Cost Benefit Analysis for Digital Network Implementation

VPN (CitiPower & Powercor) and United Energy

CBA Digital Network VPN & UE

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Contents

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Executive Summary

Large changes in the way electricity is generated and consumed impact management of the low voltage (LV) network. In particular residential and small commercial customers are forecast to adopt an increasing number of technologies which could impact on their usage and ability to generate power, such as rooftop solar, electric vehicles, and smart demand side technologies, rendering predictive demand profiles obsolete. Without controls, this uptake could overload the customer's nominal supply capacity leading to a supply outage, shutting down their own and nearby rooftop PV generators, or worse, result in the network becoming unreliable, unsafe and unstable.

There is therefore a need for more active management of VPN and UE’s LV networks to ensure the networks can handle customers' needs, and customers can harvest the benefits of their investments in 'behind the meter' technologies.

As a result, VPN and UE are considering investing in new smart grid capabilities that will provide greater visibility of the LV network through analytics that will provide several customer and network benefits. The capabilities include implementing new data and analytics platforms as well as rolling out network monitoring devices to targeted additional locations. These capabilities are referred to as the ‘Digital Network Framework’ and are the main subject of this report.

Jacobs developed a Digital Network business case for VPN and UE investigating two investment options. Each investment option includes a set of pre-defined Digital Network platforms and devices with associated benefits that can be achieved when implemented.

The following main benefit categories are included in the business case:

- Benefits from reduction of non-technical losses;
- Benefits from cost reflective pricing;
- Electrical vehicle charging optimisation benefits; and
- Customer load monitoring and optimisation benefits.

The two implementation options are described below:

- Option 1 - utilising only currently deployed AMI (residential) in the VPN and UE networks
- Option 2 - deploys additional network measuring devices for contestable sites and a significant number of critical distribution substations.

It was found that the extra coverage will deliver greater coverage and increase effectiveness of the Digital Network Framework increasing the benefits for investment Option 2, resulting in the highest Net Present Value of the two options compared for both VPN and UE.

Table 1 includes the business case results for Option 2 with a Net Present Value for VPN of $141 million and an NPV for UE of $89 million.

Table 1: NPV Results for Option 2 – UE and VPN, excluding Opex ($DEC2018)

Option Results	VPN $m.	UE $m.
PV value of costs	44	37
PV value of benefits	185	126
NPV of costs and benefits at 2.75% real WACC	141	89
Benefit-cost ratio (NPV)	4.21	3.45
IRR	30.6%	25.2%

Glossary

3/4G	Third/ Fourth Generation Mobile Network
AEMO	Australian Energy Market Operator
ADMS	Advanced Distribution Management System
AEMC	Australian Energy Market Commission
AMI	Advanced Metering Infrastructure
BCR	Benefit Cost Ratio
BEV	Battery Electric Vehicle
Capex	Capital Expenditures
CBA	Cost Benefit Analysis
DC	Direct Connect
DER	Distributed Energy Resources
DNF	Digital Network Framework - IT platforms including network monitoring devices, algorithms, data analytics, initiatives and use cases.
DNSP	Distribution Network Service Provider
GIS	Geographic Information System
HEV	Hybrid Electric Vehicle
IRR	Internal Rate of Return
IoT	Internet of Things
IT	Information Technology
LRMC	Long-Run Marginal Cost
LV	Low Voltage
LVCT	Low Voltage Current Transformer
LV Model	Low Voltage Model – a modelled representation of the characteristics, behaviour and (future) needs of a low voltage distribution network or a part thereof.
NBN	National Broadband Network
NER	National Electricity Rules
NPV	Net Present Value
Opex	Operational Expenditures

PHEV	Plugin Hybrid Electric Vehicle
PLC	Power Line Carrier
PV	Present Value
Repex	Replacement Expenditures
ToU	Time of Use
UE	United Energy
UMS	Unmetered Supplies
VIC	State of Victoria
VPN	Victoria Power Networks – Powercor & CitiPower
Wi-Fi	Wireless Fidelity

1. Introduction

1.1. Project overview

Large changes in the way electricity is generated and consumed impact management of the low voltage (LV) network. Residential and small commercial customers are forecast to adopt an increasing number of technologies including:

- Solar PV being generated, varying over the day and dependent on sun/cloud conditions, which will impact power flows on the network;
- Solar PV being exported to the grid depending on the amount of generation being self-consumed;
- Charging or discharging power being input to and from a battery storage unit;
- Charging power being input to an electric vehicle, fast or trickle charging; and
- Energy being consumed depending on appliances being used, time of day and weather conditions

These could impact on their usage and ability to generate power, rendering predictive demand profiles obsolete. Without controls, this uptake could overload the customer's nominal supply capacity leading to a supply outage, shutting down their own and nearby rooftop PV generators, or worse, result in the network becoming unreliable, unsafe and unstable.

This highlights the need for more active management of VPN and UE's LV networks to ensure the networks can handle customers' needs, and customers can harvest the benefits of their investments in 'behind the meter' technologies.

As a result, VPN and UE are considering investing in new IT capabilities that will provide greater visibility of the LV network through initiatives based on several benefit categories. The IT capabilities include implementing new data platforms and analytics as well as rolling out network monitoring devices to targeted additional locations. These capabilities are referred to as the 'Digital Network Framework', discussed in more detail below.

The aim of this program of works is to optimise network investment (i.e. augmentation), maximise network utilisation and deliver customer benefits in response to known network issues as well as ensuring readiness for the expected customer driven changes to traditional network operations.

1.2. Scope of this assessment

Jacobs' scope of work is to quantify and compare for VPN and UE the potential benefits of the DNF, by investigating two implementation options. Each investment option will include a set of pre-defined Digital Network initiatives with associated benefits that can be achieved when implemented.

The modelling is focussed on the net societal benefit of each investment, considering customers and the network business. Transfer payments between VPN/UE and customers, if any, have not been included as they would represent a cost for VPN and a benefit to customers. An example of a transfer payment is a rebate a consumer receives for their participation in a load reduction program. This payment would be a cost for the network business, but also an equivalent benefit for the customer. The net effect of this rebate is therefore zero and so not counted towards the benefits or costs.

1.3. Structure of the document

This report is structured as follows:

- Section 2 provides an overview of the DNF including the potential high-level benefit areas;
- Section 3 describes two investment options that include the implementation of the DNF, with the second option to include the deployment of additional network devices in the field;

- Section 4 quantifies some of the major benefits identified in section 2 including a description of how potential EV and Customer load control programs could emerge;
- Section 5 outlines the costs associated with the different options including Capex, Opex and replacement costs during the assessment period; and
- Section 6 delivers a comparison of the costs and benefits of the different options.

All monetary values presented in this report are expressed in December 2018 Australian dollars, unless otherwise stated.

2. Digital Network Framework

2.1. Overview of the Digital Network Framework

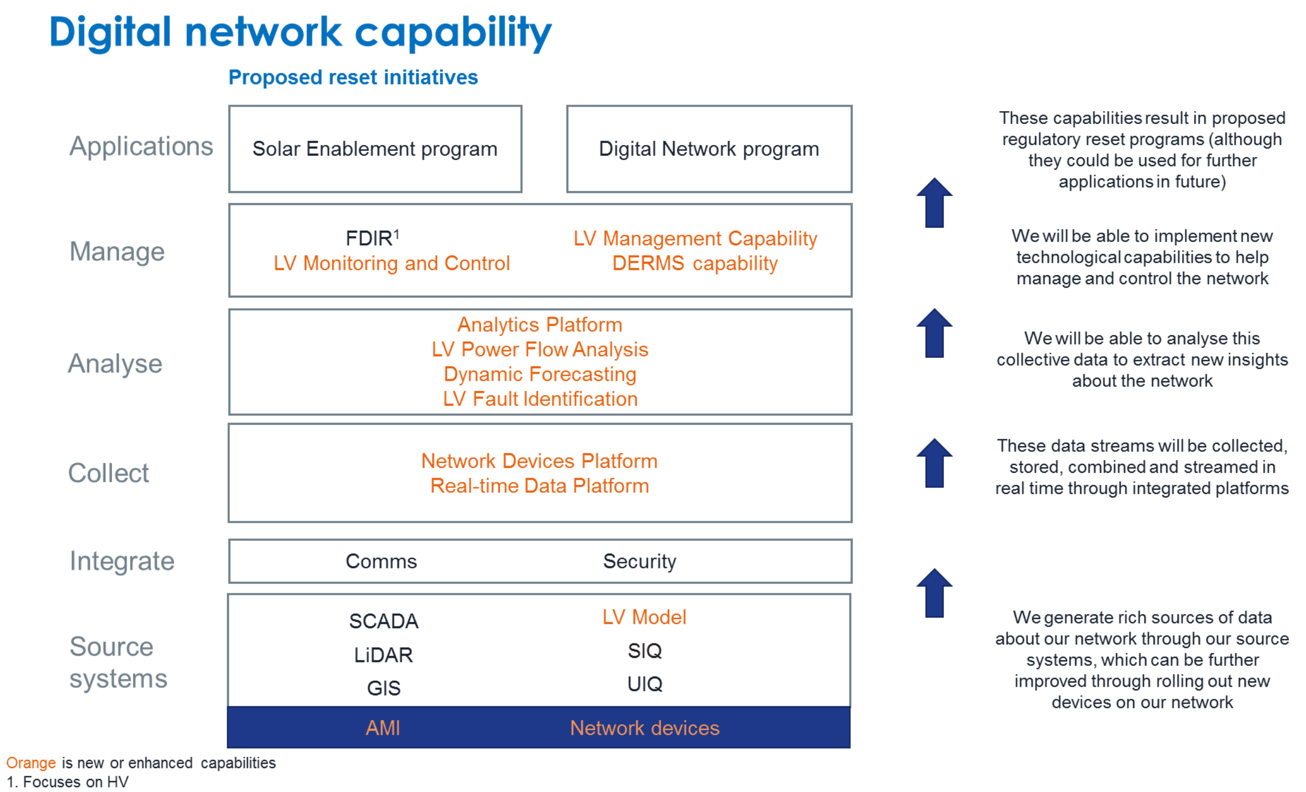
The Digital Network Framework is shown in Figure 1 on the next page.

The complete Digital Network Framework (DNF) consists of:

- Source systems; software and hardware systems that form the foundations of the DNF e.g. SCADA, AMI and other network devices;
- Communications and security to integrate source systems into the DNF;
- Analytics platforms (e.g. LV power flow analysis) for processing data from source systems and provide appropriate information to optimise grid operation and monitoring;
- Management of distribution assets through LV monitoring and control and management of distributed energy resources; and
- Applications such as the Solar Enablement program and the Digital Network program.

Both the Digital Network and Solar Enablement program are main initiatives from VPN and UE for the current regulatory reset. This report provides a detailed cost benefit analysis for the Digital Network program.

Figure 1: The Digital Network Framework



Source: VPN

For the Digital Network program, we have specified several key benefits that we expect will materialise with the implementation of the DNF.

2.2. Digital Network benefit categories

The sections below include a brief description of the identified Digital Network benefit categories and a high-level description of how benefits are realised. Section 4 provides a more detailed description of the benefits and how they are quantified.

2.2.1. Reduction of non-technical losses (1)

Non-technical losses in the distribution network refer to losses not attributable to the distribution of electricity through the wires of the distribution network (i.e. technical losses). Non-technical losses are generally the result of the inaccuracy of measurement of electricity usage by the end-user. This metering inaccuracy can have several reasons, including:

- Inaccurate measuring instruments;
- Electricity usage based on estimations rather than measuring instruments; and
- Illegal usage of electricity by tapping into service connections before the installed metering device (i.e. electricity theft).

The deployment of AMI in Victoria for most residential customers has improved measurement accuracy. However, there are still a significant number of connections without AMI, or even without any form of metering. The latter category is termed unmetered supplies (UMS) and a significant and growing category of these UMS connections are difficult to estimate. This subcategory includes communication exchanges and a growing number of NBN sites.

For this benefit category the Digital Network utilises the AMI meter data together with the LV model[1] and other analytics to pinpoint theft in the network. Alongside the reduction in theft is the more accurate recording of UMS. When the unmetered sites are currently under-recording actual usage, overall losses will increase, leading to inaccurate allocation of these losses over unmetered customers.

The reduced non-technical losses will directly decrease customer bills as recoverable costs for losses will be reduced following decreasing tariffs.

Additional benefits are related to safety as electricity theft is done by circumventing the electricity meter which creates significant hazards like risk of electrocution or fire.

The coverage and accuracy of this benefit can be improved by installing more network measuring devices (e.g. AMI) at the following sites:

- Contestable metering sites;
- Unmetered supplies; and
- Distribution transformers (more accuracy through accumulation measurements).

Coverage does not have to be 100% for the above sites to provide significant benefits for this category. A subset of connections can be equipped with metering devices to improve accuracy of under recording and/or unauthorised usage of electricity.

2.2.2. Cost reflective pricing (2)

From 1 December 2014, the National Energy Regulations (NER) were changed to require regulated network businesses to structure their prices to reflect the costs of providing the electricity to consumers with different patterns of consumption.[2] The costs of providing electricity are highest during peak demand periods, generally between 5 pm – 9 pm during weekdays, especially in summer.

