGCs. The model allows for the price of VEECs in each year to be adjusted by the user but for the purposes of developing and presenting results for this report we have adopted a constant real VEEC price of $18 (close to recent market levels) and a constant abatement factor (also adjustable by the user) set at the current level of 1.095 tonnes of CO_2 per MWh.

The model delivers results for megawatts of uptake creating VEECs and the number of VEECs created according to two alternative situations: systems are allowed to export electricity to the grid; or they aren't allowed. The model will only report megawatts of uptake creating VEECs where VEECs deliver a shorter payback than creating LGCs.

in addition, two spreadsheet versions of the model have been provided. One assumes relatively modest ongoing reductions in the installation cost of solar PV systems declining from a level of $1400 per kilowatt in 2019 by 2.5% per annum in real terms. This might be thought of as a pessimistic scenario. The other version of the model has a linear straight line series of cost reductions from $1400 per kilowatt in 2019 to $900 per kilowatt by 2030 (in 2019 real dollars). The 2030 assumed cost is relatively close to that projected by CSIRO ($951/kW in 2018 dollars) in their forecasts undertaken for the Australian Energy Market Operator's 2018 Statement of Opportunities[2]. Such a cost reduction pathway is more likely and more in line with the plans of solar technology researchers and manufacturers.

4.3.1 Megawatts installed creating VEECs

Figure 4-2 illustrates the model results for megawatts installed each year claiming VEECs under the assumption VEECs are worth $18 throughout the outlook period and all solar systems gain authorisation to export to the grid. This is based on the version of the model involving ongoing significant declines in cost for solar systems. Please note that while the model produces results for 2019, given no one has yet developed processes for claiming VEECs from solar systems these are not expected to eventuate in reality.

Figure 4-2 Megawatts installed creating VEECs where all systems can export and solar costs continue to fall rapidly

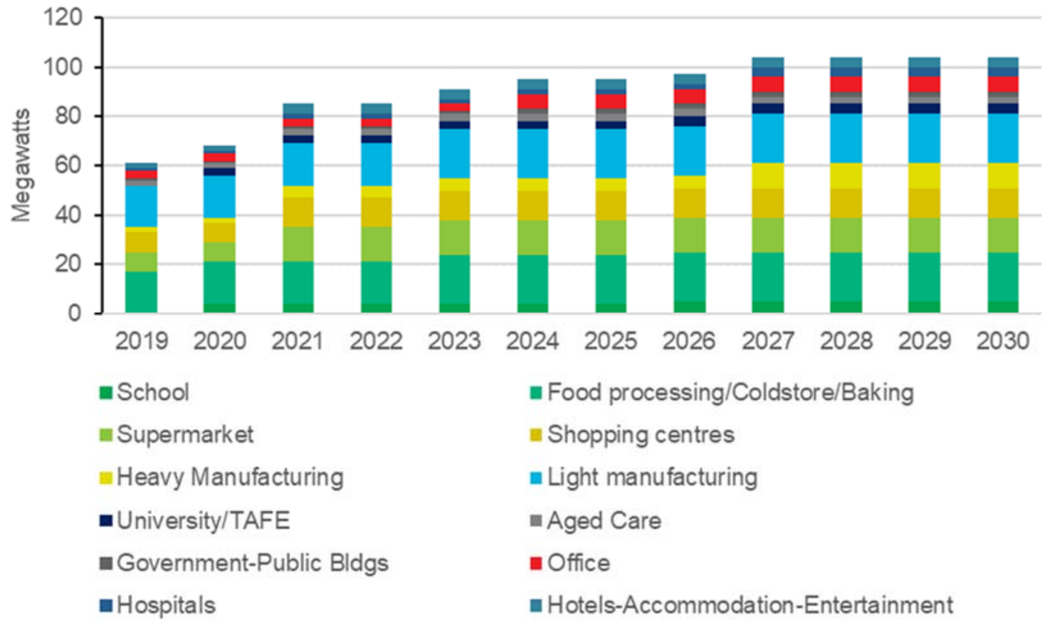


Figure 4-3 below presents the results for megawatts claiming VEECs under a situation where solar systems don't export power off-site and the cost of solar systems falls slowly, while maintaining the other assumptions used in developing the results are detailed in Figure 4-2.

