Enhanced System Planning Project

C4NET | ESP Enhanced System Planning

C4NET Project Overview

Investment Coupled Whole-System Planning

WP 3.13

April 2025

C4NET

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1. Purpose of the report

The Enhanced System Planning (ESP) project is a significant and collaborative research project aimed at informing electricity planning below transmission level in Australia beyond 2030. Its focus is on building methodologies and approaches for bottom-up modelling and to highlight the opportunities presented through the distribution system and by integrating Consumer Energy Resources (CER) and Distributed Energy Resources (DER), with the goal of informing whole of system planning. The ESP seeks to inform gaps that would emerge if the Australian Energy Market Operator's (AEMO) current Integrated System Plan (ISP)[1] is expanded beyond its current scope to take a more whole-of-system approach in alignment with the Energy and Climate Change Ministerial Council's (ECMC) recommendations for enhancing energy demand forecasting in the ISP.[2] The ESP project is targeted at addressing the distribution system considerations aspect of this expanded scope, with particular focus on bottom-up modelling approaches from the low voltage distribution system upwards, as outlined in *Figure 1*. For the bigger picture of integration with the ISP see *Appendix Two.*

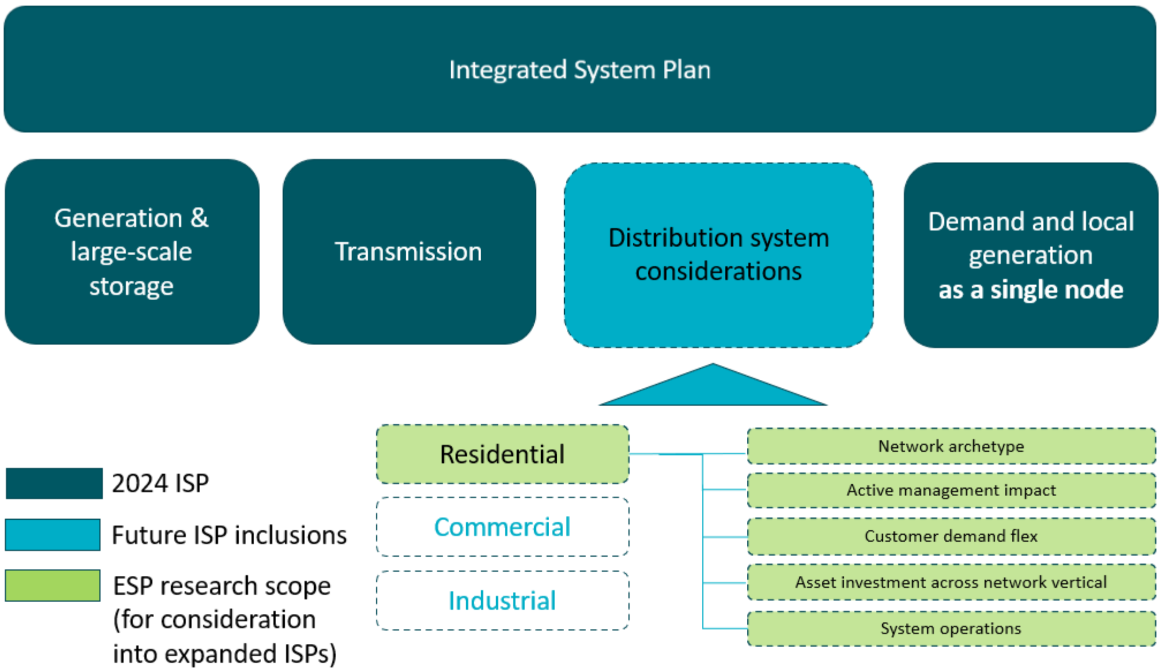


Figure 1 – Relationship between ISP and ESP

This has been addressed through fifteen projects across three distinct work packages:

- **Work package one:** Key inputs, methodologies, and demand network implications of electrification to inform foundational elements of bottom-up modelling.

[1] 2024 Integrated System Plan (ISP), Australian Energy Market Operator, June 2024

[2] Review of the Integrated System Plan: ECMC Response, ECMC, April 2024

- **Work package two**: Impact of flexibility options within distribution networks Techno-economic implications of future architectures.
- **Work package three:** Active distribution network considerations for whole-of-system planning implications: technical, economic and policy.