Cost reflective pricing can be implemented in different ways by either discouraging the use of electricity during peak times through higher tariffs (e.g. time of use tariffs) or by means of rebates to customers who decide to reduce their consumption at peak times or shift their consumption away from peak time.

[1] Low Voltage Model – a modelled representation of the characteristics, behaviour and (future) needs of a low voltage distribution network or a part thereof.
[2] AEMC

Digital Networks introduce analytics platforms and algorithms that interpret customer AMI interval data and can be used to construct more accurate cost reflective network pricing. This improves the associate load flows as customer behaviour changes are triggered by alternative pricing structures. A DNF can inform new time-of-use tariffs, rebates or other pricing programs (e.g. UE's summer saver program, Powercor's energy partners program) that will ultimately influence customer behaviour, reduce peak demand and improve overall utilisation of the distribution network.

Whereas current tariffs are mostly determined and implemented statically, it is anticipated that tariffs can instead be developed in a more dynamic fashion enabled by a combination of DNF and targeted voluntary programs, trials and/or dynamic time-of-use tariffs. This will also enable subsequent analysis of behavioural changes to construct more accurate cost reflective pricing structures.[3]

The current programs (energy partners and summer saver) could be further optimised with Digital Network to increase the coverage of these programs, creating greater value. A well-developed LV model will support the appropriate inclusion of customers as there is a better understanding of the transformers and the phases customers are connected on, further improving our ability to target those customers in highly utilised areas.

The main benefit in this category is augmentation deferral, because of greater effectiveness of tariff structures in reducing peak demand on the local network (the cost reflective pricing can be better targeted). There are also direct benefits for customers enrolled in cost effective pricing schemes, as they can become eligible to receive rebates.

The potential for program coverage and accuracy of cost reflective pricing can be improved by installing more network devices at contestable metering sites.

2.2.3. Electric vehicle charging optimisation (3)

Forecasts for electric vehicles show significant growth over the next 20 years and will have a large impact on overall energy consumption as well as the maximum demand. Charging patterns for electric vehicles include night and daytime charging at home, around commercial zones and buildings as well as at public charging facilities. In the absence of incentives to encourage consumers to charge at times optimal to networks, it is expected that the most popular charging pattern will relate to convenience, when consumers come home after work and plug-in their EV, coinciding with existing peak periods. This will increase the load on networks at a time when solar generation is declining, and maximum demand is otherwise rising.

This benefit category is setup to capture the benefits of EV load monitoring, control and optimisation towards local network and/or wholesale market supply and demand. Utilising the DNF to monitor, control and optimise EV charging will become a necessity to understand and estimate the impact of increasing demand on the distribution network resulting from rising EV penetration. It allows the network business to optimise and reduce their augmentation investment.

Customer benefits from EV charging optimisation will include:

- Deferral or reduction of augmentation expenditures though optimisation of charging to reduce peak demand on the network;
- Improved risk management of assets leading to optimised investment strategies to allow for higher levels of EV penetration, under the assumption that widely available charging infrastructure will facilitate EV penetration;
- Optimisation by coordinating charging with local PV output; and
- Direct market benefits through limiting increases in generation costs.

There are two implementation levels that have been investigated by Jacobs, including:

1) Implementing charging optimisation to residential charging infrastructure for a share of customers with EV.
2) Implementing charging optimisation to residential charging infrastructure (as under 2.2.1) and public and commercial charging infrastructure, by implementing devices at those locations.

[3] Recent studies performed by Jacobs suggest that current time-of-use tariffs in Australia are generally not adequately designed to capture the rapidly changing demand profile on local distribution networks. The timing of peak demand is changing and does not necessarily coincide with state or NEM-wide maximum demand. This issue will increase in relevance due to the introduction of EVs and distributed battery storage complementary to existing and new rooftop PV.

Different implementation options are modelled by Jacobs to understand additional benefits from including more charging locations across Victoria in VPN and UE's network.

2.2.4. Customer load monitoring and optimisation (4)

Alongside EVs, appliances like air-conditioners, refrigeration, pool pumps and electric hot water systems can increase maximum demand when not optimised for time of use. Air-conditioners are generally the largest contributors to the evening peak and are still growing in terms of the impact on peak load and overall volume of demand on the network.

The penetration of ToU tariffs is currently too low to make any significant changes to the behaviour of customers. Furthermore, it may be challenging to increase the penetration of these tariffs in the current market. Therefore, an opt-in program for load control and usage optimisation of appliances (air conditioners, pool pumps and hot water storage systems), as managed through the DNF, can offer a valuable solution to reduce the impact on network system peak demand. Load controlled appliances can be managed dynamically avoid peak periods and optimise loads towards periods of excess solar PV generation to reduce the cost of supply might be available.

Two applications of customer monitoring and optimisation are considered by Jacobs, these are:

1) Large air conditioner (and pool pump) control programs, to shift customers load and reduce peak demand for the network businesses.
2) Optimisation of hot water charging. Historically hot water systems were all switched on during the night. As available night time generation becomes scarcer when coal plants begin to retire, the load could be shifted to the middle of the day when solar is generating. Where solar exists behind the meter, the DNF could enable the hot water charge to be aligned with spare solar capacity, maximising value to the network and the customer. This is particularly important if export of solar generation is constrained.

We assume that either VPN and UE would provide relevant devices for customers (as per current trials) or that the manufacturer would include devices (e.g. as is common practice currently for air conditioner manufacturers).

The main benefits of the above applications are short term direct bill reductions for consumers (optimisation of their load devices with solar capacity) and for the long-term deferral of augmentation expenditures, resulting from optimised utilisation of the network and reduction of peak demand.

Jacobs will investigate two options in this CBA for customer load reduction and hot water load control. This starts with the monitoring and optimisation of appliances (e.g. air conditioners) for a percentage of current connections equipped with AMI. The second investment option includes additional benefits through extending coverage of load control to large customers (i.e. contestable metering sites), by implementing AMI network devices at these sites.

The second benefit for both investment options focuses on adapting the current load control of hot water systems to use excess solar generation to the benefit of the consumer.

Wider consumer and market benefits may also be achieved. These include:

- Generation cost reductions for consumers as distributed resources are operated more efficiently reducing requirements for centralised generation and reducing system losses
- Facilitating market development for aggregators and retailers to develop voluntary load control applications in the market. The DNF can provide the foundation and prevent duplication of infrastructure costs (e.g. platforms, comms, security, data repositories) for other stakeholders.

2.2.5. Other potential benefits

This section discusses some additional potential benefit categories and the reasons why they have not been quantified are outlined below.

LV phase identification

The Digital Framework can support LV phase identification. LV mapping will serve to provide VPN and UE with information that improves the identification process of customers and loads on the different phases and make it easier to rearrange these to balance the phases.

The current ability to identify customers on phases is based solely on estimates using AMI meters. Through Digital Network technology and by installing more network sensors on distribution transformers, contestable and unmetered sites, VPN and UE can improve the process for identifying customers on each phase. In addition, the accuracy and resulting benefits may be improved from updates to GIS.

Customer notifications of planned outages

Another benefit of improving the identification process of customers and loads on the different phases is to provide more accurate notification of customers for planned outages, which is particularly important to the safety of life support customers. Cross referencing life support customers to distribution substations will make sure these customers are properly notified and network businesses can avoid penalties for non-compliance which are ultimately passed on to customers.

LV asset failure prediction

The DNF can improve VPN and UE's ability to predict failures of connection assets (e.g. service mains). Voltage and current data will be used to inform an LV model (foundation of DNF) that can accurately monitor impedance changes for supply points and predict if failures are likely to occur. When actioning points of failure in a timely way, the number of fire-starts in the LV network, or any catastrophic events resulting from these fire-starts can be reduced significantly.

Currently systems are under development to provide the bulk of the functionality necessary to accomplish the benefits of LV asset failure prediction, but integration of this application into the DNF is likely to benefit and improve asset failure prediction. However, this incremental improvement is hard to quantify and has therefore not been valued in the business case.

Distribution substation (DS/S) asset condition monitoring

VPN and UE can install sensors (e.g. oil level measuring) and AMI on critical distribution assets (mainly transformers), allowing asset conditions to be monitored, and action taken to prevent failures, outages and/or prolong life. The DNF would then provide the framework for analytics and operational support for condition monitoring.

The initiative can generate benefits for customers through preventing failures, reducing associated outages and/or safety issues related to these failures (e.g. explosions of transformers, oil leaks). It may also save costs on inspections for those assets that are remotely monitored.

Additional benefits include better risk management and replacement prioritisation that can potentially defer replacement expenditures, but this would only be significant for a limited number of high risk and/or critical assets in the distribution networks.

Currently the potential benefits of distribution substation asset condition monitoring are difficult to quantify as the DNF is to be used to collect data to determine what assets mostly benefit from condition monitoring. In addition, costs for condition monitoring devices are relatively high and further investigation would be required to assess if a positive business case exists.

3. Investment options

3.1. Overview of options and associated benefits

Table 2 includes a brief description of the investment options.

Option 1 involves the introduction of the DNF, while Option 2 builds upon the existing DNF by increasing the coverage of network devices. The benefits as discussed in Section 2.2 applicable to each of these investment options are discussed in the third column of the below table.

Table 2: Digital Network investment options

Investment option	Description	Benefits Delivered
Baseline	Currently AMI data and functionality is utilised through ad-hoc applications which derives a basic level of benefits.	No additional benefits from Digital Network
Option 1 – introduction of Digital Network Framework	This introduces the DNF by investment in the Digital Network Infrastructure, including Foundations, Platforms, Comms, Integration, Security and Application Platforms. Digital Network will provide monitoring and control and will provide benefits through integrating the existing customer AMI in the DNF.	1. Reduction of non-technical losses 2. Cost reflective pricing 3. EV charging optimisation – control and optimisation of residential EV 4. Customer load monitoring and optimisation – control and optimisation of residential loads
Option 2 – increased coverage of network devices	As the foundation for Digital Network has been implemented in Option 1, Option 2 is about increasing the current coverage of network devices to improve efficiency, accuracy, effectiveness and coverage of the Digital Network. Network devices will be rolled out as follows: • Installing AMI at contestable metering sites that have large, variable or likely fast-growing loads, such as selected commercial LV and HV customers • Installing Smart PE Cells at unmetered sites with variable or likely fast-growing loads, such as NBN and telephone exchange connections. • Installing CT measuring devices at critical distribution transformers. Real-time data and analytics will be extended through the inclusion of additional measuring devices in the distribution network. Greater coverage improves the effectiveness of the Digital Network applications, maturing the existing benefits and allowing for additional capabilities and higher accuracy.	1. Reduction of non-technical losses* 2. Cost reflective pricing – increased benefits through expansion of pricing programs and enhanced effectiveness resulting from additional device deployment. 3. Electric vehicle (EV) charging optimisation – higher benefits through increased coverage to include public and commercial charging facilities. 4. Customer load monitoring and optimisation – higher benefits through inclusion of large customer load control. * initiative will reach higher coverage and become more accurate, increasing benefits.

The optimal deployment levels of network devices under Option 2 has been the subject of analysis by VPN and UE and is incorporated into separate material. This input data has been supplied by VPN and UE to Jacobs for this engagement.

3.2. Timeframes for benefit realisation

The NPV calculations compare the cost and benefits of two different options over 4 regulatory periods from FY2021 to FY2040 as some of the programs are assumed to take time to establish before they begin realising material benefits, particularly the rollout of customer devices and EV and other load controls.

In recognition of the extended timeframes and costs, the modelling includes refresh[4] costs for the IT along with Opex for program costs and network device procurement and installation costs.

3.3. Benefit categories and platforms

The DNF includes several source systems and platforms. For the benefits to materialise VPN and UE need to invest in and maintain these systems and platforms.

Regular investments are already made for some of the source systems of the DNF, such as upgrades to the Geographic Information System (GIS) and the completion of residential AMI deployment in 2015. This business case will include extension of these source systems, especially deployment of network devices (e.g. AMI, PE cells) to contestable and unmetered sites, as discussed in the previous section.

Moreover, there are several analytical platforms necessary to realise the benefits we have identified. These platforms provide the analytics and interpretation of the data and transforms the data into useful information triggering processes within VPN and UE.

The relevant Digital Network platforms for this business case[5] are:

- Real time data platform
- IoT platform for network sensors
- IoT platform extension for customer sensors
- Real-time grid analytics platform
- Real-time LV power flow analysis
- LV model extension
- Real-time grid monitoring and control
- LV management capability
- Dynamic forecasting capability
- DER monitoring capability
- DER automation

In Table 3, Digital Network Infrastructure platforms are plotted against the benefit categories. Identifying this is important as the platforms determine the additional IT-costs to the Digital Network Infrastructure as defined in Figure 1.

Platform costs were provided by VPN, as the technical specification and costing of analytics platforms is outside Jacobs' scope of work. Applicability and costing of the platforms has been determined based on information provided to Jacobs. Additional detail about costing is provided in section 5.2.

[4] Refresh costs assume that IT systems are partially replaced, refurbished and/or updated, but not fully replaced.
[5] The presented benefits may also use existing platforms, these have not been included in the list as they do not add to the cost.