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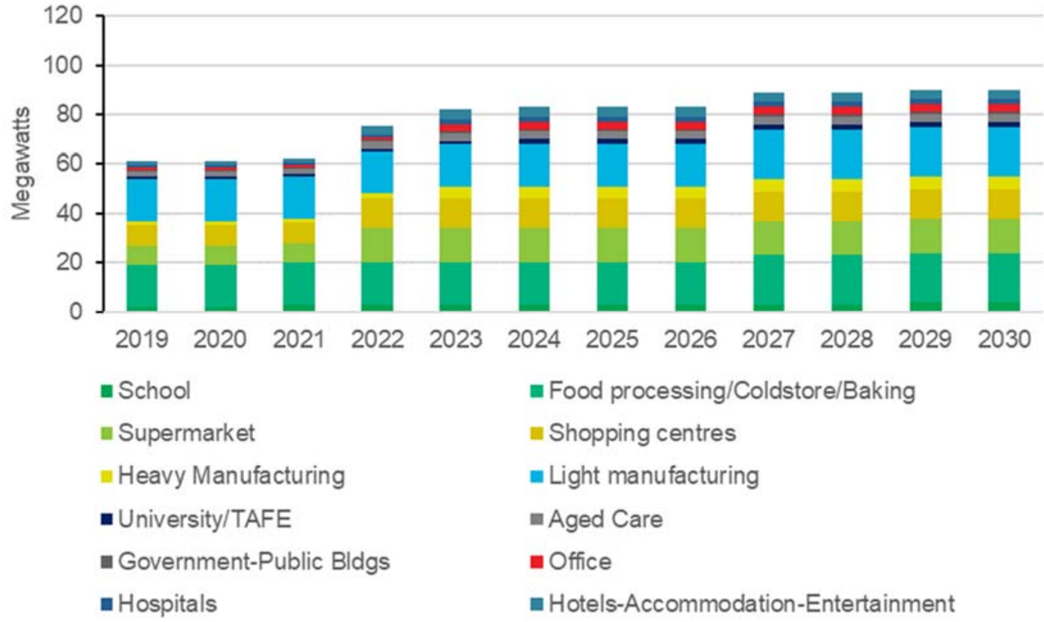
[2] See: CSIRO (2018) *GenCost 2018 Updated projections of electricity generation technology costs*, December 2018 available from:
https://publications.csiro.au/rpr/download?pid=csiro:EP189502&dsid=DS1

Figure 4-3 Megawatts installed creating VEECs where systems do not export and solar cost reductions are slow



Irrespective of the option chosen the availability of VEECs delivers equivalent or shorter paybacks than claiming LGCs across all sectors from 2020 onwards.

Given the VEECs associated with 9 and half years of forecast self-consumption can be claimed in an advance lump-sum after the plant has operated for a year, these also represent a vastly lower risk option than LGCs (which can only be progressively claimed as power is produced). Both the RET and the Victorian Energy Upgrades Scheme have faced serious threats of wind back by governments. Understandably, prospective solar customers have traditionally been sceptical about the prospects of a market for LGCs beyond a few years. Even if the price of LGCs had not experienced the falls in prices over the last 6 months, we suspect many solar customers would still heavily favour creating VEECs given this substantially reduces the degree of risk around future regulatory change. Being able to create the certificates upfront and if desired sell them immediately also allows the customer to avoid ongoing exposure to market risk in a commodity that most are incredibly unfamiliar with and which has historically experienced considerable price volatility.

4.3.2 VEEC creation volume from 100kW+ solar systems

The number of VEECs created to 2030 from these installs where systems export power and solar costs continue to decline substantially is detailed in Figure 4-4. Note that creation in a given year reflects megawatts of installations in the prior year due to the need to demonstrate a year's performance before VEECs can be claimed.