A key project of work package three, Melbourne University undertook an independent research project: Investment Coupled Whole-System Planning (WP 3.13) to investigate an approach that could coordinate decision-making over transmission and distribution system investments under the current Australian framework in which DNSPs planned for the distribution networks and AEMO planned for the transmission network.

The project proposes a distributed decision-making approach whereby DNSPs produce parametric representations of the investments required (e.g., active network management, distributed storage, network reinforcements) to support DER adoption at multiple levels in the distribution networks, communicating this from LV networks up to HV or sub-transmission level, allowing to hierarchically inform distribution investments for AEMO planners to consider within transmission planning frameworks, enhancing whole-of-system planning. The project conducted case studies to illustrate the potential of this approach that could reveal distributed resources, and the sequence in which they are connected to the distribution networks, to be more competitive than larger scale developments connected to the transmission network. In addition, the case studies illustrated that investment cost could be significantly reduced with higher percentage of CER control/orchestration in the MV/LV level of the distribution networks.

This summary report is designed to guide stakeholders in their understanding of this whole-of-system investment decision-making framework.

In addition, C4NET has sought through this report to summarise and evaluate the research, identify any opportunities or limitations with the approach taken, and highlight any observations or insights for distribution network service providers (DNSPs), regulators and policy makers and market operators and for future research. This has also been done taking into consideration broader consultation and a range of stakeholder views and seeks to maintain a focus on consumers as the beneficiaries of an integrated energy system.

2. Project Summary

Power system planning aims to find cost-effective and reliable investments for the future. However, this problem is increasing in complexity due to new interactions and the integration of new technologies that increase the variability of supply, flexibility requirements, and industry structure that spreads decision-making across multiple players. In particular, the widespread deployment of small-scale assets, while increasing the uncertainty of demand profiles, also offers the potential prospect of increased controllability within distribution networks (e.g., demand response, electric vehicles, distributed storage) and the ability of customers to take control over their own energy demand. Consequently, there is a transition from passive to active distribution networks that will decentralise and impact the planning of power systems worldwide.

A clear example of this trend is in Australia. The Australian Energy Market Operator (AEMO), as depicted in Figure 2, is forecasting a big portion of the available electricity supply assets by 2050 will be in distribution networks in the form of CER storage, rooftop and distributed solar, and demand-side participation. In addition, AEMO estimates that $4.1 billion in large-scale investments could be avoided if such resources are effectively orchestrated[3].

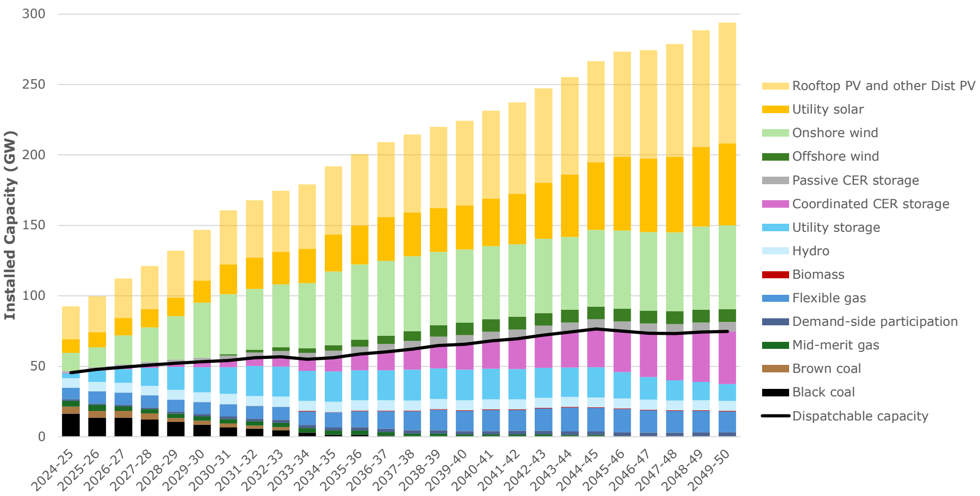


Figure 2 - Expected Installed Capacity, ISP Step-Change Scenario

In this regard, consumer energy resources (CER) and more broadly, distributed energy resources (DER)[4], have the potential to impact planning, deferring, or complementing costly infrastructure investments. Assets like demand response (DR), electric vehicles (EV), distributed generation (DG), storage, and aggregated resources as virtual power plants (VPP) increase the controllability coming from the demand side, enhancing the whole-system flexibility. Consequently, investment in active distribution networks (ADNs) to support CER and its orchestration will be key to facilitate strong supply-demand linkages.