Table 3: Digital network benefits – platform matrix

Benefit category	Real-time data platform	IoT Platform for Network Sensors	IoT Platform Extension Customer Sensors	Real-Time Grid Analytics Platform	Real-Time LV Power Flow Analysis	LV Model Extension	Real-Time Grid Monitoring and Control	LV Management Capability	Dynamic Forecasting Capability	DER-Monitoring Capability	DER - Automation
1	✓	✓	✓								
2	✓	✓	✓	✓	✓				✓	✓	
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Legend:

1 - Reduction of non-technical losses

2 - Cost reflective pricing

3 - Electric vehicle (EV) charging optimisation

4 - Customer load monitoring and optimisation

4. Quantification of benefits

4.1. Approach to quantification

Jacobs have focussed the quantification on the four benefits previously outlined, as they are expected to be the most material.

4.2. Approach to valuing peak demand reduction

The most significant benefits attributed to the DNF, relate to the reduction in peak demand growth. Given their relative importance the approach to valuing these benefits is described below.

VPN and UE provided the data included in Table 4 on the maximum demand growth (column 2) and augmentation expenditures (column 3) over the forthcoming regulatory period (FY21-25). For both VPN and UE, we have taken the total projected growth in peak demand and the associated augmentation expenditures for the FY21-25 regulatory period and calculated the average $/kVA as included in column 4 of Table 4.

Table 4: Average augmentation expenditure per kVA

Distribution business	Forecasted peak demand growth for FY21-25 MVA	Projected augmentation expenditures for FY21-25 $ million	Average cost per kVA $/kVA
VPN	406	282	695
UE	153	79	518

Most benefits are based on programs that reduce peak demand through control of customer load and EV. The benefits of these programs have been valued applying the average cost per kVA reduced as an avoided cost. Jacobs recognise that this represents an average figure across the network as some growth requires no network reinforcement, whilst other small amounts of peak demand growth can require larger reinforcement expenditure. However, without the ability to individually assess each demand reduction it reflects a proxy for the value of augmentation to VPN and UE.

There are two other major elements of peak demand reduction that have not at this stage been valued but could be as material as the direct benefit to VPN and UE. These are:

- Reduced customer contributions for demand augmentation (some growth in non-residential connections and demand may be possible without network reinforcement)
- Reduced requirement for generation capacity and reduced generation costs – as peak demand grows there is a need for (additional) peaking generation and/or electricity storage.

4.3. Benefit category 1 – reduction of non-technical losses

There are 2 elements of non-technical losses that could be reduced covering theft from the network and under-recording unmetered supplies (UMS). These are described separately below.

4.3.1. Reduction in unauthorised usage

The introduction of AMI meters in Victoria has already made unauthorised usage (theft) more difficult and therefore the current level of unauthorised usage is quite small and estimated by the network businesses at 0.03% of the total energy demand. Through Digital Network, it is possible to further reduce this level of unauthorised usage by applying the appropriate analytics and detecting where missing consumption is occurring in the network. The ability to detect unauthorised usage is enhanced with more measurement points in the network and estimated savings range from 25% to 50% for respectively Options 1 and 2.

This results in the following annual savings:

- VPN: Savings for Option 1 of $250k and for Option 2 increasing to a maximum of approximately $500k.
- UE: savings for Option 1 of $118k and for Option 2 increasing to a maximum of approximately $235k

4.3.2. Reduction in unmetered supplies under-recording

Additional devices in the network, and in the case of smart metering at unmetered supplies (UMS), would allow better identification of unmetered supplies that may under-record (underestimate) their consumption. We have assumed that for unmetered supplies on average there is 10% of under-recorded consumption and this could be reduced by 90%. This is accomplished by targeting the rollout of network devices to the UMS “other” category including mainly telephone exchanges, NBN and other telecom sites. These sites have less predictable usage patterns and have shown significant growth over the past few years. The expectation is that under-recording is most likely for these sites.

Applying the above assumptions results in the following annual savings:

- VPN: for 1,388 UMS sites starting with a benefit of $35k increasing to approximately $273k at the end of the assessment period for Option 2.
- UE: for 1,397 UMS sites starting with a benefit of $35k increasing to approximately $275k at the end of the assessment period.

These annual savings are based on a demand growth of 2.5% per annum and an annual growth of the UMS sites of approximately 11%, based on historical data. There are no savings for UMS in Option 1 as there are no additional network devices deployed with this option.

4.3.3. Summary reduction of non-technical losses

Table 5 shows the present values of the benefits from reduction of non-technical losses by introducing the functionalities of the DNF. Benefits for VPN range from $3.6 million for Option 1 to $9.5 million for Option 2.

Table 5: Reduction of non-technical losses for VPN – PV

Option VPN Benefits	Option 1 $m.	Option 2 $m.
Benefit from reduction in theft	3.6	6.7
Benefit from reduction in under-recording of UMS	-	2.8
Total benefit from reduction in non-technical losses	**3.6**	**9.5**

Table 6 shows the present values of the benefits from reduction of non-technical losses by introducing the functionalities of the DNF. Benefits for UE range from $1.7 million for Option to $6 million for Option 2.

Table 6: Reduction of non-technical losses for UE – PV

Option UE Benefits	Option 1 $m.	Option 2 $m.
Benefit from reduction in theft	1.7	3.2
Benefit from reduction in under-recording of UMS	-	2.8
Total benefit from reduction in non-technical losses	**1.7**	**6.0**

4.4. Benefit category 2 – cost reflective pricing

Currently UE has already implemented a program called 'Summer Saver' that is used as an example for the estimation of the cost-reflective pricing benefit. Within UE the Summer Saver program has been successful in deferring around $8 million (2017/18) of augmentation each year through demand reduction in areas close to their capacity limits. This is a rolling $8 million that continues to be saved for each year the program is operational.

By introducing the DNF, the value of the program can be further extended through the inclusion of e.g. winter peak programs. Winter peaks are likely to become more relevant in future years when winter peak demand is expected to grow faster than summer peak demand in the next decade. For UE we have estimated that this will increase the augmentation benefits with another 25% or $2 million permanent deferral.

For VPN a comparable benefit arises in the deployment of a program that is like the current Summer Saver program being operated by UE, as discussed above. As VPN's network covers a larger area, we expect that the introduction of a DNF will provide the necessary requirements to generate a rolling $12 million benefit while the program is operational.

Deployment of additional network devices to contestable and UMS sites is expected to improve coverage and effectiveness of the program, meaning that with similar resources VPN and UE expect to have greater coverage and can reach higher augmentation deferral. The assumption is that the deferred augmentation increases 35% of the total deferral achieved under Option1 (an additional $3.5 million for UE and $4.2 million for VPN).

The 35% increase is a conservative estimate based on the following assumptions:

- The additional rollout of network smart metering devices for large customers (HV, LVCT and 3 phase) will enable the businesses to extend cost reflective pricing programs not only to include several large customers to participate, but also provides a better understanding of the origin of the loads on critical parts of the distribution network. This will enable VPN and UE to make better informed decisions on the network assets, suitable for these types of programs and therefore make them more effective. For example, if only one large customer is responsible for an issue on a critical transformer, the distribution business can identify this more effectively and can apply resources more efficiently. For example, the business can target one customer rather than use a broader program like Summer Saver.
- Deployment of network devices on 25-35% of the largest and most critical distribution transformers will provide information to the network businesses to more accurately determine what distribution substation assets and associated areas across the network can be targeted for cost effective pricing programs, as well as the type of programs suitable for the identified issues. For example, if capacity issues are the result of solar PV export rather that peak demand other type of incentives should be applied or developed to solve the observed issue.

The Summer Saver program is just one example of pricing programs that can be developed to influence customer behaviour more dynamically. Other programs (e.g. dynamic ToU tariffs, critical peak pricing) can be developed and tested using the functionality of the DNF. Cost reflective pricing programs can be integrated with load optimisation and control programs involving EVs, air-conditioners, smart solar PV inverters and residential battery storage.

The value of this benefit category is based on the avoided augmentation expenditure, that would have been required without programs like Summer Saver. The benefit is enduring through a consistent rolling program. This avoided capital expenditure has been spread over three years, one year after the program has been initiated. In case this program is stopped then we would expect the avoided expenditure to be incurred immediately after.

4.4.1. Summary cost reflective pricing benefits

The information in Table 7 represents the total expected benefits for cost reflective pricing programs implemented over FY2022 to FY2041 by VPN using Digital Network. The present value of benefits is expected to be approximately $11 million for Option 1 and $14 million for Option 2.

The present value of cost reflective pricing programs for UE is included in Table 8, showing benefits of $1 million for Option 1 and $5 million for Option 2.

Table 7: Cost reflective pricing benefits VPN – PV

Option VPN Benefits	Option 1 $m.	Option 2 $m.
Deferred Capex (augmentation)	**10.6**	**14.3**

Table 8: Cost reflective pricing benefits UE – PV

Option UE Benefits	Option 1 $m.	Option 2 $m.
Deferred Capex (augmentation)	**1.9**	**5.2**

4.5. Benefit category 3 – EV charging optimisation

This category includes benefits from the DNF related to the optimisation of a share of electric vehicles that are forecast to enter the market. It is expected that EVs will have a significant impact on the maximum demand, particularly during the evening peak, and are likely to become one of the most important factors determining future demand driven augmentation expenditures for most distribution network businesses in Australia.

To reduce or eliminate the negative impacts of EVs on the distribution networks, EV charging can be optimised by using several methods that can be controlled and coordinated automatically through the DNF. These include:

- Charging pile selection - maximising the number of EV plugged-in at the same time
- Optimisation of charging to coordinate with local PV output
- Optimisation of charging to coordinate with ToU tariffs
- Targeted real-time optimisation based on local network bottlenecks and/or congestion[6]

For residential customers the communication through AMI and/or home Wi-Fi is used as well as a separate device that can control the EV charger, comparable to the devices that are used for control of air conditioners.

For commercial charging facilities behind the meter Jacobs expects similar devices to be implemented and controlled though either an AMI device (if installed), or through a secured local Wi-Fi network.

For public charging facilities it is assumed that these are dedicated facilities and are implemented with AMI and a direct comms link with the network business, either through Wi-Fi, 3/4/5G or Power Line Carrier (PLC) communication.

This section discusses the assumptions used to determine the benefits from EV charging optimisation for VPN and UE.

[6] Local congestion can trigger the need for network optimisation through the DNF. The DNF can then target connected EVs in the same area and reduce their load temporarily to alleviate the congestion.

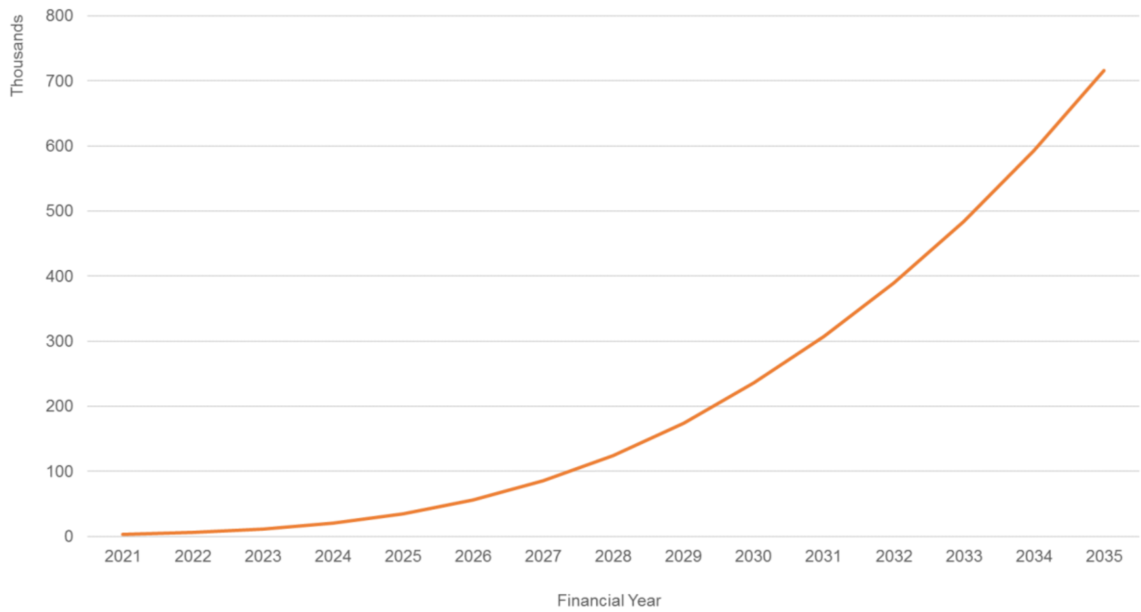
4.5.1. EV penetration forecast

Jacobs have used the data from the AEMO ISP 2019 (August 2019) Input and Assumptions workbook to forecast the penetration of EVs in Victoria in the Central scenario.

EV penetration numbers have been derived by dividing the total annual energy forecast of EV for Victoria by the average annual energy demand of one Battery EV (BEV) equivalent vehicle. The average daily vehicle energy demand (through charging) is set to 9.5 kWh which equates to just under 3.5 MWh per annum per BEV.