Figure 4-4 VEECs created by solar systems where they are capable of exporting and solar costs fall rapidly

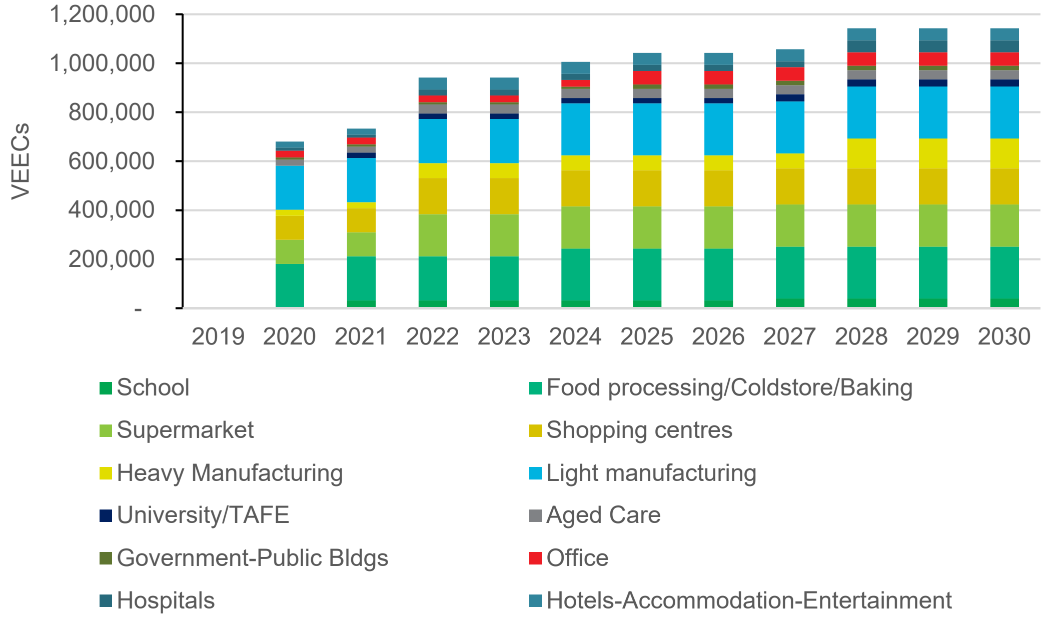
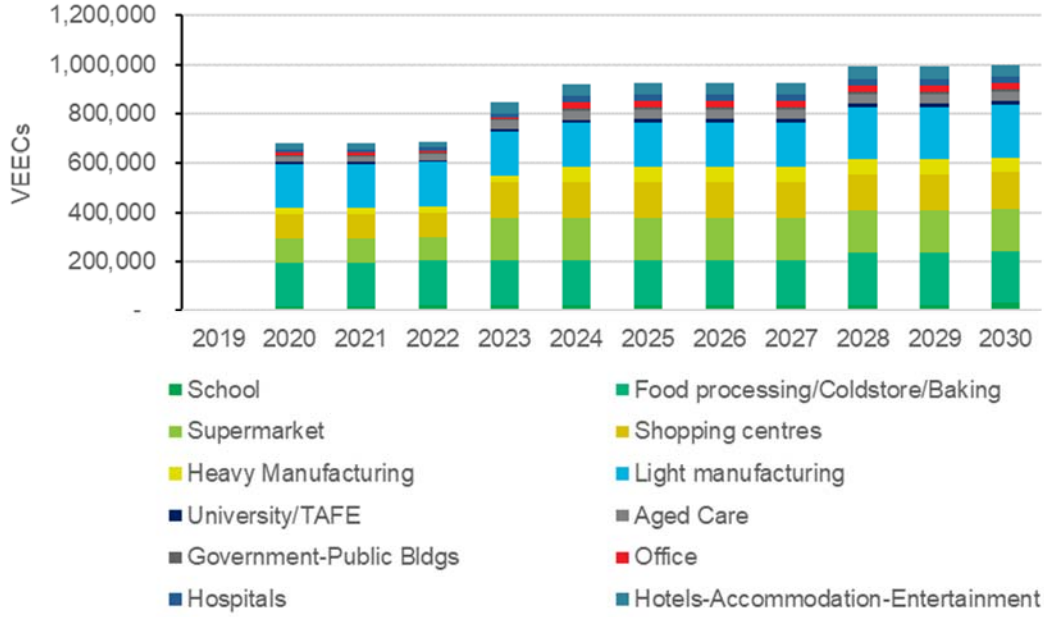


Figure 4-5 provides VEEC creation for the alternative situation where systems are unable to export surplus electricity and solar system costs fall slowly.

