Sustainable Built Environment National Research Centre AUSTRALIA

Exploring Approaches to Harness Onsite Renewable Energy Options in Industrial and Commercial Precincts

Final Industry Report

Project 1.24b - Zero Carbon Airport Precincts

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Preface

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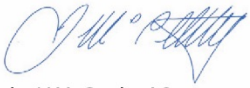

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Contents

EXECUTIVE SUMMARY

While the residential sector has seen a strong and rapid uptake of photovoltaic panels on rooftops in the last decade, especially in Australia, the uptake has been much slower on commercial and industrial buildings and estates. This research focuses on how commercial and industrial precincts fitted with an embedded electricity network can cost-effectively transition to onsite renewable energy generation and storage, based on findings from a case study of Perth Airport supported by renewable energy specialists Balance Utility Solutions. The key findings of the research project are summarised in this report, namely:

- *Customer-owned rooftop solar can be an opportunity for network operators*: Rather than seeing customers' intentions to install rooftop solar as a threat to the energy business, it can be seen as the basis for a number of new economic benefits for the network operator.

- *Customer-owned rooftop solar can be an opportunity for precinct tenants*: As would be expected, rooftop solar presents benefits to precinct tenants, however there are a range of benefits that are often overlooked that can provide greater service to tenants.

- *Customer-owned rooftop solar can be an opportunity for the precinct owner*: Rooftop solar is an opportunity for the property business as clean, affordable and flexible energy supply is likely to retain existing premium tenants, attract new ones and support land development on the precinct.

- *Rooftop solar needs to be managed centrally using precinct-scale storage*: At low levels of solar penetration, the impacts can be manageable with costs passed on, however when higher levels are reached, this will present risks for the network if not properly managed.

- *Customers are becoming more energy savvy and want to be more involved*: Energy retailers are the primary contact with customers, however given customers now have the ability and incentive to generate electricity, network operators must establish direct engagement.

- *Embedded electricity network operators need to offer new services or outsource them*: The role of the electricity network operator of an industrial precinct needs to be revised to offer a range of new services, many of which are being asked for by energy-savvy customers and tenants.

Based on these lessons, the key recommendations from the research can be summarised as:

- Focus on network optimisation rather than fixate on energy retail,
- Create new governance and customer engagement models sooner than later,
- Precinct tenants installing own solar need to contribute to precinct-scale storage, and
- Design tariffs to reflect the network impact of customers' energy use and generation.

This report provides greater detail on the key lessons and recommendations.

1 INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) identified that of all sectors the industry sector is the one that lags most in terms of efforts to reduce GHG emissions and in seeking low emissions energy alternatives (IPCC, 2014)[1]. This is particularly true in Australia where the installation of solar panels has been dominated by the residential sector, with commercial and industrial buildings lagging behind, as shown in Figure 1. This research project focused on understanding the various factors that have contributed to the slower uptake of solar energy in commercial and industrial buildings in order to find acceleration leverage points.

A key distinction with typical residential installations is that industrial and commercial businesses often gather in industrial precincts that can have their own electricity distribution network, referred to as an "Embedded Electricity Network" (EEN). This network is typically privately managed and connected to the public grid with the precinct owner owning the infrastructure and an '*Embedded Network Operator*' managing the operation of the network.

[1] IPCC (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp 151.