Figure 2 shows the penetration of BEV over time until 2035 when an equivalent of approximately 716k BEVs are expected to be on Victorian roads. The share of electric vehicles of the total vehicle fleet in Victoria is estimated at approximately 0.6% in 2025, 3.6% in 2030 and 9.8% in 2035.[7]

Figure 2: EV penetration numbers in Victoria (all vehicle types)



Source: Jacobs' analysis of AEMO ISP 2019 input and assumptions data.

It is expected that there will be a higher combined number of Plug-in Hybrid Electric Vehicles (PHEV), Hybrid Electric Vehicles (HEV) and Battery Electric Vehicles (BEV), but the 9.5 kWh energy consumption per day is based on the average usage of a BEV equivalent vehicle[8] and therefore BEV equivalent penetration numbers are used. In the remainder of this document BEV, HEV and PHEV are all referred to as EV.

The number of Victorian EVs is scaled to the relative size of the VPN and UE businesses in Victoria. This accounts for approximately 40% of the total Victorian share for VPN and 23% share of Victoria for UE.

4.5.2. EV charging load profiles

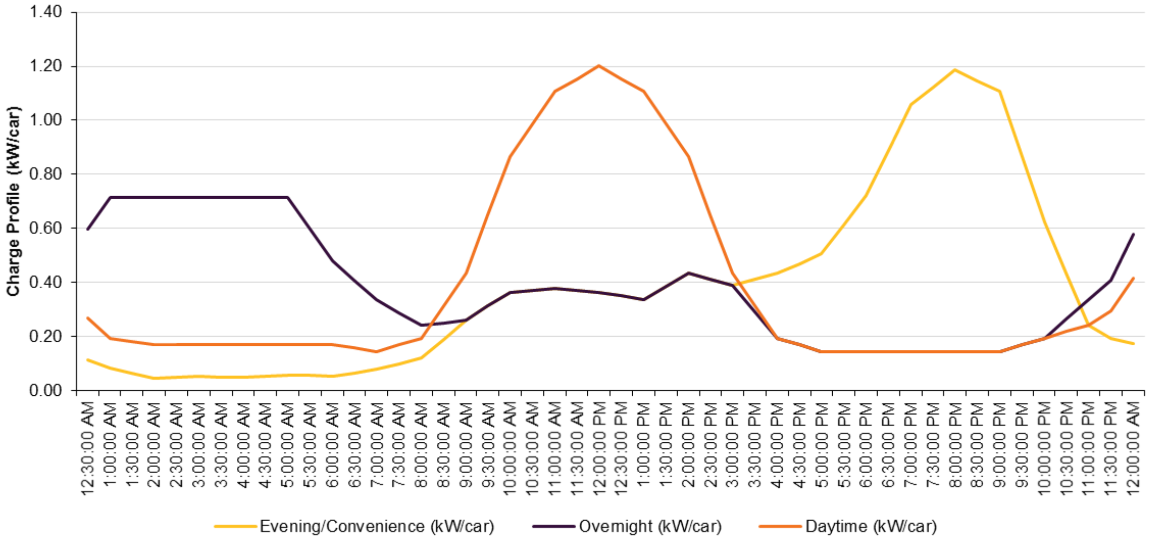
To understand the potential impact of EV on the maximum demand, 9.5 kWh average energy demand per day is plotted over time during the day. We have estimated the half-hourly demand of a single EV by applying the three time-of-day charging profiles that AEMO has published and then weighted them against percentage split of charging profiles forecasted by AEMO[9]. By applying the intertemporal weighting factors to these charging profiles, we have constructed different charging load profiles for EV. Several of these load profiles are included in Figure 4, and show a 0.95 kW maximum demand per EV increase during the evening peak in financial year 2021, this is reducing to 0.59 kW in FY2035 as the share of overnight and daytime charging profiles increase. Note that the highest EV demand in FY2035 shifts to the middle of the day, but this will only affect the

[7] Based on Victorian historical number of vehicles and growth rate for the period 2014-2019 from ABS 93090DO001_2019 Motor Vehicle Census, Australia, 2019.
[8] This includes residential vehicles, trucks, light commercial vehicles (LCV) and busses.
[9] We have applied the charging profiles and percentage split from the ISP 2018.

underlying demand, as (rooftop) solar PV covers a large share of this load. In this scenario the observed demand during the day will still be significantly lower than the evening demand.

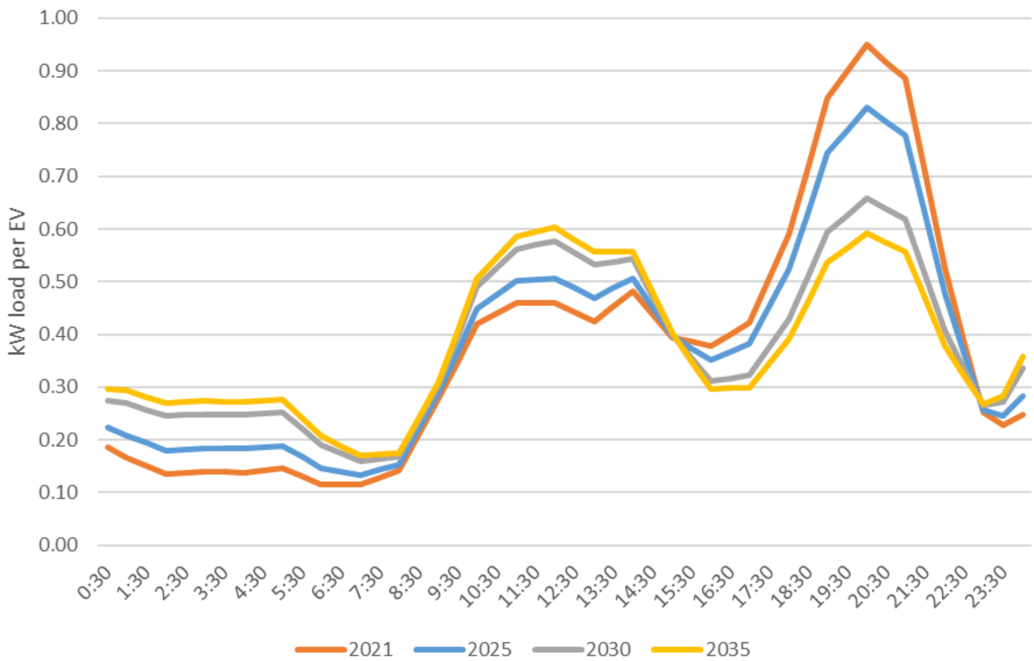
It is assumed that the residential evening peak coincides with the highest average maximum demand shown in Figure 5. Current standardised residential load profiles suggest that maximum demand generally occurs between 5pm and 9pm, depending on the season.

Figure 3: AEMO charging profiles



Source: AEMO 2018 Integrated System Plan Modelling Assumptions.

Figure 4: EV charging load profile change over time.

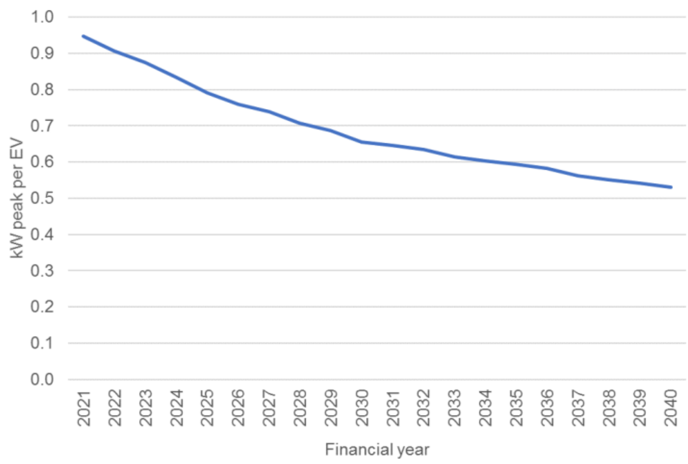


Source: Jacobs' analysis of AEMO ISP 2019 draft input and assumptions data.

The shares are likely to change over time, favouring a larger share of charging towards daytime and/or during the night. The latter may be the result of (ToU) tariffs introduced to mitigate some of the additional peak demand, consumers shifting vehicle charging during the day to take advantage of their own solar PV generation and/or consumers becoming more aware (educated) of the impact of their charging behaviour. The resulting average additional maximum demand over time is included in Table 9.

Table 9 and Figure 5: Intertemporal EV load impact on evening peak – kW per EV

Financial year	EV load impact	Financial year	EV load impact
2021	0.95	**2031**	0.65
2022	0.91	**2032**	0.63
2023	0.87	**2033**	0.61
2024	0.83	**2034**	0.60
2025	0.79	**2035**	0.59
2026	0.76	**2036**	0.58
2027	0.74	**2037**	0.56
2028	0.71	**2038**	0.55
2029	0.69	**2039**	0.54
2030	0.66	**2040**	0.53



4.5.3. EV charging optimisation at different sites

The modelling has assumed different levels of control for residential charging infrastructure, public charging infrastructure and commercial sites dependent on the Option selected.

In the Baseline (BAU), no EV charging optimisation is assumed as a full DNF is required to effectively optimise EV charging without impacting the convenience of consumers. For Option 1 only, residential charging sites are included in the business case, while for Option 2 residential, commercial as well as public charging facilities are included. This is because charging stations will need to be equipped with measuring and control devices and we are assuming that manufacturers, retailers, councils and/or other third parties will install and maintain these devices.

Table 10: Assumptions controllable EV charging facilities by site

Charging Sites	Sites as % of EVs	Optimised/controlled sites	Total as % of EVs optimised/controlled
Residential	100%	30%	30%
Public	20%	90%	18%
Commercial	20%	20%	4%
Total share of EVs controlled			52%

Table 10 includes the percentage of controlled charging infrastructure by VPN and UE as a share of the total EVs on the road in the VPN or UE area (column 2). We are assuming that each household with an EV also has a charging point. A further assumption is made that commercial and public charging infrastructure only cover 20% each of the number of EVs in the VPN or UE network areas.

Moreover, we have estimated the expected number of EVs that can be controlled by VPN or UE (column 3). Effectively this means that about half of the EV fleet in the VPN or UE area (column 4) are controllable, regardless of where they are located. The remaining share of EVs is assumed not to be controlled or optimised voluntarily through other means such as tariffs[10].

[10] The reduction of maximum demand per EV is an average based on different charging patterns as discussed in section 4.5.2. Because averages are used it is assumed in this analysis that the EV's location does not determine its time of charging. The inclusion of commercial and public charging facilities takes into account that not all EVs will be charged (only) at home and that 'intraregional' cars may be charged at these facilities as well, although this has not been explicitly considered in this CBA.

We have assumed a high share of controlled public charging facilities (90%) as they are more likely to be developed together with the distribution businesses and connected through municipal and/or VPN or UE owned and operated distribution lines. For commercial charging we expect that these will include mostly charging facilities at commercial parking facilities, office buildings, universities and shopping malls. These are likely to be connected behind the meter as part of private networks and therefore we have assumed a low percentage of 20%.

Overall, we believe that the 52% total share of EVs controlled (refer to charging stations will need to be equipped with measuring and control devices and we are assuming that manufacturers, retailers, councils and/or other third parties will install and maintain these devices.

Table 10) is relatively conservative because of the following:

- This share applies to vehicles originating from the VPN and UE areas only and as CitiPower covers the Melbourne CBD area it is likely that many EVs originating from other network areas in greater Melbourne (Jemena, AusNet) will travel into the CBD during the day as well as in the evening, increasing the controlled charging EV population.
- We have assumed normal capacity charging (available to residential customers) for our maximum demand estimates. However, more high capacity charging[11] is likely to become available in commercial, public and even residential sites. The impact of these high capacity EV chargers is likely much higher than the estimates included in this business case.
- The charging profiles are based on passenger vehicles, we have not included the impact of light commercial vehicles and medium size rigid truck charging profiles and/or buses. These profiles could have a greater impact on evening peak demand.

The above issues can contribute positively to the amount of increased maximum demand during the evening peak. Without any control or optimisation of charging the impact is likely to lead to significant load increases on the distribution network.

4.5.4. Summary of EV charging optimisation benefits

The information in Table 11 represents the total expected benefits for EV charging optimisation implemented using Digital Network by VPN, present value benefits are estimated at $46.1 million for Option 1 and $79.8 million for Option 2.

Table 11: EV charging optimisation benefits for VPN – present Value

Option VPN Benefits	Option 1 $m.	Option 2 $m.
Residential EV charging optimisation - reduction of Capex (augmentation)	46.1	46.1
Public EV charging optimisation - reduction of Capex (augmentation)	-	27.6
Commercial EV charging optimisation - reduction of Capex (augmentation)	-	6.1
Total All Benefits for EV Charging Control	**46.1**	**79.8**

Table 12 includes the expected benefits for EV charging optimisation for United Energy over twenty years. The present value benefits for Option 1 are $27.0 million and $46.8 million for Option 2.

[11] Normal charging occurs at a rate of 2.5 – 7kW, while high capacity chargers can reach 25 to 135kW, sometimes referred to as ‘fast charger’ or ‘super charger’.

Table 12: EV charging optimisation benefits for United Energy – present value

Option UE Benefits	Option 1 $m.	Option 2 $m.
Residential EV charging optimisation - reduction of Capex (augmentation)	27.0	27.0
Public EV charging optimisation - reduction of Capex (augmentation)	-	16.2
Commercial EV charging optimisation - reduction of Capex (augmentation)	-	3.6
Total All Benefits for EV Charging Control	**27.0**	**46.8**

4.6. Benefit category 4 – customer load monitoring and optimisation

There are 2 separate benefits related to Customer load monitoring and optimisation.