Figure 4-5 VEECs created by solar systems where they don't export and solar costs fall slowly



4.4 Cross checking model results relative to potential physical constraints

To ensure the model does not forecast a level of solar installations that is physically infeasible we have:

- Examined the megawatts of solar projected to be installed by the model under a situation where the VEEC price was held permanently at a very high level of $40. This is in addition to also maintaining the assumption of wholesale electrical energy prices at their current, very high levels by historical standards;
- Assessed whether the amount of megawatts projected to be installed might exceed available roof space of the sectors analysed;
- Assessed the levels of solar generation likely to be produced relative to each sectors' overall electricity consumption levels.

Table 4-2 below provides a summary of the overall assessment. It suggests that at least within the outlook period to 2030, even under circumstances where assumptions are adopted that would provide very strong incentives to install solar, the megawatts projected are within physically feasible levels.

Table 4-2 Upper end solar installations relative to constraints

Sector	MWs installed (2019-2030)	Conservative assessment of space constraints (MW)	Total annual electricity consumption (MWh)	Solar share of consumption
School	45	833	581,389	10%
Food processing/Coldstore/Baking	260	See discussion on non-commercial buildings	1,694,446	19%
Supermarket	104	239	2,117,502	6%
Shopping centres	104	284	2,356,252	5%
Heavy Manufacturing	130	See discussion on non-commercial buildings	9,396,952	5%
Light manufacturing	260	See discussion on non-commercial buildings		
University/TAFE	44	198	788,890	7%
Aged Care	40	84	No data	No data
Government-Public Bldgs	23	47	165,501	17%
Offices	69	129	2,382,621	4%
Hospitals	45	83	721,389	8%
Hotels-Accommodation-Entertainment	52	85	766,834	8%

Further detail on the basis for these estimates are outlined below for each sector.

Schools

Pitt and Sherry's 2012 publication, *Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia* indicates that the floor area of Victorian schools is expected to be 11.9m square metres in 2020. This is assuming an average of one and half storeys that provides a roof space of slightly more than 7.9 million square metres. High efficiency solar panels available on the market today generate around 0.21 kilowatts per square metre and this level of efficiency will likely become common across the market in the next few years. Assuming 50% of the roof space is suitable for solar this gives 833MW. This takes no account of the fact that schools may also have vacant land available for ground mount systems.

Electricity consumption for schools is also drawn from Pitt and Sherry's 2012 study.

Supermarkets

Pitt and Sherry's 2012 publication, *Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia* indicates that the floor area of Victorian supermarkets is close to 2.3 million square metres. Assuming an average of one storey translates that to the same square metres of roof space. Using the solar panel efficiency benchmark of 0.21 kilowatts per square metre with 50% of roof space suitable suggests enough space to support 239 megawatts. This could be considered quite conservative given it ignores the fact that supermarkets also often have extensive land allocated to car parking where solar can be installed overhead providing a dual function as shading and rain cover.

Electricity consumption for supermarkets is also drawn from Pitt and Sherry's 2012 commercial buildings study.

Shopping centres

The same approach and sources were applied to shopping centres as employed for supermarkets and schools described above, but with floor area divided by 2 storeys to get roof space. This ignores the fact that shopping centres often also have extensive land allocated to car parking where solar can be installed overhead providing a dual function as shading and rain cover.

Universities and TAFEs

The same approach and sources were applied to universities and TAFEs as employed for supermarkets and schools described above, but with the floor area divided by 3 storeys to obtain roof space. The fact these facilities often have other idle land or car parking that could also host solar has not been considered.

Government and public buildings

The same approach and sources were applied to public buildings, law courts and correctional centres as employed for supermarkets and schools described above, but with the floor area of public buildings, law courts and correctional centres divided by 2 or 3 storeys to estimate roof space.

Hospitals

The same approach and sources were applied to hospitals as employed for supermarkets and schools described above, but with the floor area of divided by 4 storeys to estimate roof space.

Aged Care

According to data from the Australian Institute of Health and Welfare there are 53,277 residential aged care facilities in Victoria with more than 40,000 of them housing 60 or more residents. Assuming 20 square metres of floor space for each resident covering sleeping, bathrooms, kitchen and living areas gives a total area of 800,000 square metres. Assuming this is almost entirely single storey and allowing for just half of it to be utilised would accommodate 84 MW of solar.

Offices

Electricity consumption sourced from Pitt and Sherry.