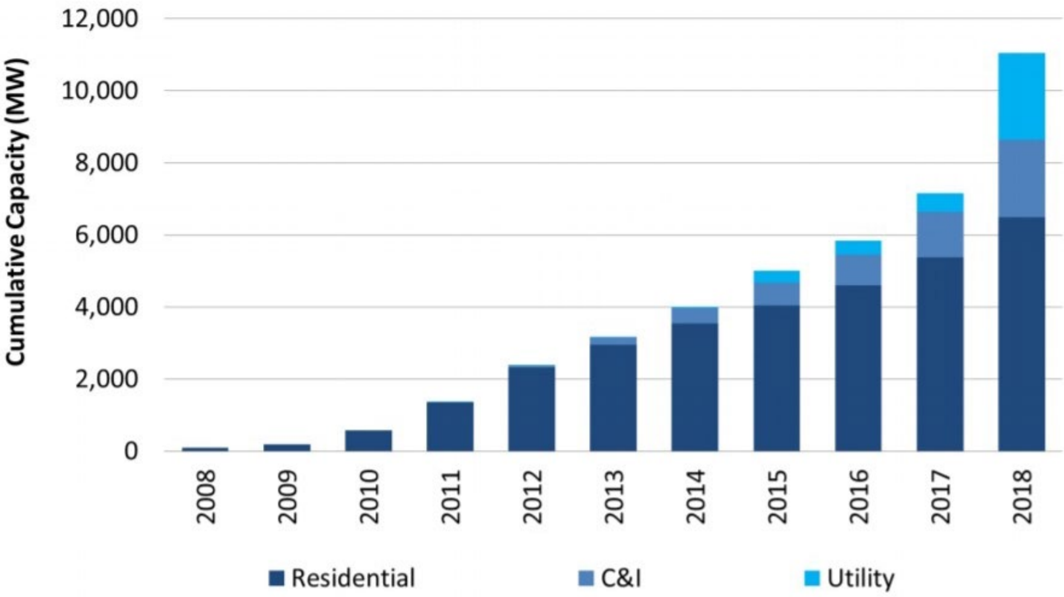

Figure 1: Cumulative Australian photovoltaic installations by category, 2008-2018

Source: 2018 AIPV Annual Report, 2019[2]

The embedded electricity network of commercial and industrial precincts configuration presents a unique research opportunity given that these embedded energy networks:

1. Are often subject to different legislative controls compared with residential developments.
2. Provide a contained and somewhat simplified version of the public grid at a meaningful scale (demand from various customers is aggregated and managed across the network, and often have significant rooftop space).
3. Are privately operated and hence have fewer barriers to innovation and commercialisation compared with the public grid.[3]
4. Typically have low levels of solar installations and still have a chance to develop effective business models to achieve multiple benefits.
5. Provide the potential to operate in the event of a grid black-out with sufficient storage, referred to as being in 'Island Mode'.
6. Provide scalable outcomes that can inform larger estates and even the public grid.

In particular, the fact that, on the whole, industrial precincts have yet to settle on a business model that maximises benefits of solar installations means that there is a pivotal role for industry-led research. For instance, a typical approach is for the owner of the network to discourage, and even block its tenants from installing solar panels in order to protect retail margins of the embedded network operator on selling electricity to its embedded energy customers. In this case, if solar is introduced, then it is typically owned by the embedded

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[2] Egan, R. (2018) National survey report of PV power applications in Australia. *Australian PV Institute*

[3] Tayal, D., and Rauland, V. (2017) Future business models for Western Australian electricity utilities. *Sustainable Energy Technologies and Assessments, 19*, 59-69.

network operator and installed in a central location where it is used to offset part of the electricity imported into the precinct from the public grid. This approach is tailored to the owner's advantage, with little benefits for the tenants (e.g. minor reduction of energy bills, access to slightly cleaner electricity).

This particular approach is a key reason for the slow uptake of solar in industrial and commercial precincts, however, this is changing with tenants of such precincts becoming more and more interested in cutting energy costs and being directly involved in energy generation which is now causing tensions with precinct owners and embedded network managers.[4] In some states in Australia, tenants have been given the right to source electricity from a third-party retailer, sidestepping the monopoly once held by Embedded Network Operator (such as the Power of Choice Reform in 2017[5]). So not only are tenants putting pressure on Embedded Network Operators to allow them to install more solar infrastructure, there are moves to allow them to source electricity directly from third party retailers, with both outcomes having a negative impact on the energy-related business of the precinct.