4.6.1. Customer controlled load for augmentation reduction

This initiative would apply across the VPN and UE networks but may be more targeted with an additional marketing focus in areas that have higher capacity utilisation. VPN and UE would use the DNF to identify which customers were typically higher users during peak. They would approach those customers and offer an opt-in program with the aim of implementing some form of control and/or optimisation over the main appliances to reduce peak demand. This would be based on a recent VPN trial that used air conditioner controllers (e.g. Sensibo).

The main devices for customer control are expected to be large (>4 kVA) air conditioners, but pool pumps could also be considered in a similar manner. There is expected to be a peak demand saving of 1 kVA per device that is controlled (allowing for diversity), which is conservative as the DNF would have identified which premises were high peak time consumers. The program starts in financial year 2022 by rolling out load control to additional customers and is expected to initially have 2,500 customers per annum added for VPN and 2,000 customers per annum added for UE and grow by 10% per annum. However, the benefits of these additional customers do not start accumulating before the applicable Digital Network IT platforms are fully deployed in 2024. Furthermore, it is assumed that once these demand reductions are achieved, they are enduring.

The benefit applies to Options 1 and 2 but is larger for Option 2, as it is assumed that with the roll-out of AMI devices at contestable sites, several commercial air-conditioners can be added to the program. This share is estimated at 25% of the AMI implemented at commercial customers and for these sites the peak demand saving is assumed to be 5 kVA.

The average annual savings for VPN over twenty years are $4.3 million for Option 1 and $4.4 million for Option 2. The average annual savings for UE are $3.4 million per annum for Option 1 and $3.5 million for Option 2.

4.6.2. Using solar for hot water charging

Utilising the functionality of the Digital Network VPN and UE can align part of the hot water charging with spare solar capacity to maximise the value of solar PV for the distribution network and the customer.

Many solar customers are currently exporting spare solar capacity during the day but could be using this export capacity more effectively by charging (part of) their storage hot water systems generating direct benefits as well as alleviating some export constraints in the distribution network. The benefit of this application can be calculated by using the difference of value of the feed-in tariff compared to the controlled load tariff. However, this customer benefit also includes a reduction in the charged network tariff, which will result in all other consumers making up this difference under revenue cap regulation. The modelling has therefore not valued this benefit (due to the offsetting negative impact on other consumers), but instead it has focused on a societal benefit where generation from rooftop PV may otherwise be constrained.

The modelling has assumed that with increased solar generation there will be residential customers who face export constraints where it is uneconomic to augment the network. If these customers have hot water load control, then this solar can be used to charge the hot water storage during the day and allow the generation to be used. This would be controlled by the distribution business who would forecast weather conditions to determine in advance if the customers' solar is likely to be available the following day, or whether grid electricity is needed to charge the hot water.

The modelling assumes that there are initially 2,500 customers for VPN and 2,000 customers for UE that can benefit from this form of optimisation and that this will grow by 1,000 customers per year for both VPN and UE.[12] This assumption is based on customers preferring to receive the full use of their solar but recognising this is not always economic, in which case maximising their solar within existing network constraints would be the next best option. Each of these customers can shift at least 1,215 kWh of hot water load control (1/3 of an approximate consumption of around 3,650 kWh per annum for a typical electric hot water system).[13] Each unit that can now be charged from export constrained solar is worth the avoided costs of wholesale power, which has been estimated at 11c/kWh.

The annual value of this benefits builds up over time with increasing customers on the program. The average annual benefit over twenty years is $1.42 million for VPN and $1.36 million for UE.

4.6.3. Summary of customer load monitoring and optimisation benefits

The information in Table 13 represents the total expected benefits for VPN customer load monitoring and optimisation using Digital Network, present value benefits are estimated at $79.1 million for Option 1 and $81.6 million for Option 2.

Table 13: Customer load monitoring and optimisation benefits - PV

Option **VPN Benefits**	Option 1 $m.	Option 2 $m.
Customer Controlled Load for Augmentation Reduction	59.2	61.7
Digital Network using Solar for Hot Water Charging	19.9	19.9
Customer Controlled Load Total	**79.1**	**81.6**

Table 14: Customer load monitoring and optimisation benefits - PV

Option **UE Benefits**	Option 1 $m.	Option 2 $m.
Customer Controlled Load for Augmentation Reduction	47.4	48.8
Digital Network using Solar for Hot Water Charging	19.0	19.0
Customer Controlled Load Total	**66.4**	**67.8**

[12] We acknowledge that consumers on (or switching to) solar and instantaneous hot water systems may reduce the application of this particular program. However, the maximum total amount of customers included in this program is less than 3% of the total customers connected to the respective networks and can therefore be considered a conservative assumption.

[13] Estimates of total consumption of electric hot water storage systems range from 1,500 kWh to over 5,000 kWh per annum depending on the size of the system and the hot water usage. Based on research, Jacobs estimates that a typical 80-100 litre storage will use approximately 3,650 kWh per annum or 10 kWh per day.

Table 14 includes the load monitoring and optimisation benefits for United Energy of $66.4 million for Option 1 and $67.9 million for Option 2.

4.7. Total benefits for all options VPN

A summary of the present value of benefits for VPN for each of the options is provided in the table below. The total present value of the benefits for Option 1 is $139 million and $185 million for Option 2.

Table 15: Total benefits for each Option by category – Victoria Power Networks

Option VPN Benefits	Option 1 $m.	Option 2 $m.
(1) Reduction in non-technical losses	3.6	9.5
(2) Cost reflective pricing	10.6	14.3
(3) Electric vehicle charging optimisation	46.1	79.8
(4) Customer load monitoring and optimisation	79.1	81.6
Total present value of all benefits	**139.4**	**185.2**

4.8. Total benefits for all options UE

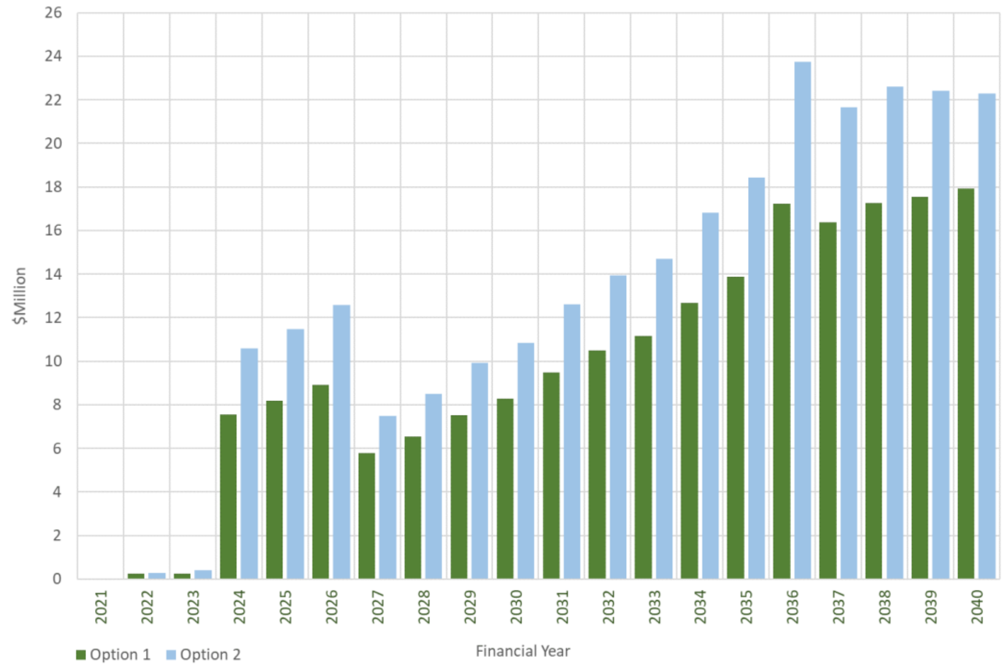
A summary of the present value of benefits for United Energy for each of the options is provided in the table below. The total present value of the benefits for Option 1 is $97 million and $126 million for Option 2.

Table 16: Total benefits for each Option by category – United Energy

Option UE Benefits	Option 1 $m.	Option 2 $m.
(1) Reduction in non-technical losses	1.7	6.0
(2) Cost reflective pricing	1.9	5.2
(3) Electric vehicle charging optimisation	27.0	46.8
(4) Customer load monitoring and optimisation	66.4	67.8
Total present value of all benefits	**97.0**	**125.8**

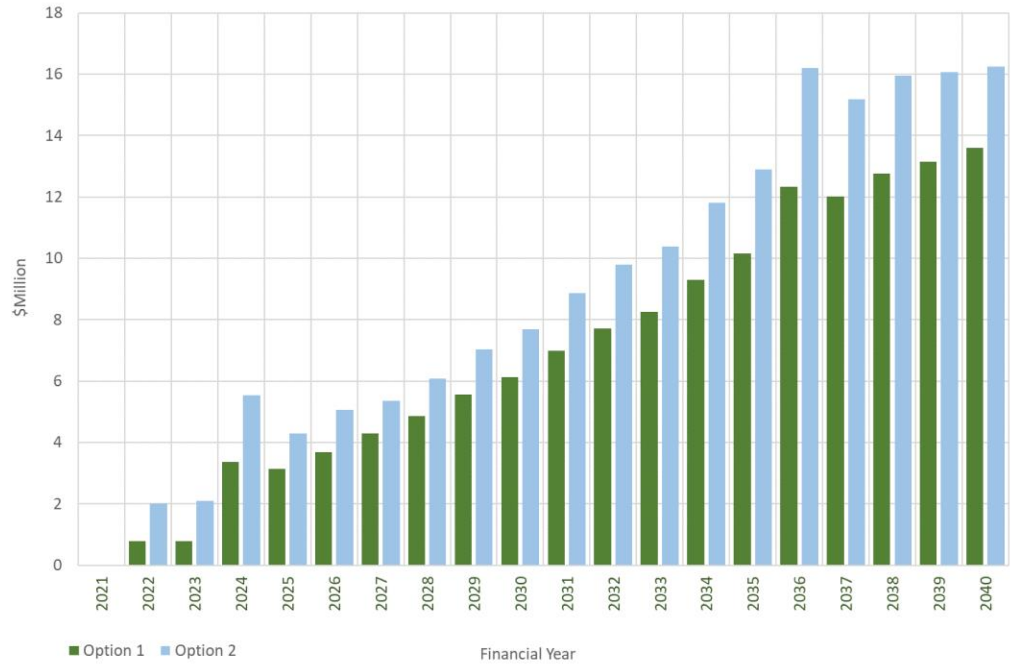
For VPN the annual benefits for both options are plotted in Figure 6. The figure shows real non-discounted benefits up to and including financial year 2040. In the first few years of the project there are no to limited benefits as the DNF implementation is spread out over several years and most benefits only materialise after the full implementation in FY2024. In FY2024-26 an increase is visible because of the impact of the cost reflective pricing benefit, spread over three years. In FY2027 the benefits fall back to previous levels as the complete benefit from cost reflective pricing has been recovered. Then the benefits are gradual increasing again to approximately $18 million per annum for Option 1 and $22 million per annum for Option 2 in FY2040.

Figure 6: Annual benefit projections Option 1 (green bars) and Option 2 (blue bars) for VPN



For UE the annual benefits for both options are plotted in Figure 7. The figure shows real non-discounted benefits up to and including FY2040. In the first few years of the project there are limited benefits as the DNF implementation is spread out over several years and most benefits only materialise after the full implementation in FY2024. The additional benefits from cost reflective pricing programs are included for FY2022-2024[14], showing a rebound in FY2025. After FY2025 there is a gradual increase in benefits for both Options, increasing to a maximum of approximately $13.5 million per annum for Option 1 and $16 million per annum for Option 2.

Figure 7: Annual benefit projections Option 1 (green bars) and Option 2 (blue bars) for UE



[14] UE's additional benefits for cost reflective pricing materialise earlier than VPN as UE have already setup the program. DNF helps improve the program and therefore increases the benefits only slightly for Option 1, but more significantly for Option 2 as discussed in section 2.2.2.

5. Costing approach and calculations

Most costing for the DNFDNF has been provided by VPN and UE without adjustments. A high proportion of the costs for the DNF are related to the implementation of the DNF platforms as discussed in Table 3.

5.1. Overview of costs

The costs can be broken down into several elements including:

- IT platforms required for DNF benefit categories
    - Capex initial installation
    - Opex for operations and maintenance
    - Refresh Capex for IT (Repex)
- Network measurement devices (for Option 2 only)
    - Capex costs for installation
    - Opex cost for reading of the devices
- Additional program costs for several benefit categories
    - Operating costs (Opex) for benefit categories 2, 3 and 4
    - Customer incentive costs for benefit categories 3 and 4

Some further potential costs have been identified, but these have not been included in the cost-benefit analysis for various reasons, examples are:

- Hardware and installation costs for customer control devices, as these are assumed to be supplied by the manufactures of new appliances like air-conditioners; and
- Customer incentive costs, as these are considered to have a net zero effect as they are costs for distribution businesses but equivalent benefits for customers.