To determine available roof space to accommodate solar two sources were employed. To determine suitable roof space for offices outside the Melbourne CBD a 2018 publication authored by AECOM and published by Sustainability Victoria - *The Next Wave Refresh – Retrofitting Victoria's Commercial Buildings* - indicates that offices greater than 1000m2 (the type of size that could host a 100kW+ system) outside the CBD have a floor area of close to 1.2 million square metres. Assuming an average of 2 storeys and similar assumptions as applied to supermarkets suggest space to support about 62 MW of solar.

For the CBD, the Australian Photovoltaic Institute or APVI has undertaken quite detailed spatial analysis of this area and surrounding areas within the City of Melbourne area to assess how much solar could be accommodated -*Spatial Analysis of Solar Potential in Melbourne*. Within the main CBD, CBD north area, Docklands and along the area bordering St Kilda Road and the eastern side of Albert Park – which are dominated by office space – it estimated 107.8 MW could be viably installed. Assuming that 70% of this suitable space is offices equates to 75.46MW.

Hotels-Accommodation-Entertainment

Data on sectors outside of hotels is not readily obtainable so we have simply listed electricity consumption for hotels sourced from Pitt and Sherry.

For available space to host a solar system we used the same sources as for offices.

The *Next Wave Refresh* publication provides data breaking down CO2 emissions by accommodation facilities of different sizes in different regions. Facilities with greater than 1000 square metres of floor space lying outside the City of Melbourne made up 15% of emissions. Assuming they also make up 15% of total accommodation floor stock at an average of 3 storeys suggests enough space to host 12.45MW of solar.

As noted under offices the APVI identified suitable roofspace to host solar equal to 107.8MW within the CBD, CBD Nth Docklands and along the St Kilda Road. We'd very roughly expect that 20% of this or 21.56MW would be on a mixture of hotels and apartment buildings. The APVI also identified suitable roofspace within the sports and entertainment district along the Yarra that could host 30.8MW of solar.

Non-commercial sector buildings involved in manufacturing, food processing and cold storage

Data on electricity consumption within the sectors of manufacturing and food processing in Victoria has been obtained from the Australian Government Department of the Environment and Energy's publication, *Australian Energy Statistics*, published in August 2018.

However we lack comprehensive data on the nature of the building stock occupied by the businesses within these market segments that might allow us to readily calculate their total available space to host solar systems.

Nonetheless drawing on what was found in the APVI assessment of solar hosting capacity in the City of Melbourne and comparing this with major industrial zones in Melbourne indicates that the high-end projections for solar installations could be comfortably accommodated without encountering significant roof space limits.

The APVI study used a range of sophisticated tools to assess the complex topographical profile of roof space within this area. The study took into account things like equipment on roofs that had to be built around and also the need to minimise their shadowing of panels, roof tilt that might reduce or enhance the amount of solar radiation and affect the feasibility of certain panel layouts and also shading effects from surrounding buildings. In spite of the very complex nature of roofspace within Melbourne's CBD and substantial shadowing affecting many of the buildings, the study estimated CBD buildings could host almost 35MW of solar capacity. According to the analysis these systems could be expected to achieve an average capacity factor of 12.9%, which is not all that far off what is generally expected from a standard residential solar installation in Melbourne. Furthermore, this study assumed a standard module size (dimensions of around 1m by 1.6m) would deliver 250 watts when modules commonly used in the Australian market today exceed 300 watts.

If we take that area of Melbourne which could support 35MW in spite of its complex roof structures and overshadowing buildings, and then lay it out next to a number of Melbourne's major industrial zones at the same scale, it becomes readily apparent just how large an amount of solar capacity could be accommodated by facilities operating in these industrial sites.

Figure 4-6 overlays a picture of the Melbourne CBD in the bottom right corner (surrounded by a red border) relative to Dandenong South's Industrial Zone - all at the same scale. Figure 4-7 provides that same contrast for the Cambellfield/Somerton industrial zone and then Figure 4-8 illustrates the CBD's size relative to the Laverton North industrial zone. In all three industrial zones their existing building roof space is several times what is situated in the CBD.