Hence the research project sought to investigate innovative business, ownership and governance models that could enable the accelerated uptake of onsite solar energy generation in embedded electricity networks while delivering multiple outcomes. The main outcomes considered included:

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[4] Hess, D. (2018) Energy democracy and social movements: A multi-coalition perspective on the politics of sustainability transitions. *Energy research & social science*, *40*, 177-189.
[5] AEMO (2017) Power of Choice. Guide to Embedded Networks. Australian Energy Market Operator.

1. Economic outcomes such as direct financial benefits for the precinct owner, the embedded network operator, and the tenants.
2. Environmental outcomes such as the reduction of greenhouse gas emission and other air pollution by reducing the amount of electricity generated from fossil fuels.
3. Social outcomes such as equity of access to clean energy and enhanced involvement of energy customers to enable better outcomes for all parties, referred to as 'Energy Democracy'[6].

With the goal of the research clear, the task was to design an appropriate approach to accelerate the transition to onsite solar energy generation on commercial and industrial precincts in a manner that provided multiple benefits. The process included considering questions such as: Who would own and maintain the solar energy equipment? How would the energy be metered and charged? What would be the role of energy storage, how would it work, and how would it be financed? How would the overall system be managed? - and importantly - what would be the tangible benefits for each of the parties involved? This report presents a summary of the key findings and introduces the 'Industrial Village Energy Approach' which is intended to respond to these and other important questions and inform efforts to increase the uptake of solar energy in precincts.

In order to represent the various options for ownership and configuration of solar systems that could be installed on industrial and commercial precincts, the following configurations were selected:

1. A customer-owned distributed solar system.
2. A community-owned centralised solar system.
3. A third-party-owned distributed solar system.
4. A third-party-owned centralised solar system.
5. A utility-owned centralised solar system.
6. A utility-owned distributed solar system.

Here the customer is a tenant of the precinct, the community includes both tenants and the Embedded Network Operator, and a third party is a service provider. The term 'distributed' is used for generation installed behind the customer meter and feeding that customer before exporting its excess energy to the network, such as rooftop solar installed on customers' buildings. The term 'centralised' is used for generation connected directly to the network (in-front of customer meters) hence feeding several customers, such as a solar array installed on the grounds of the precinct.

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[6] Van Veelen, B. (2018) Negotiating energy democracy in practice: Governance processes in community energy projects. *Environmental Politics*, *27*(4), 644-665.

The analysis of each of the options included a study of academic literature to inform consideration of strengths and weaknesses from the perspective of the Embedded Network Operator and the energy customers. The research concluded that the option of 'Customer-owned distributed solar' was most beneficial overall. However, there was one more element to consider as increasing the level of solar energy (that creates a variable volume of electricity depending on the weather) on the network creates challenges to stability and reliability.[7] Hence onsite energy storage is needed to help balance demand and supply by charging and discharging accordingly, allowing for better utilisation of solar energy.

In particular, there are five main services that onsite storage can provide:[8]

1. *Solar Shifting*: This is when excess solar energy that is generated onsite is stored for later use. For instance, this is beneficial as energy can be stored and used on-demand at night or at times of peak prices.[9]

2. *Peak Shaving*: This is when stored energy is used specifically during peak demand times to reduce the amount of energy imported from the public grid when the energy price is high. This is important as it not only reduces the amount of energy imported from the grid but can also reduce the demand charge and offset capital costs to increase the size of the grid connection as the precinct's energy demand grows.[10]

[7] Georgilakis, P. (2008) Technical challenges associated with the integration of wind power into power systems. *Renewable and Sustainable Energy Reviews*, *12*(3), 852-863.
[8] Akbari, H., Browne, M. C., Ortega, A., Huang, M. J., Hewitt, N. J., Norton, B., and McCormack, S. J. (2018) Efficient energy storage technologies for photovoltaic systems. *Solar Energy*, *192*, 144-168.
[9] Dufo-López, R., and Bernal-Agustín, J. (2015) Techno-economic analysis of grid-connected battery storage. *Energy Conversion and Management*, *91*, 394-404.
[10] Sardi, J., Mithulananthan, N., Gallagher, M., and Hung, D. (2017) Multiple community energy storage planning in distribution networks using a cost-benefit analysis. *Applied energy*, *190*, 453-463.