A more detailed description of each of these costs and how they have been applied across the two options is described in the next section. It has been decided that the benefits as described in section 2.2.5 (e.g. LV phase identification, distribution substation asset monitoring) will not be valued and therefore the incremental costs for these benefits have not been included.

5.2. Digital Network platforms cost

We have assumed business as usual as a base-line with no additional costs and benefits and therefore this can be considered the ‘do nothing’ option.

For the other two options we have included the costs against the analytics platforms identified in Table 3. The platform Capex and Opex for each platform are shown in Table 17 for VPN and Table 18 for UE.

Refresh costs of Capex for all the platforms are assumed to be required at 7 year[15] intervals, after the system is operational and to be set at 50% of the initial cost, over the 20-year project period as there are two occurrences where the IT systems are refreshed.

[15] Replacement cost is typically 5-7 years; however we have used 7 years as we believe 2 replacements/refurbishments are appropriate for a project period of 20 years.

Table 17: Platform cost VPN for Digital Network Framework

Group	Platform Name	Duration (months)	Capex start year (FY)	Implementation Years	Operational Year (FY)	Capex	Base Annual Opex
Real Time Unified Data Space	Real-Time Data Platform	18	2021	1.5	2022.5	2,112,063	200,000
	IoT Platform for Network Sensors	54	2021	4.5	2025.5	5,079,840	124,000
	IoT Platform Extension for Customer Sensors	12	2022	1	2023	1,191,840	166,000
Real Time Grid Analytics	Real-Time Grid Analytics Platform	12	2022	1	2023	1,191,840	166,000
	Real-Time LV Power Flow Analysis	12	2021	1	2022	2,069,720	200,000
	LV Model Extension	12	2022	1	2023	1,081,860	50,000
	Real-Time Grid Monitoring and Control	18	2021	1.5	2022.5	3,167,424	0
	LV Management Capability	12	2022	1	2023	2,169,700	210,000
	Dynamic Forecasting Capability	12	2022	1	2023	1,070,262	0
	DER - Monitoring Capability	12	2023	1	2024	965,880	74,000
Network Flexibility and Automation	DER - Automation	12	2023	1	2024	1,070,262	0

Table 18: Platform cost UE for Digital Network Framework

Group	Platform Name	Duration (months)	Capex start year (FY)	Implementation Years	Operational Year (FY)	Capex	Base Annual Opex
Real Time Unified Data Space	Real-Time Data Platform	18	2021	1.5	2022.5	2,033,926	200,000
	IoT Platform for Network Sensors	48	2022	4	2026	2,495,225	124,000
	IoT Platform Extension for Customer Sensors	12	2022	1	2023	1,191,840	166,000
Real Time Grid Analytics	Real-Time Grid Analytics Platform	12	2022	1	2023	1,371,840	166,000
	Real-Time LV Power Flow Analysis	12	2021	1	2022	2,069,720	200,000
	LV Model Extension	12	2022	1	2023	1,081,860	50,000
	Real-Time Grid Monitoring and Control	18	2021	1.5	2022.5	3,009,420	0
	LV Management Capability	12	2022	1	2023	2,010,526	210,000
	Dynamic Forecasting Capability	12	2022	1	2023	1,070,262	0
	DER - Monitoring Capability	12	2023	1	2024	1,087,840	74,000
Network Flexibility and Automation	DER - Automation	12	2023	1	2024	1,079,660	166,000

The present value of the costs for the IT platforms for VPN and UE over 20 years are shown in Table 19. There is no difference in IT platform costs between Option 1 and 2. The expenditures for both businesses are comparable as the systems are duplicated across the two businesses. Capital expenditures for UE are lower than for VPN, but operational expenditures are higher, overall costs are slightly higher for VPN.

Table 19: Total costs of IT platforms over 20 years – present value

Distribution Business Expenditure type	VPN $m	UE $m
Capex	20.1	17.5
Replacement Capex	15.2	13.2
Opex	15.5	17.5
Total	**50.8**	**48.2**

5.3. Program costs (Opex)

Cost reflective pricing, EV charging optimisation and customer load monitoring and optimisation will all have program costs to deliver the associated benefits.

Table 20: Program costs (Opex) for cost reflective pricing, EV and load optimisation

Distribution Business Program	VPN – Program Cost	UE – Program Cost
Cost reflective pricing	• 2 FTE/a of $125k, totals $250k p.a. • $300k p.a. program costs including legal and marketing costs • For Option 2 we have increased above costs by 35%	• 1 FTE/a of $125k, totals $125k p.a. • $205k p.a. program costs including legal and marketing costs • For Option 2 we have increased above costs by 35%
EV charging optimisation	• 2 FTE/a of $125k, totals $250k p.a. • $300k p.a. program costs including legal and marketing costs • $10 per customer enrolled in the program	• 1.2 FTE/a of $125k, totals $150k p.a. • $205k p.a. program costs including legal and marketing costs • $10 per customer enrolled in the program
Load optimisation	• 2 FTE/a of $125k, totals $250k p.a. • $300k p.a. program costs including legal and marketing costs • $10 per customer enrolled in the program	• 1.2 FTE/a of $125k, totals $150k p.a. • $205k p.a. program costs including legal and marketing costs • $10 per customer enrolled in the program
Hot water-solar load control	• 1 FTE/a of $125k, totals $125k p.a. • $10 per customer enrolled in the program	• 1 FTE/a of $125k, totals $125k p.a. • $10 per customer enrolled in the program

Table 20 includes the Opex for cost reflective pricing for VPN and UE. Total Opex for VPN in Option 1 are $550k per annum and $330k per annum for UE. For Option 2 we have assumed an expansion of the program is possible and therefore scaled-up the variable cost by 35%. There will also be customer incentives each year for participation in the program. However, whilst this is a cost to the distribution businesses, it is also a benefit to customers so has no net impact on the NPV of the Initiative.

In the third row of the table above, EV charging optimisation Opex is included for VPN and UE. Additional to the base Opex an average additional cost of $10 per customer has been allowed to account for program growth.

The fourth row of the table includes the Opex for air conditioner load optimisation. The load optimisation program costs are assumed to be equal to the program costs for EV charging optimisation.

The last row includes the Opex for hot water load control with solar, costs for these programs are the same for UE and VPN, but lower than the costs for the other programs as a large share of the hot water systems are already connected to controlled load services. No customer incentive is provided for this program as there is a clear benefit for customers (tariff difference) in allowing their generation to be used to charge their hot water storage.

For cost reflective pricing, EV and load optimisation programs there are likely to be customer incentives. However, whilst this is a cost to the distribution businesses, it is also a benefit to customers so has no net impact on the NPV and has therefore not been included.

The present value of the program costs for VPN of Option 1 and Option 2 are provided in Table 21 and the program costs for UE are included in Table 22.

Table 21: Program Opex for load optimisation programs VPN – present value

Option **VPN program Opex**	Option 1 $m	Option 2 $m
Cost reflective pricing	7.4	9.6
EV charging optimisation	9.8	18.4
Customer load optimisation	9.4	13.3
Hot water load control using solar	3.1	3.1
Total customer load control devices	**29.7**	**44.4**

Table 22: Program Opex for load optimisation programs UE – present value

Option **UE program Opex**	Option 1 $m	Option 2 $m
Cost reflective pricing	5.1	6.3
EV charging optimisation	5.7	11.2
Customer load optimisation	6.9	9.5
Hot water load control using solar	3.0	3.0
Total customer load control devices	**20.7**	**30.0**

5.4. Additional network devices

Option 2 involves the installation of several additional network devices to improve the information available to VPN and UE on the operation of the network.

Table 23 shows the assumptions made on the number of additional VPN network devices expected to be rolled-out over the FY2021-2025 regulatory period. For UMS the roll-out is limited to customers in the ‘other’ categories including NBN sites and telephone exchanges. There has been significant growth in these types of customers over the past few years and this growth has also been included in the additional devices to be rolled-out.

For UE the additional devices in Option 2 are included in Table 24. There 4,464 devices to be deployed in the United Energy network compared to over 8,766 devices in the VPN network.

The highest number of devices will be deployed at LVCT customers (large commercial customers) with 2,840 devices on VPN’s network and 2,512 devices on UE’s network, as included in the tables below.

Table 23: Additional network device deployment at contestable metering sites – VPN

Device deployment for VPN (#)	2021	2022	2023	2024	2025	Total
UMS (all “other” category new and 10% retrofit)	278	278	278	278	278	**1,388**
HV customers (100%)	56	56	56	56	56	**282**
LVCT customers (30%)	568	568	568	568	568	**2,840**
1/3 Phase customers (10%/50%)	426	426	426	426	426	**2,131**
Distribution substations (Tx>300 kVA & >2 contestable customers, 24%)	425	941	941	941	941	**2,125**
Total additional devices per year	**1,753**	**1,753**	**1,753**	**1,753**	**1,753**	**8,766**

Table 24: Additional network device deployment at contestable metering sites – UE

Device deployment for UE (#)	2021	2022	2023	2024	2025	Total
UMS (all “other” category new and 10% retrofit)	279	279	279	279	279	**1,397**
HV customers (100%)	19	19	19	19	19	**95**
LVCT customers (40%)	502	502	502	502	502	**2,512**
1/3 Phase customers (10%/50%)	92	92	92	92	92	**460**
Distribution substations (Tx>300 kVA & >2 contestable customers, 35%)	268	268	268	268	268	**1,341**
Total additional devices per year	**1,161**	**1,161**	**1,161**	**1,161**	**1,161**	**5,805**

The hardware and installation costs of these additional network devices are different for each of the categories and are included in Table 25 for VPN and Table 26 for UE. The total cost for additional network devices is $9.5 million for VPN and $6.4 million for UE.

Table 25: Installation and hardware costs of network devices by type of customer – VPN

Customer type	Hardware	Installation	Total $k
UMS (all "other" category new and 10% retrofit)	$200	$206	**$330**[16]
HV customers (100%)	$700	$600	**$370**
LVCT customers (30%)	$669	$300	**$2,750**
1/3 Phase customers (10%/50%)	$192 / $366	$128 / $200	**$1,180**
Distribution substations (Tx>300 kVA & >2 contestable customers, 24%)	$880	$1,431	**$4,910**
Total Capex for installation of additional AMI	**-**	**-**	**$9,540**

Table 26: Installation and hardware costs of network devices by type of customer – UE

Customer type	Hardware	Installation	Total $k
UMS (all "other" category new and 10% retrofit)	$200	$206	**$330**[17]
HV customers (100%)	$700	$600	**$120**
LVCT customers (30%)	$736	$300	**$2,600**
1/3 Phase customers (10%/50%)	$192 / $398	$128 / $200	**$260**
Distribution substations (Tx>300 kVA & >2 contestable customers, 24%)	$880	$1,431	**$3,100**
Total Capex for installation of additional AMI	**-**	**-**	**$6,420**

Table 27 shows the total Capex for installation and hardware for the additional network devices to be rolled-out for both VPN and UE in Option 2. The highest costs are for the network devices on large distribution substations.

The roll-out number of these devices is an estimate of coverage necessary to generate additional benefits as calculated for Option 2. The actual number of devices needed, and the resulting additional benefits of this increased coverage is subject to change. Through implementation of the DNF it is likely that more information is collected on the effectiveness of increased measuring device coverage of the VPN and UE networks, including extension of the coverage to contestable sites.

Table 27 includes the present value of the network device Capex, based on the inputs as provided in Table 23 to Table 26.

No replacement expenditures have been considered for these devices as it is assumed that the devices will have a minimum average life of 20 years.

[16] No cost are included for newly installed UMS.
[17] No cost are included for newly installed UMS.

Table 27: Option 2 additional device costs – present value

Distribution Business Expenditure type	VPN $m	UE $m
Network device Capex at contestable metering sites	4.2	3.0
Network device Capex at distribution substations/ transformers (non-ZSS)[18]	4.5	2.8
Total present value Capex for additional AMI network devices	**8.7**	**5.8**

5.5. On-going Opex (device reading and maintenance)

The modelling has made the following assumptions about the Opex associated with reading and processing the information for the additional devices in Option 2.

- Annual metering cost of $73 for single phase meters (also applies to UMS new and retrofits)
- Annual metering cost of $91 for three phase meters (also applies to HV and direct connect customers)
- Annual metering cost of $113 for LCVT Connection (applies to LVCT customers and distribution transformer sites)

The above costs are assumed to be the same for VPN and UE.

The table below includes the present value of all operational cost over the 20-year project duration. The total present value of the Opex is $10.8 million for VPN and $7.2 million for UE and includes the reading, comms and maintenance of all additional network devices rolled-out.

Table 28: Option 2 additional operational costs - PV

Distribution Business Expenditure type	VPN $m	UE $m
Network device Opex for contestable metering sites	7.9	5.3
Network device Opex at distribution substations/ transformers (non-ZSS)	2.9	1.9
Total present value Opex for additional AMI network devices	**10.8**	**7.2**

As some of these new AMI devices may be used for billing and settlement processes the total Capex and Opex may be shared across different services and therefore the costs burden on the Digital Network business case is likely to be lower than estimated in this section, this will ultimately improve the NPV of the project.