Figure 4-6 Melbourne's CBD (bottom right) relative to Dandenong South's industrial area

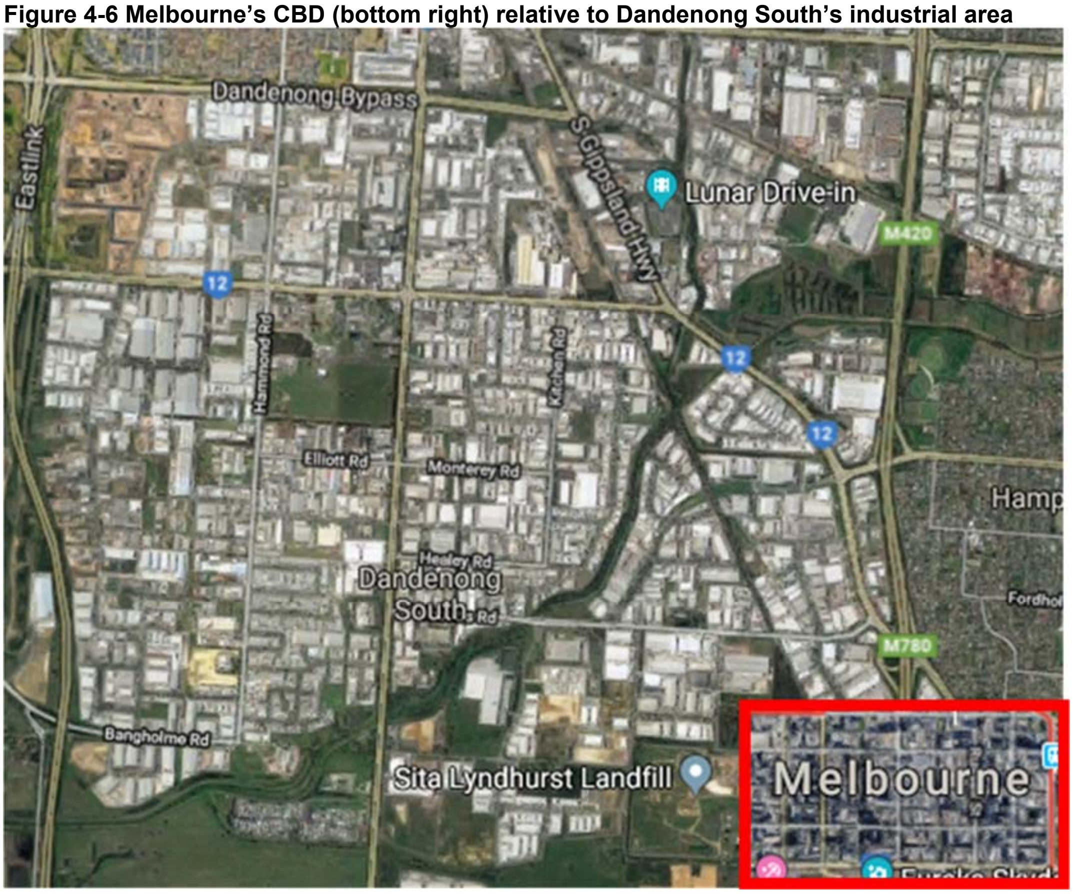


Figure 4-7 Melbourne's CBD (top right) relative to the Cambellfield-Somerton industrial area