3. *Solar Smoothing*: This is when storage is appropriately used to smooth out short term variations in solar generation (e.g. due to scattered clouds) and the consequent impact on voltage and frequency of the electricity on the network.[11]
4. *Back-up Power*: This is when the energy storage, with or without the help of onsite energy generation, powers the embedded network during a blackout or if the grid connection fails. For economic reasons linked to the size and cost of the energy storage, this back-up power is typically reserved for critical loads and designed to last long enough to either restore power or shut down activities properly.
5. *Ancillary Services*: This is when storage is used to absorb quick variations of demand on the distribution network by rapidly storing or releasing energy as needed, effectively replacing both a load and a generator. This service helps maintain the frequency and voltage within the set limits and ensure the quality of the supply.

Though these roles are distinct and ideally energy storage should be dedicated to just one role, it is often seen in the literature that an energy storage system delivers more savings when designed and used for more than one function.[12] Based on a detailed review including consideration of the multiple services that can be provided (as above), the types of battery technology commercially available (including Lithium-Ion Batteries, Advanced Lead-Acid Batteries, Sodium-Sulphur Batteries, and Flow Batteries), and options for configuration and ownership models, it was decided that for the purpose of the research a Lithium-Ion battery energy storage system with the primary role of solar smoothing would be investigated.

The findings also suggested that it was preferable to have tenants who installed solar panels contribute to the cost of the battery system and that is should be operated by the embedded network operator. A further benefit of installing storage capacity is that it increases the amount of solar generation that can occur onsite without causing issues for the network, allowing greater access to tenants rather than just being on a first come first connected basis (fulfilling the social outcome of equity of access to clean energy). Hence the option chosen as the basis for the 'Industrial Village Energy Approach' was '*Customer-owned distributed solar*' with operator-managed and customer contributed battery storage, i.e. '*Customer-owned distributed solar with storage*'.

[11] Thorbergsson, E., Knap, V., Swierczynski, M., Stroe, D., and Teodorescu, R. (2013) Primary frequency regulation with Li-ion battery based energy storage system-evaluation and comparison of different control strategies. In Intelec 2013; 35th International Telecommunications Energy Conference, *Smart Power And Efficiency* (pp. 1-6).
[12] Shi, Y., Xu, B., Wang, D., and Zhang, B. (2017) Using battery storage for peak shaving and frequency regulation: Joint optimization for superlinear gains. *IEEE Transactions on Power Systems*, 33(3), 2882-2894.

2 LESSONS LEARNED AND PRACTICAL SOLUTIONS

The research team from Curtin University worked closely with Adjunct Associate Professor Rod Hayes and Perry Ward from Balance Services Group to apply the 'Balance Energy Business Analysis Tool' to explore a range of models and scenarios in order to consider the implications of rooftop solar in industrial precincts. The following part outlines the key findings.

– Customer-owned rooftop solar can be an opportunity for network operators

The research involved the investigation of several simulations in order to assess how the installation of solar PV panels on the rooftop of buildings occupied by tenants in an industrial precinct would affect the energy network operator financially. On the one hand, as electricity generated by solar PV on these buildings is effectively 'behind the meter' it reduces the amount of electricity that tenants need to purchase from the network operator, reducing retail revenue. On the other hand, at the precinct scale, this reduced demand will lead to a reduction in operating costs for the network operator, such as grid charges, and may even allow the deferral of expensive network augmentation. Moreover, these benefits to the network operator do not involve the latter to take a risk in capital investment since the solar installations (and energy storage) would be financed by the tenants. All in all, the research findings suggest that the net result levelled over a 10-year period amounted to in the order of a 10 percent loss for the energy network operator solar compared to a business-as-usual scenario where PV would not be introduced. However, this did not account for benefits such as attracting premium tenants to the precinct, reducing greenhouse gas emissions and allowing for some form of storage offering.