5.6. Total present value of cost per option

The present value of all costs over 20 years for VPN are included in Table 29. The total costs are $80 million for Option 1 and $115 million for Option 2.

[18] Includes an once-off $200,000 IT cost.

Table 29: Total cost per Option for VPN – present value

Option VPN costs	Option 1 $m	Option 2 $m
Capex for IT platforms	35.3	35.3
Capex for network devices	-	8.7
Total Capex	***35.3***	***44.0***
Opex for IT platforms	15.5	15.5
Program costs (Opex)	29.6	44.3
Opex for network devices	-	10.8
Total Opex	***45.1***	***70.6***
Total present value of costs	**80.4**	**114.6**

The present value of all costs over 20 years for UE are included in Table 30. The total costs are $69 million for Option 1 and $91 million for Option 2.

Table 30: Total cost per Option for UE – present value

Option VPN costs	Option 1 $m	Option 2 $m
Capex for IT platforms	30.7	30.7
Capex for network devices	-	5.8
Total Capex	***30.7***	***36.5***
Opex for IT platforms	17.5	17.5
Program costs (Opex)	20.7	30.0
Opex for network devices	-	7.2
Total Opex	***38.2***	***54.7***
Total present value of costs	**68.9**	**91.2**

6. Comparison of results

6.1. Summary of results VPN

Results for VPN for both options are included in Table 31, showing the present value of costs and benefits, the Net Present Value (NPV), benefit cost ratios and the internal rate of return for Option 1 and 2. Option 1 and 2 both have positive NPVs but Option 2 has a higher NPV and a higher Internal Rate of Return (IRR). These results do not include operational expenditures, a results table with the Opex is included in Appendix A.

Table 31: NPV Results for options VPN – excluding Opex

Option **VPN costs & benefits**	Option 1 $m.	Option 2 $m.
PV value of costs	35	44
PV value of benefits	139	185
NPV of costs and benefits at 2.75% real WACC	104	141
Benefit-cost ratio (NPV)	3.95	4.21
IRR	28.7%	30.6%

6.2. Summary of results UE

Results for UE for both options are included in Table 32, showing the present value of costs and benefits, the NPV, benefit cost ratios and the internal rate of return for Option 1 and 2. Option 1 and 2 both have positive NPVs but Option 2 has a higher NPV and a higher IRR. These results do not include operational expenditures, a results table with the Opex is included in Appendix A.

Table 32: NPV Results for options UE – excluding Opex

Option **UE costs & benefits**	Option 1 $m.	Option 2 $m.
PV value of costs	31	37
PV value of benefits	97	126
NPV of costs and benefits at 2.75% real WACC	66	89
Benefit-cost ratio (NPV)	3.16	3.45
IRR	21.7%	25.2%

6.3. Cashflow comparison

Figure 8 presents the real costs and benefits of VPN for Option 1 over the project duration, it shows the benefits gradually building up from FY2024 onwards, with a rebound in FY2027, when the benefits of the cost reflective pricing have been realised.

On the cost side the graph shows an initial large investment in FY2021-2023 and then refresh Capex in FY2028-2032 and FY2035-2039. The grey line (left axes) provides the cumulative result, showing break-even at FY2025. A similar graph is included for Option 2, the break-even point for Option 2 is also in FY2025.

Figure 8: Costs and benefits over project duration – VPN Option 1

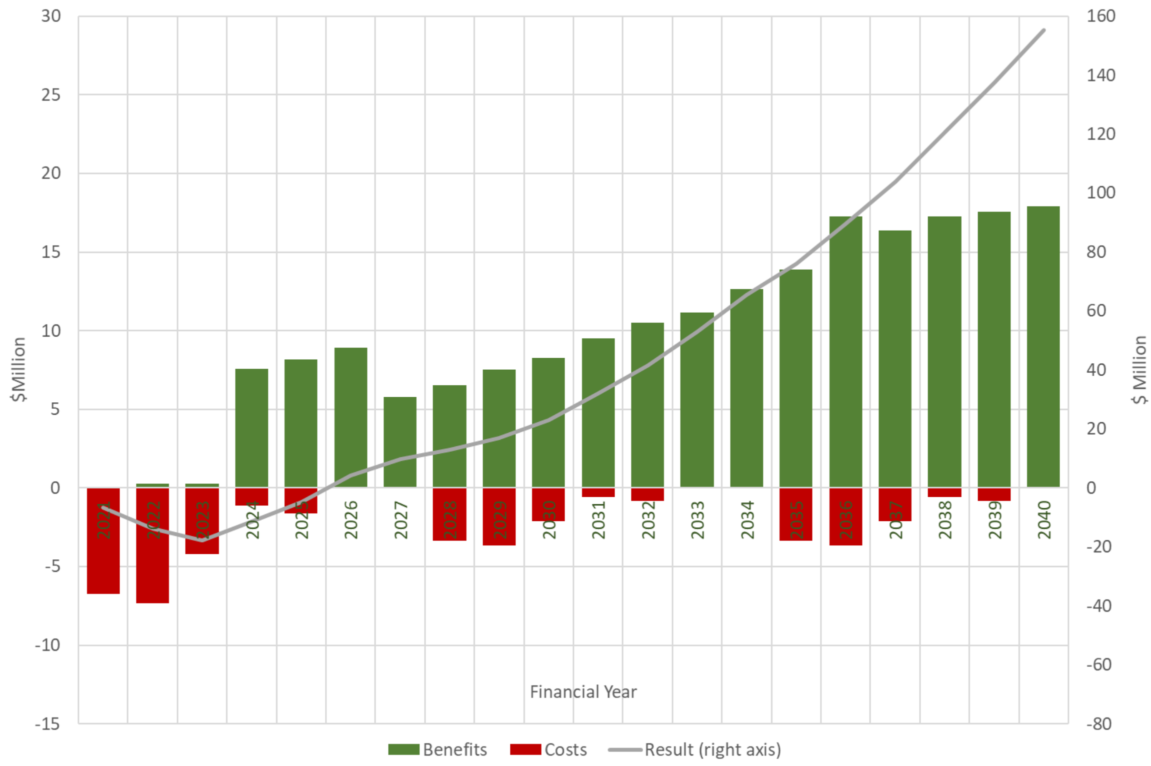


Figure 9: Costs and benefits over project duration – VPN Option 2

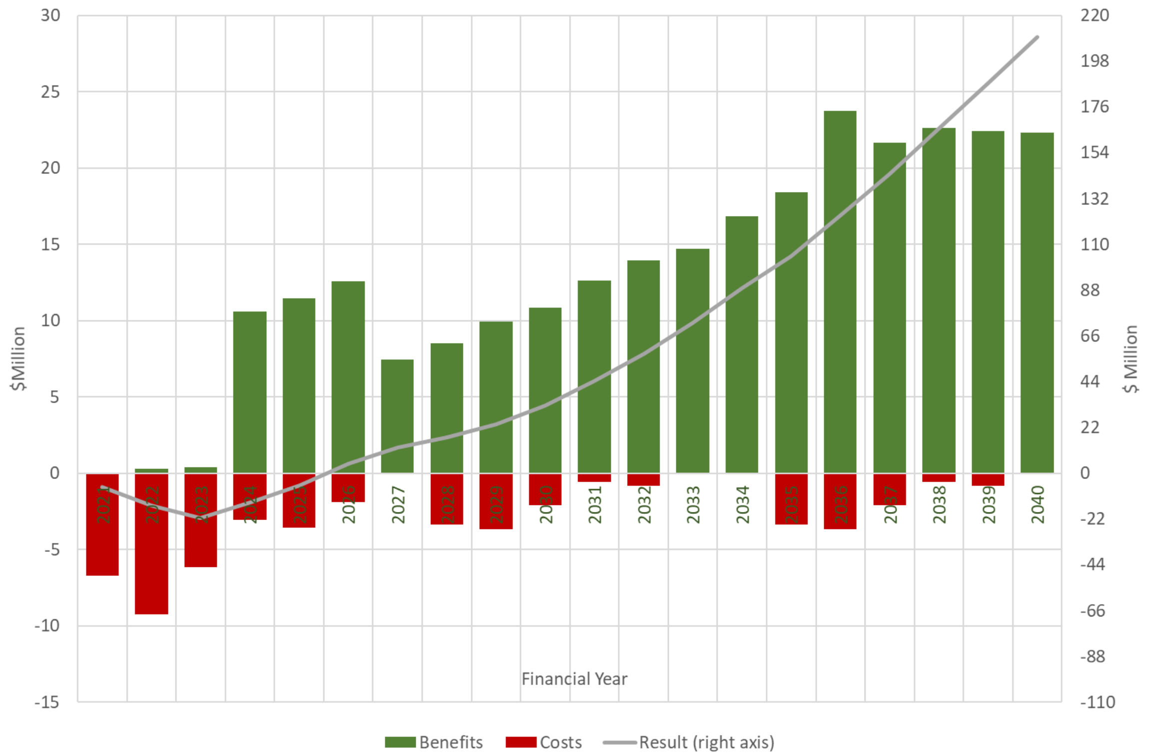
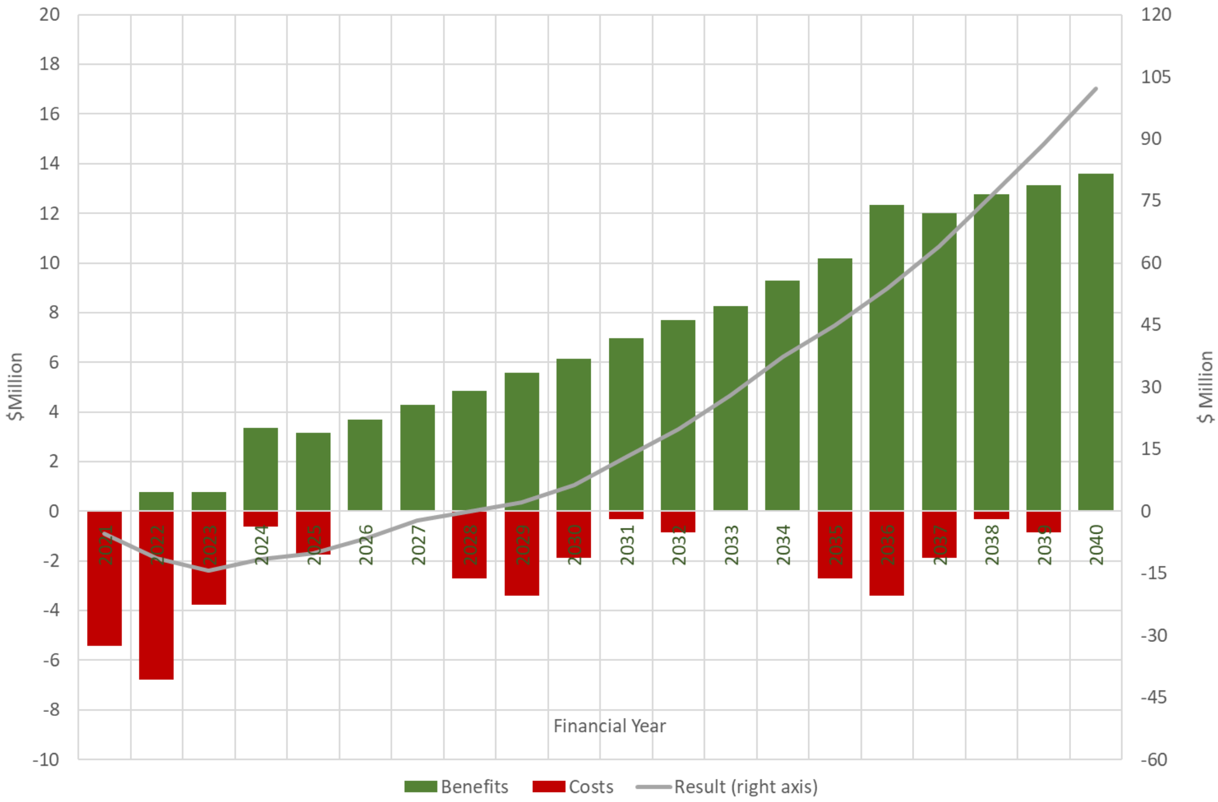


Figure 10 presents the real costs and benefits of UE for Option 1 over the project duration, it shows the benefits gradually building up from FY2024 onwards.

On the cost side the graph shows an initial large investment in FY2021-2025 and then refresh Capex in FY2028-2032 and FY2035-2039.