[3] 2024 Integrated System Plan (ISP), Australian Energy Market Operator, June 2024
[4] For the purpose of clarification, in this context, DER refers to resources in front of the meter which can be found in LV/MV/sub-transmission networks whereas CER refers to resources behind the meter and most likely found in LV networks.

Current power system planning practices often consider DERs as an inherent feature of the analysed scenarios in planning processes, and the limitations and investments within distribution networks, without looking at the potential beneficial effects DERs can bring to the broader transmission and distribution systems. Thus, mechanisms to adequately assess and quantify the investments needed at the distribution level to unlock DER's operational flexibility are not accounted for, missing out on trade-offs between large- and small-scale investments. In turn, this may lead to inaccurate assessments of the value provided by these resources, and inefficient and conflicting investments across the system. Moreover, although these challenges have been identified by power system planners across the world, particularly in the UK and Australia, an implementable integrated planning framework within the real world is yet to be found.

In this vein, a paradigm shift is needed in planning frameworks. Integrating ADNs as investment opportunities within an integrated planning process could be key to providing insights on where is more convenient to develop power systems (e.g., large- or small-scale developments). Nevertheless, the lack of coordination and standardised data exchange protocols due to differing scales and scopes between system operators, and the computational challenges of large-scale optimisation formulations, hinder an integrated planning process.

To facilitate integrated planning with a whole-system perspective, this project proposes a bottom-up methodology to represent the planning of active distribution systems management within transmission planning frameworks. The aim is to establish clear methodological steps on how DNSPs can produce information, in the form of a parametric representation of the investments needed within distribution networks that unlock the adoption and orchestration of multiple levels of DER, and communicate that to AEMO to include in their national planning frameworks.

This methodology is based on an investment and operational framework to determine an equivalent representation of active distribution system management's planning, from any reference node (e.g., low, medium or high voltage). Then, this representation is embeded into a transmission planning problem, where whole-system costs are minimised considering distribution systems as investment options. The project's relationship with other research projects in Work Packages 1, 2 & 3 is illustrated in Figure 3.