– Customer-owned rooftop solar can be an opportunity for precinct tenants

The research findings suggest that customer-owned rooftop solar could bring multiple benefits to the tenants. An obvious benefit is the reduction in energy bills, however there is a range of benefits that are often overlooked, such as supply flexibility. For example, rooftop solar can allow tenants to exceed the maximum demand possible from the embedded network by topping it up with behind-the-meter solar energy at specific points of time. This may allow the tenant to run additional equipment on their premises during peak demand times, or to charge electric equipment, batteries or vehicles without drawing on the embedded network supply and hence avoiding costly connection upgrades.

– Customer-owned rooftop solar can be an opportunity for the property business

The research findings suggest that rooftop solar can be an opportunity for the property business as the clean, affordable and flexible energy supply is likely to retain existing tenants and attract premium tenants and hence support land development on the precinct. Unlike a centralised power plant, rooftop solar is a form of generation that can grow organically with the load (at the precinct-scale). This means that while each new building brings a new load, if fitted with rooftop solar, the building can also bring a new generation that is located close to the load (at the tenant-scale). This co-location of generation and use can contribute to a better distribution of overall load on the embedded network, reducing the risk of congestion and eventually limiting or deferring the need for costly upgrades. Hence the property business is now linked to the energy business in new ways that can be mutually beneficial, rather than new buildings just increasing the load that the embedded network needs to meet.

– Rooftop solar needs to be managed centrally using precinct-scale storage

The *ad hoc* uptake of rooftop solar on the public electricity grid in many cities in Australia has delivered financial benefits to those that have installed them on their homes and businesses, but it has also caused issues for the grid due to the variable and distributed nature of the generation that is not easy for the network operator to accommodate. For this reason, as the level of rooftop solar increased, this then called for increased maintenance and costly upgrades of some of the components of the distribution grid, such as the tap changers of transformers that wear out from additional use. At low levels of solar penetration, this can be manageable with these costs being passed on to customers, however if, and likely when, higher levels are reached this could quickly turn into a threat for the distribution network if not properly managed. This is due to two main issues:

i. Local generation can cause energy to flow back through the network through components that were not designed for bi-directional flow. This could be managed centrally by the energy network operator, allowing the rooftop solar generation to be curtailed when needed, and

ii. A typical electricity grid is designed with supply to follow demand and to allow for predictable variability in demand that is informed by historic demand profiles that suggest what the demand is likely to be at given points in the day. Given rooftop solar is a supply with unpredictable variability, the system can be stressed beyond the anticipated levels with little to no warning and crash into a black-out.

In order to compensate for both excess electricity (that would otherwise flow back into the grid causing issues) and variability in supply, a number of storage options can be used, typically chemical storage in batteries. Such storage would be used to both quickly absorb excess energy during a burst of generation and quickly release energy during a sudden drop in generation while helping to balance out variations in energy demand across the network. It is likely that precinct or community-scale energy storage options will quickly become a common element of electricity grids in the coming decade for that very reason.

– Customers are becoming more energy savvy and want to be more involved

Up until recently, it was normal for the energy retailer to be the primary, if not only, contact with commercial customers, with the network operator playing a somewhat invisible support role. However, given customers now have the power, and the incentive, to generate their own electricity on their premises, and this behind-the-meter variable generation can significantly affect the network, it is essential for network operators to establish direct contact with the customers, especially in embedded networks. This presents a new model for customer engagement that can allow embedded network operators to reduce expenditures while offering customers new value-adding services. This collaboration is also in the interest of the customers as network costs can make up an important portion of their electricity bill, and some of the most efficient network costs reduction programs rely on customer engagement and participation.