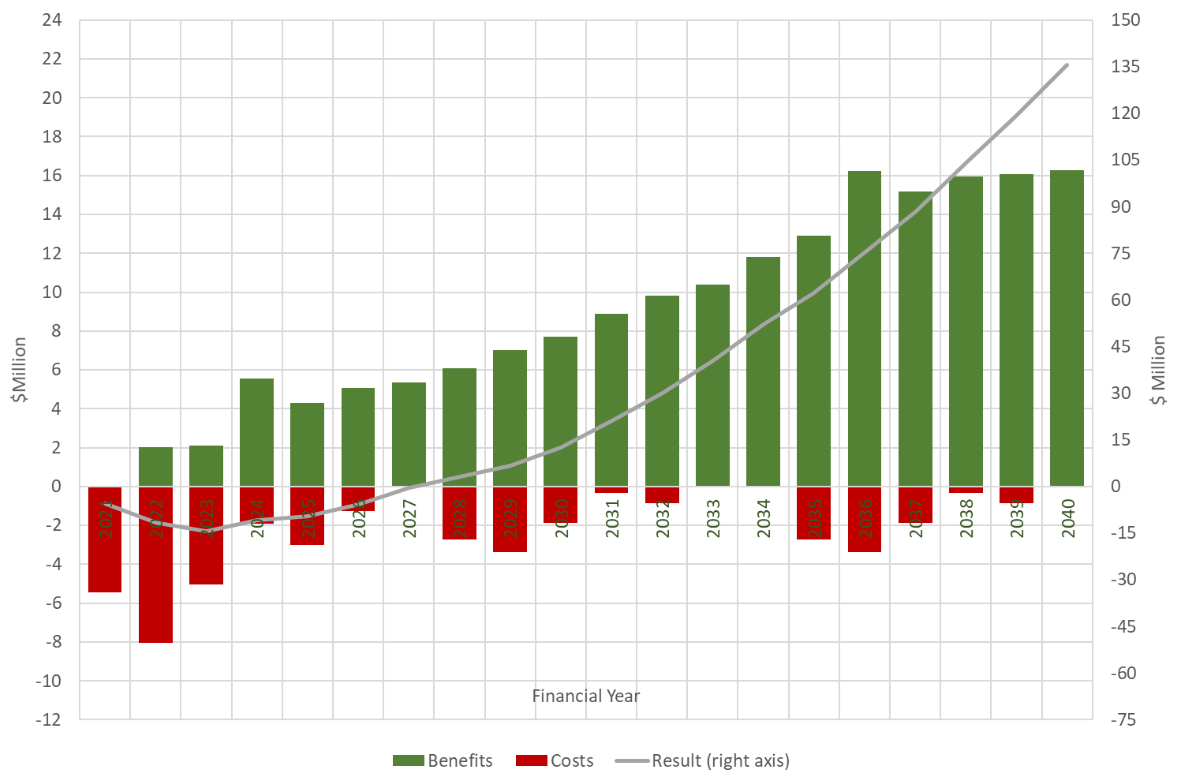
The grey line (left axes) provides the cumulative results, showing break-even after FY2028. A similar graph is included for Option 2, the break-even point for Option 2 is around FY2027. The breakeven point for UE is 2-3 years later than for VPN as IT-platform Capex for UE is similar, but benefits are lower due to the smaller size of the network.

Figure 10: Costs and benefits over project duration – UE Option 1



Additional cashflow graphs for VPN and UE have been included in Appendix A, the graphs in the appendix include Opex.

Figure 11: Costs and benefits over project duration – UE Option 2



6.4. Conclusion and recommendations

For both United Energy and Victoria Power Networks the NPV for Option 2 is highest considering Opex and Capex in the business case. In addition, also for both VPN and UE the NPV, IRR and benefit cost ratio of Option 2 is highest if Opex is excluded.

In all cases and for both distribution businesses the NPV at a regulated real WACC of 2.75% is highest for Option 2 and is therefore the recommended option for investment.

Appendix A. Additional result tables and figures

Table 33: NPV Results for options VPN – results including Opex

Option VPN costs & benefits	Option 1 $m.	Option 2 $m.
PV value of costs	54	76
PV value of benefits	139	185
NPV of costs and benefits at 2.75% real WACC	40	39
Benefit-cost ratio (NPV)	1.41	1.27
IRR	15.3%	15.0%

Table 34: NPV Results for options UE – results including Opex

Option UE costs & benefits	Option 1 $m.	Option 2 $m.
PV value of costs	42	55
PV value of benefits	97	126
NPV of costs and benefits at 2.75% real WACC	17	16
Benefit-cost ratio (NPV)	1.21	1.14
IRR	8.3%	9.2%

Figure 12: Costs and benefits over project duration – VPN Option 1, Including Opex

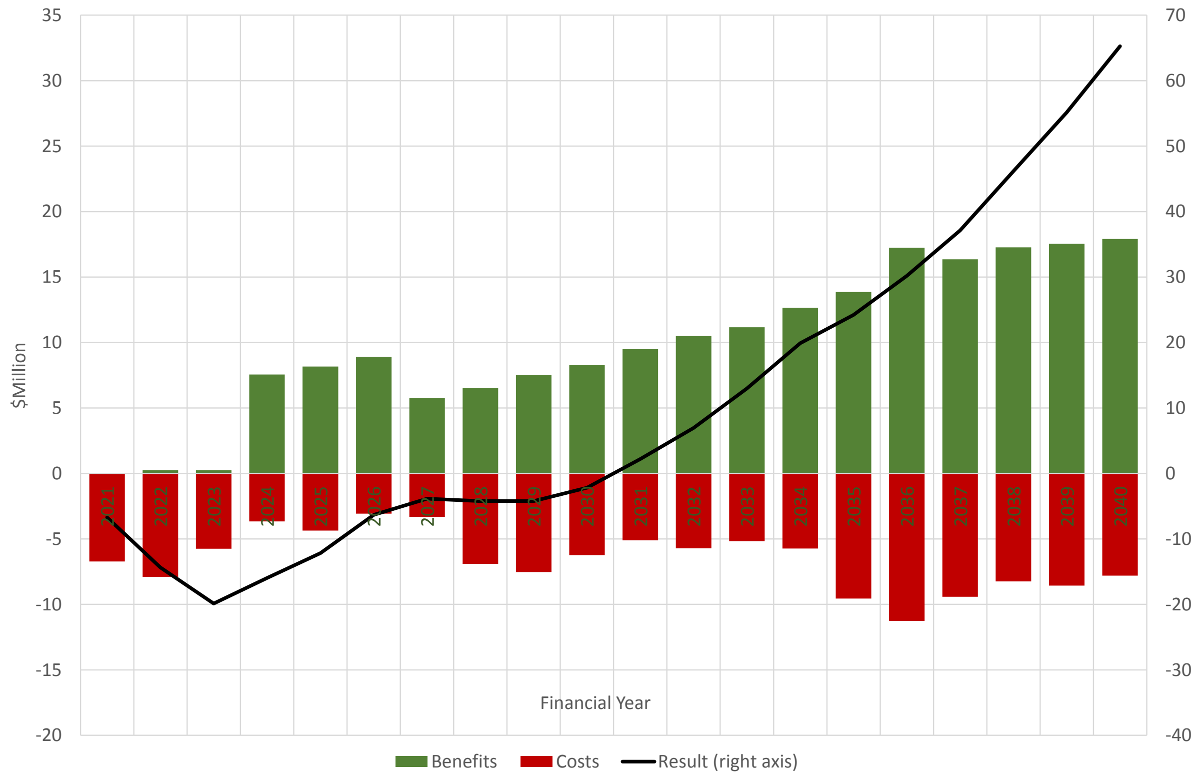


Figure 13: Costs and benefits over project duration – VPN Option 2, including Opex

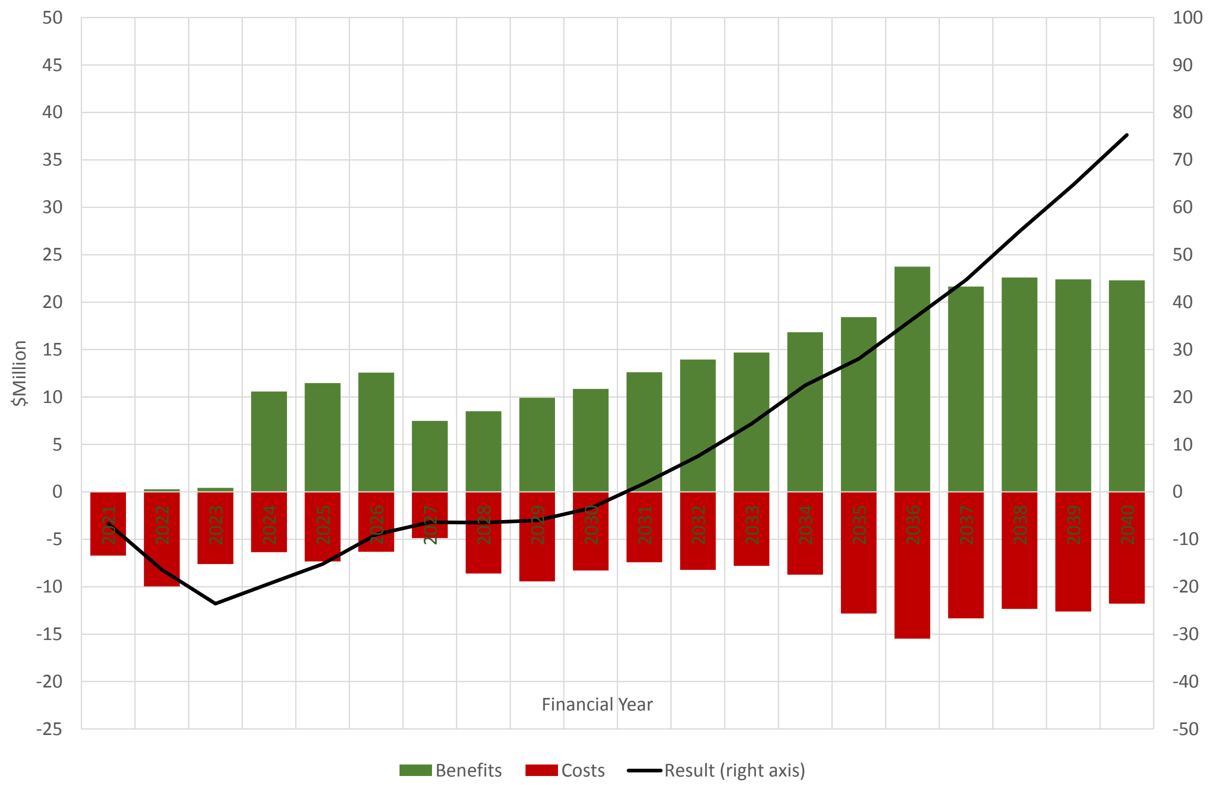


Figure 14: Costs and benefits over project duration – UE Option 1, Including Opex

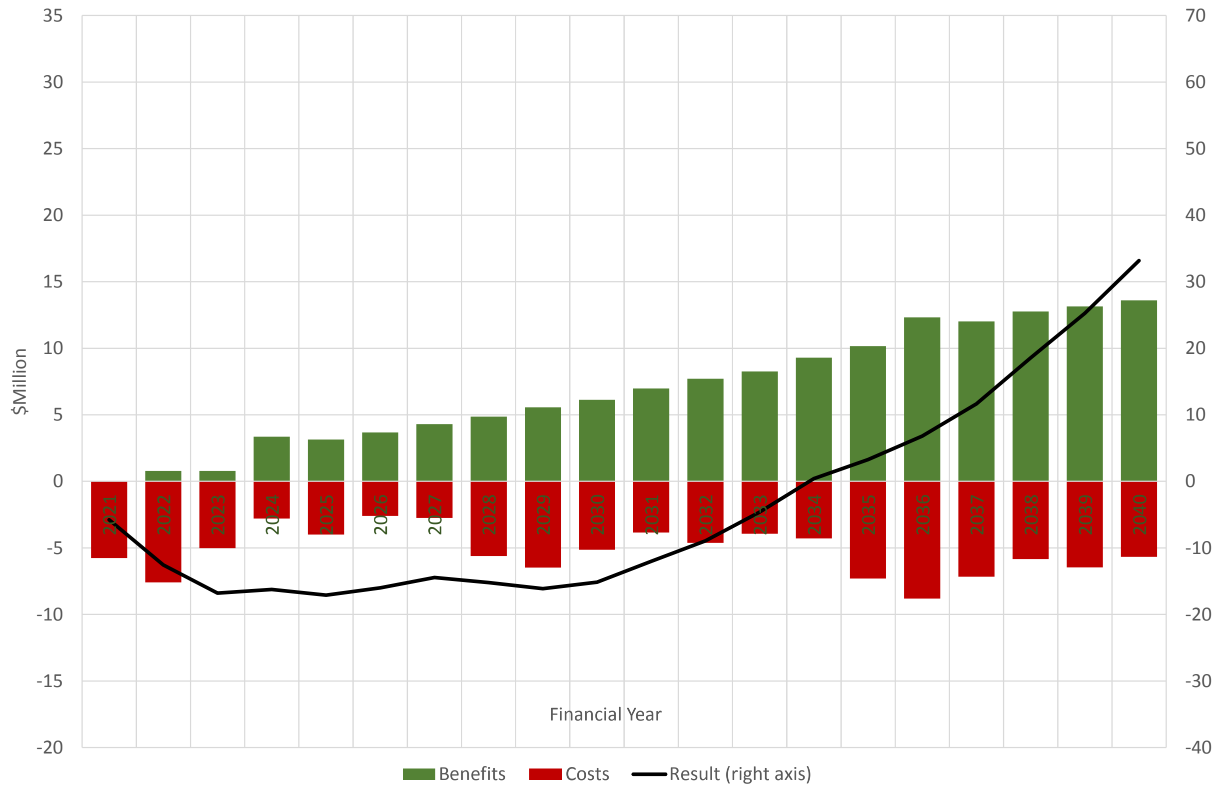


Figure 15: Costs and benefits over project duration – UE Option 2, including Opex