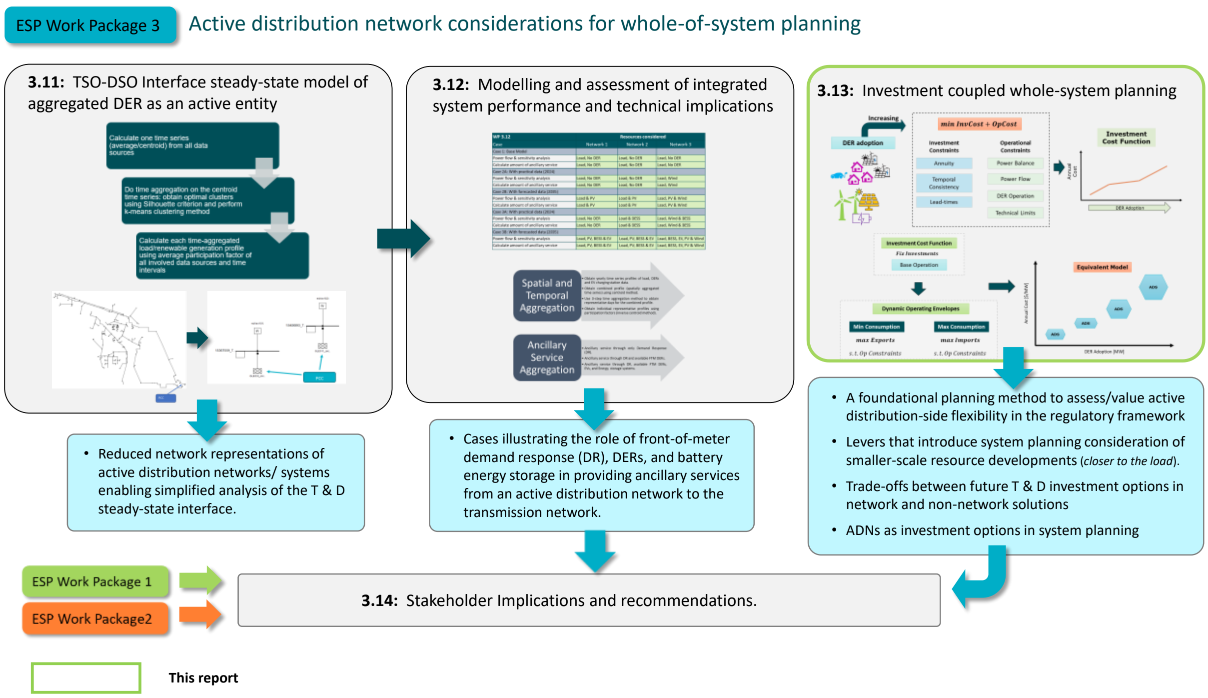


Figure 3 – Relationship between this research project and other projects in Work Packages 1, 2 & 3

3. Research methodology and approach

3.1 Investment framework

As depicted in Figure 4, the project developed an approach based on an investment problem that minimises the investment and operational costs to support DER adoption over a planning horizon, subject to investment and operational constraints at any level of distribution systems. By increasing the DER adoption in the network in an iterative fashion, the optimal portfolio of investments and its corresponding annualised costs (annuity of investments) are found. These are associated with infrastructure, that is distributed storage, network reinforcement, active network management, but could also include the annuity associated with the integration of DER if these assets were considered as investment options within an investment coupled whole-system planning framework. In turn, this iterative process produces a **parametric investment cost function**, which represents the investments needed to unlock these resources.

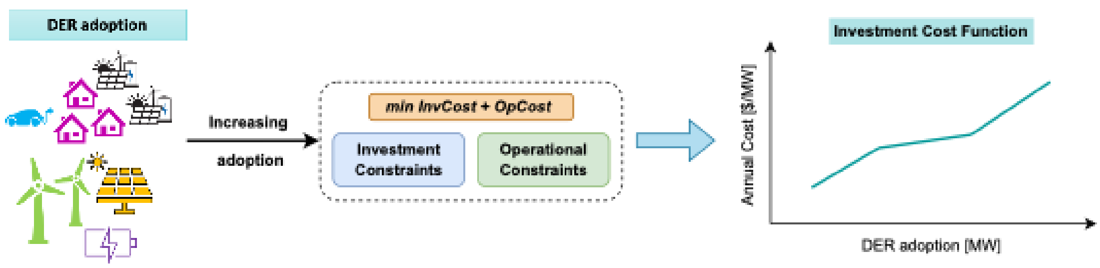


Figure 4 - Investment cost functions for ADNs

3.2 Operational framework

With the investment framework it is possible to value the upgrades needed within distribution networks to support multiple levels of DER, output that can be produced and communicated by DNSPs through their planning frameworks, allowing AEMO planners to take more informed decisions regarding where and what technologies are cost-effective to develop power systems. Nevertheless, from a whole-system modelling point of view, integrating such cost functions do not provide direct information on the operational flexibility that can be leveraged from DER, unless the whole distribution network and DER are modelled in detail (all variables and constraints) which is computationally inhibitive.

To achieve a scalable whole-system planning framework it is crucial to understand how and what is the best method to represent the operational capabilities of distribution systems (within thermal and voltage limitations) that are unlocked by additional DER and investments to support them. In this context, the project developed an operational framework that employs the concept of ***nodal operating envelopes*** **(NOEs)** to characterise the flexibility limits of distribution systems, that is, maximum exports and imports for which the system can securely operate under network constraints, so that distributed resources can be aggregated and efficiently managed from a whole-system perspective.

This information can be produced for each level of DER adoption (and its temporal availability) within the parametric investment cost function and represents a suitable methodology that could be used by DNSPs to inform their network limitations and aggregated resources at different voltage levels, all the way up to the point of connection with the transmission system. As depicted in Figure 5, this methodology follows an iterative process where the base operation of the distribution system for each level of the investment cost function is identified, which allows for analysing the upward and downward flexible capabilities based on DER adoption and investments to support these resources.