Customers have been shifting from passive end-users to active users and prosumers, and their expectations for involvement have raised. However, if customers are to be more involved in their energy supply and reap the rewards, they will also need to be responsible for the pressure they put on the network. Simply letting customers install rooftop solar and increasing customer engagement is not enough to achieve the sharing of the risks and the rewards between the network operator and customers. A deeper, more complex and long-term collaboration needs to be built in order to balance interests, and this means revamping the governance of the energy business to create opportunities for two-way communication and increased participation of the customers in the decision-making process.

– Embedded energy network operators need to offer new services or outsource them

The role of the energy network operator of an industrial precinct needs to be revised to offer a range of new services, many of which are now being asked for by energy-savvy customers and tenants. These services include accommodating variable distributed generation (such as rooftop solar), providing for new loads (such as charging electric vehicles and equipment) and providing precinct-level storage and load management. In addition to these services, as retail competition is introduced around the country, embedded network operators will need to diversify their source of revenue and decouple it from the retail of energy. This can be achieved not only by reinforcing their core activities around distribution and quality of the supply, but also by developing additional new services. These services may include facilitating relations between external energy suppliers and precinct tenants, so as not to be completely shut out. However, this should be balanced by considering which energy-related activities are suitable to be put to the market (such as generation, storage, and retailing) and which ones to keep in-house. Each precinct will have a different set of considerations and it will be important to the energy business, and also the property business as mentioned above, that a well informed and effective strategy is developed to transition to future energy network operations.

3 RECOMMENDATIONS

Based on the research the following set of recommendations have been developed to inform the transition towards greater uptake of rooftop solar in industrial and commercial precincts in Australia.

– Focus on network optimisation rather than fixate on energy retail

Though energy retail is often a profitable business for an embedded network operator, in the long term the research findings suggest that network operators should focus on strengthening their position as central operator and develop services (and related revenues) around the central role of distribution and energy supply services, with the goal to decouple revenues from the sale of electricity. As a commercial organisation, the network operator is often driven by short term profit results to be reported in annual reports. However, the energy distribution business is a capital intensive one where long-term planning is key, even more today with fast-changing technology and changing customer expectations. Distribution services have been working in the shadow of energy retail for a long time, but they are now brought to light as their duty to maintain stability and quality of the supply is challenged by new load profiles and variable and distributed generations. To successfully anticipate this transition, the findings of the research suggest that network operators become active players, engage directly with the network users and invest in 'active assets' to support the network and complement its core services.

– Create new governance and customer engagement models sooner than later

The traditional governance model for energy utilities no longer holds, especially for embedded networks, and those that quickly transition to a model based on collaboration between the network operator and the customers will reap the rewards in the coming decades. The sharing of effort, risks and rewards between the network operator and customers is an ongoing process based on a balance of interest that requires a new model of governance with a new decision process. Such a model is also necessary to clarify and reinforce the new roles and responsibilities of each party, and above all, to ensure the participation is driven by the greater good of the precinct's energy system. Indeed, by aiming at achieving long-term mutual benefits, the energy supply can be kept affordable and flexible for the customers, and manageable and profitable for the network operator. The findings of the research suggest that an appropriate governance model could be similar to that of a village. In this approach, the network operator would take the role of the 'Mayor', who would work with the energy customers, the villagers, to explore the situation, consider its expected evolution, and understand the trade-offs of each option.

– Precinct tenants installing own solar need to contribute to precinct-scale storage

As previously explained, customer-owned rooftop solar often starts as an opportunity for the network operator to reduce grid charges and mitigate network congestion. However, as the penetration level increases, it can quickly become a threat to energy supply quality which, if not handled properly, can be a costly challenge for the network operator. Hence, it is essential to anticipate increased uptake of rooftop solar rather than wait for the penetration levels to threaten the energy supply. The research findings suggest that the best way to go about this for embedded networks is for the network operator to own and operate the precinct storage, typically a battery, and require tenants wishing to install rooftop solar to make a financial contribution to the cost of the storage. Unlike other network assets, a network-scale battery system can be modular and hence easily expandable to respond to increasing levels of rooftop solar on the network. Moreover, the storage system capacity could also grow to offer customers cost-effective storage for more profitable uses such as peak load shaving and load shifting. Designing the storage system effectively so it delivers more than just network smoothing will assist network operators to decouple revenue from the sale of electricity by using the system as the basis for a suite of other services.