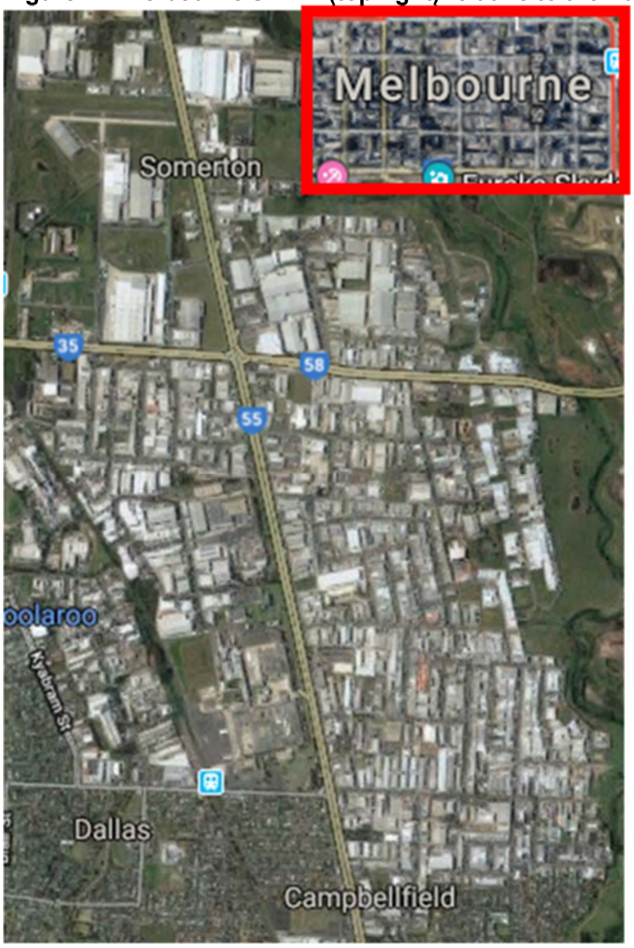
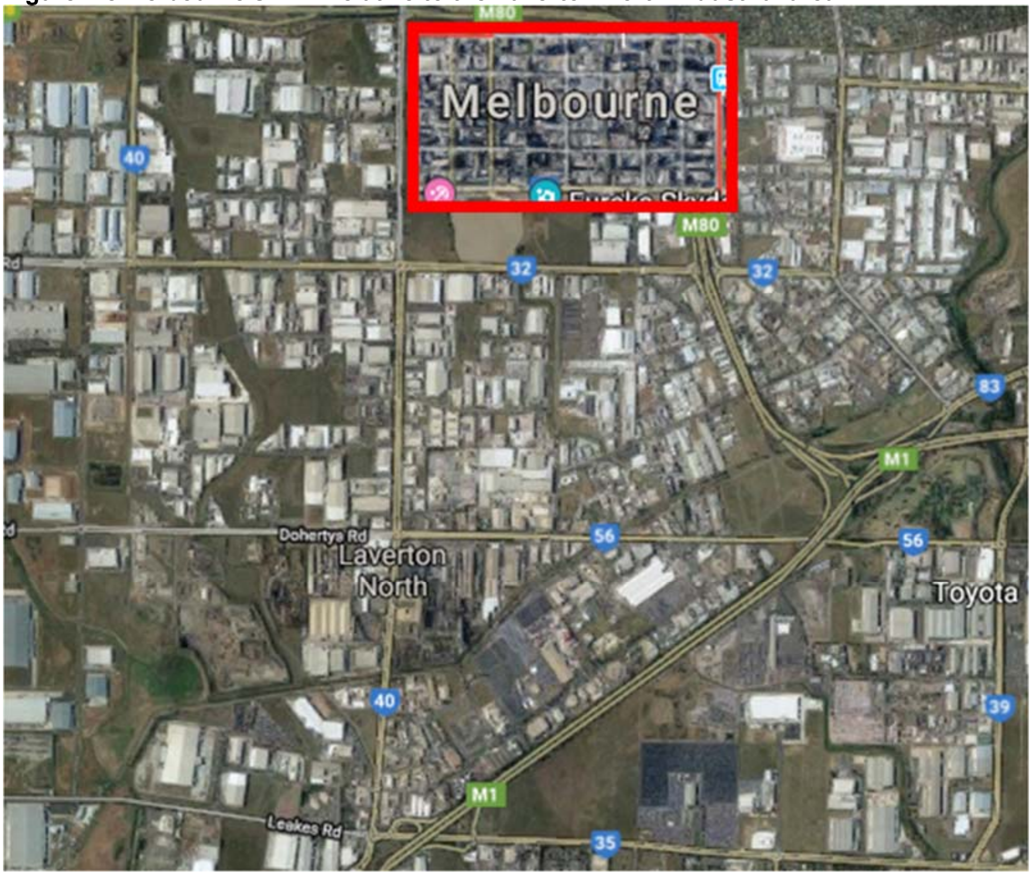


Figure 4-8 Melbourne's CBD relative to the Laverton North industrial area



Another aspect worth noting is the size of each building's roof in these industrial zones relative to those in the Melbourne CBD. Buildings within these industrial zones clearly face less challenges with overshadowing and simpler system layouts with less roof obstructions to work around.

If Melbourne's CBD can support 35MW then these three industrial zones alone could probably accommodate the 390MW that the model projects would be installed in manufacturing businesses across the entirety of Victoria if VEEC prices were to reach high prices sustained over an extended period of time. But in the end, the area of roof space that these market segments have available is far greater than just these three industrial zones.