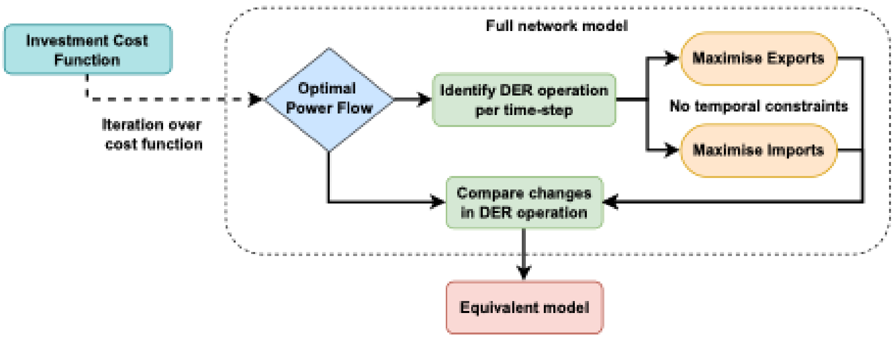


Figure 5 - Operational framework to build equivalent model for ADNs

The NOEs are produced by DNSPs running optimal power flow studies where the objective is to maximise self-consumption with network and temporal constraints given a level of DER adoption. From this operation, the maximum exports (i.e., minimisation of consumption from transmission system) and imports (i.e., maximisation of consumption from transmission system), are identified for each time-step. This allows one to find what and the degree to which flexible assets can change their operation from the base case to support exports and imports. In this context, as DER adoption increases, as well as the investments to support this adoption, the NOEs will increase in size, meaning that more flexibility within distribution systems is available to the upstream network.

Then, distribution system's operational flexibility for each investment path (e.g., parametric cost function) can be characterised with an equivalent model consisting of a generator (renewables, curtailment, and non-renewables), flexible load (inflexible and flexible loads associated with demand response schemes), and storage component, which can be disaggregated to represent the different storage technologies such as batteries, Electric Vehicles (EVs) and thermal storage. These are determined by comparing how flexible assets can change their operational states towards exports and imports compared to the base operation, capturing the power limitations of each component while satisfying network constraints and hence, active distribution systems management can be modelled through the time-varying limits of these components within any transmission planning framework. This is illustrated in Figure 6 by a dynamic representation of the active power associated with the NOE of a given distribution network, where the base operation, maximum imports and exports allow for capturing the time-varying parameters for the equivalent model are determined by analysing the flexibility from DER upwards (green arrows) and downwards (orange arrows).

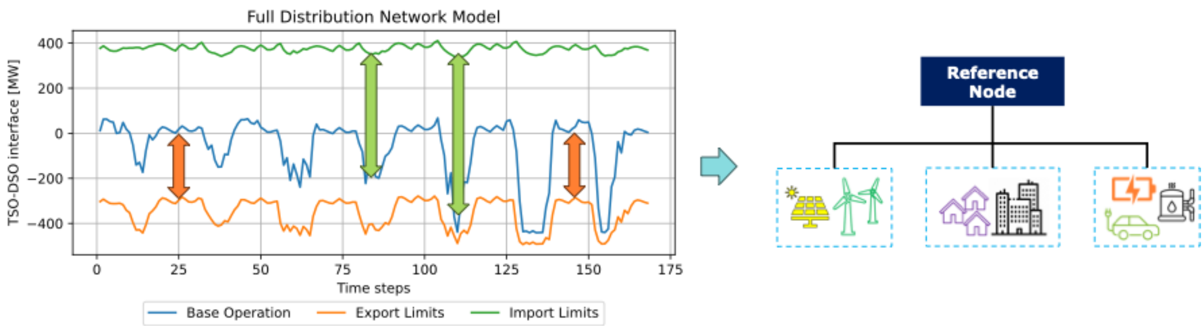


Figure 6 - Characterisation of equivalent model according to dynamic active power operating envelope

3.3 Integrated planning

This section describes the integrated expansion planning model that was developed for this project, emphasising the details behind the inclusion of the parametric planning of active distribution systems (i.e., investment cost and operational capabilities) as "flexible investment options" or as possible "future development paths" as seen in Figure 7. In this context, this whole-system formulation integrates the planning of active distribution system's management within the transmission planning framework, allowing for decision on the optimal participation from the demand side resources, DER, and the corresponding distribution network enhancement alternatives, capturing trade-offs between large- and small-scale developments from a whole-system planning perspective. The approach is based on DNSPs producing information regarding investments and operational capabilities within their networks, which is then communicated to AEMO planners, improving the coordination of the decision-making process.