– Design tariffs to reflect the network impact of customers' energy use and generation

As previously suggested, customers should be held accountable to the negative pressure they may place on the embedded network, however in order for the system to work it needs to go both ways. This means that customers need to be able to be rewarded for energy-related practices and behaviours that support the network. Therefore, it is necessary to have a direct link between the customers' use of the network and the charges they incur. Inspired by the research of Prof. Perez-Arriaga[13] the research findings suggest that the network operator should adopt a tariff system based on the principle of cost-causality. This begins with thorough modelling of the network to identify key cost factors and investigate the correlation between these costs and customer location and network use. This modelling then informs the design of tariffs that encourage customers to make energy-related decisions that support the network (such as the orientation of rooftop solar, energy consumption profiles, and vehicle charging times) by tying the pressure they place on the network to their energy bill.

[13] Perez-Arriaga, I. and Bharatkumar, A. (2016) A framework for redesigning distribution network use of system charges under high penetration of distributed energy resources: New principles for new problems. MIT CEEPR Working Paper, 2014/006.

4 CONCLUSIONS

It is clear that through advances in small scale renewable energy generation and storage, the energy sector has changed forever, and more specifically that a centralised energy system is no longer suited as the basis for a city or a nation's energy supply system. The key conclusions of the research project are:

- A ‘do-nothing’ approach to the consideration of on-site renewable energy generation in industrial precincts is unwise for economic, environmental, and social reasons, so the question is not *if* but *how* to best introduce renewables.
- Although the initial focus is often on energy business, it is wise to include and embed property considerations in the business case as there are mutually reinforcing benefits, such as attracting premium tenants.
- Despite initial concerns, the findings of the research suggest that allowing industrial precinct tenants to generate their own renewable onsite energy may not affect energy-related revenues significantly. However, careful consideration must be made of how this is undertaken.
- The use of batteries to smooth energy supply provides an enabler to maximise the value of solar photovoltaic energy generation and increase network utilisation and can be the basis of a suite of new services that allow decoupling of revenue from energy sales.

The main conclusion to the analysis is that a do-nothing, or business-as-usual, position is not a viable long-term option as whatever option is taken to protect this position will result in more pressure on margins in the energy business and negative impact on the property business. The findings of the project suggest that embedded network operators have the opportunity to adapt their energy business to align to tenants’ expectations while improving the value proposition of the network. This approach is also likely to enhance property development interests by assisting to attract premium tenants with above-standard energy supply (equity, affordability, reliability and flexibility).

The configuration of customer-financed and owned rooftop solar appears to be the best option for embedded networks to transition to solar, supported by a precinct-scale energy storage system that is used initially for smoothing purposes and is network operator owned and customer-financed. Indeed, unlike most infrastructure assets which are under-utilised much of their life, energy storage systems are modular and can be gradually scaled. Moreover, they can also be used for other economic and value-creating purposes.

5 FURTHER RESEARCH

Although this research project achieved its goals and provided significant insight into the best approaches to harness renewable energy in industrial and commercial precincts, there are still areas that need further investigation, with the following three recommended for further research:

- *Commerciality*: Set-up of contracts, tariffs and rules that keep the energy business agile and ready for change, such as accommodating new loads from electric vehicle charging, the introduction of retail competition, or to capture new energy market opportunities.
- *Business Models*: Though rooftop solar and battery technology is well understood and utilised, the use of this technology to open up new business opportunities for embedded network operators is yet to be fully explored and implemented.
- *Customer engagement*: This part of the challenge should not be under-estimated as it is key to a successful and durable transition to solar on precincts and needs to be explored on a precinct by precinct basis until acceptable standards can be developed.

An extension of this research project could concentrate on these three challenges and test and calibrate them on a demonstration project using a node on the embedded energy network with a few selected customers.

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