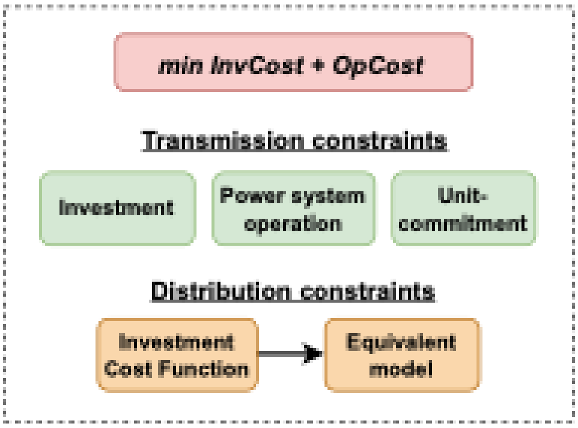


Figure 7 - Distributed framework for investment coupled whole system planning

Moreover, whole-system planning is based on the minimisation of investment and operational costs for a planning horizon for both transmission and distribution systems. The system operational component of the total costs includes operational costs of all generation units and distribution systems, including demand-response bands (based on the ISP 2024) and the cost of energy not supplied to the customers at any given period, which in the context of this study is valued at the current market price cap for the NEM[5]. Therefore, given this formulation, the operational capabilities of distribution systems are managed in a centralised manner by AEMO but based on information produced by DNSPs with their own tools in a decentralised fashion.

Furthermore, the model imposes a set of constraints for investment and operational decisions, which include:

- Transmission investment constraints: these include the so-called non-anticipativity constraints, which guarantee that an investment made at a certain node in the scenario tree will be present in the subsequent nodes connected to said node. These constraints also include the potential rules of investment across the portfolio of options, for instance, investment options that are mutually exclusive, investment options that must follow another investment option, or investment options that must be built simultaneously.
- Distribution investment constraints: these guarantee that only one future path can be optimally selected for a given distribution system representation, which could be one per sub-region within the ISP.
- Power system constraints: these correspond to all the constraints associated to power system operation, including energy balances, reserve provision, power flow, transmission limits, etc.

[5] 2024-25 market price cap. Available at: https://www.aemc.gov.au/news-centre/media-releases/2024-25-market-price-cap-now-available

- Unit-commitment constraints: the operation of conventional generator units in the system is bound by their technical characteristics, for instance, ramping limits, minimum stable generation, start-up times, etc.
- Distribution operational capabilities: these are associated with managing all the components of the equivalent model proposed for this project. That is, renewable generation curtailment, storage operation including state-of-charge constraint, demand response capabilities, and the coupling with the transmission system.

3.4 Application in Australian context

DNSPs using their frameworks, tools, and know-how capabilities, can produce ***bottom-up*** parametric investments and operational capabilities (aggregating resources) for multiple levels of DER adoption based on scenarios, projections, CER orchestration, etc., across all levels of distribution network, going from MV-LV network up to HV or sub-transmission networks, and communicate this to AEMO. AEMO then make whole system investment decisions that coordinate transmission and distribution as depicted in Figure 8. Moreover, DNSPs could compare cases that consider only network reinforcements, and others that account for non-network solutions such as additional DER, active network management, etc., aligned with the methodology proposed in WP 2.9[6] of ESP.

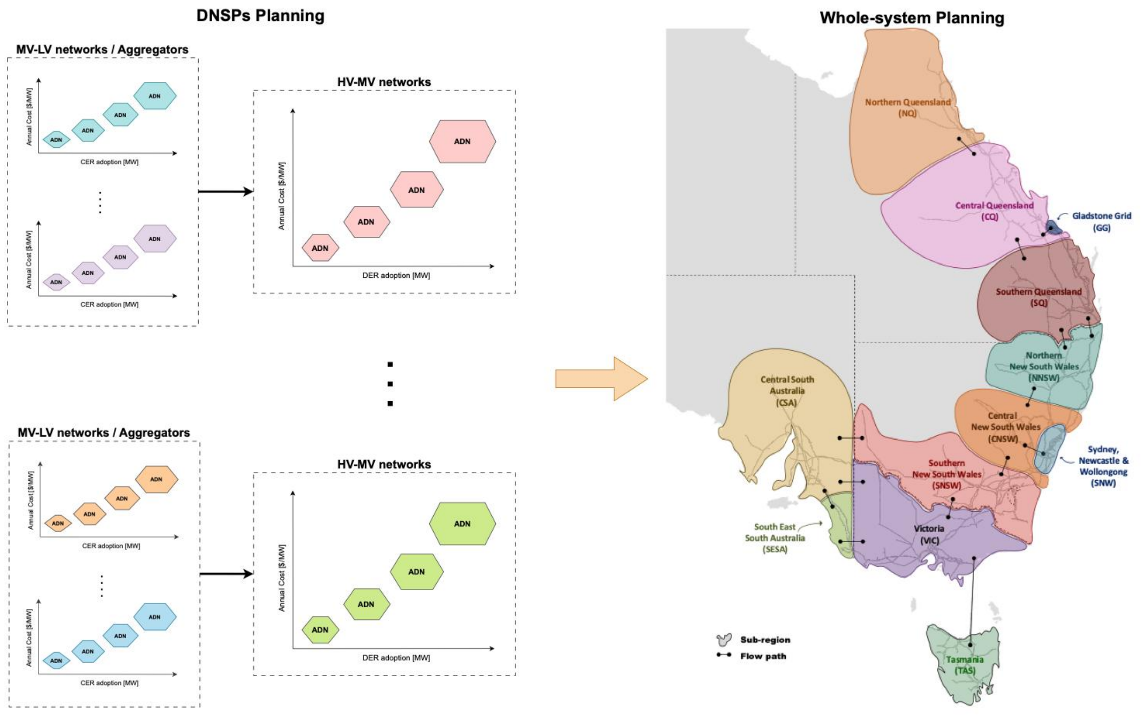


Figure 8 - Whole system planning with communication through proposed planning methodology

The proposed methodology allows for assessing the impact of active network management, non-networks solutions within distribution networks, and the impact of CER orchestration, which could reduce investments in traditional distribution network reinforcements, while also proposing the use of

[6] Techno-Economic Modelling of Non-Network Solutions, WP 2.9, April 2025

NOEs for aggregating distributed resources while accounting for network constraints. In addition, it allows for decision-making over additional DER, considering distribution networks as investment opportunities rather than infrastructure to supports expected adoption of CER.

Finally, to model these constraints effectively, AEMO will collaborate with DNSPs using two approaches. In the **data asset approach** AEMO calculates the volume of CER output being enabled for each distribution data asset, using DNSP-provided network limits and disaggregated AEMO forecasts for CER uptake and consumer load, before being aggregated back up to the sub-regional reference node. Under the **detailed modelling approach**, DNSPs would perform their own analyses using AEMO's forecasts, enabling more accurate estimations of CER integration and network constraint. For both approaches, DNSPs will provide indicative cost curves for distribution augmentation (costs and associated augmentation capacities to enable higher levels of CER operation), that the capacity outlook model uses to choose to build to allow further output of CER to reduce curtailment.

3.5 Summary of case studies

The project conducted a number of case studies to produce investment cost functions using network models (primarily sub-transmission networks) from WP 1.4, DER connection enquiries provided by one Victorian DNSP, C4NET projections of CER uptake (EVs, distributed BESS, rooftop PV, etc.), and investment costs of technologies from AEMO's ISP 2024 inputs and assumptions and public information from DNSPs' regulatory investment tests. The case study outcomes are intended to be illustrative rather than representative.

A summary of the findings from the case studies is given in the following sub-sections. Details can be found in the research report[7].

3.5.1 Proactive distribution planning

Proactively planning distribution networks jointly with expected DER proponents can produce a huge difference in the distribution infrastructure investments that need to be in place. In the case study, the total connection costs of two solar farms (aggregate capacity of 240MW) and a 110MW/220MWh BESS could be significantly reduced (due to time value of money) if the BESS connection was prioritised relative to the two solar farms (Figure 9).

[7] Investment Coupled Whole-System Planning (WP 3.13), Section 5, from page 36.

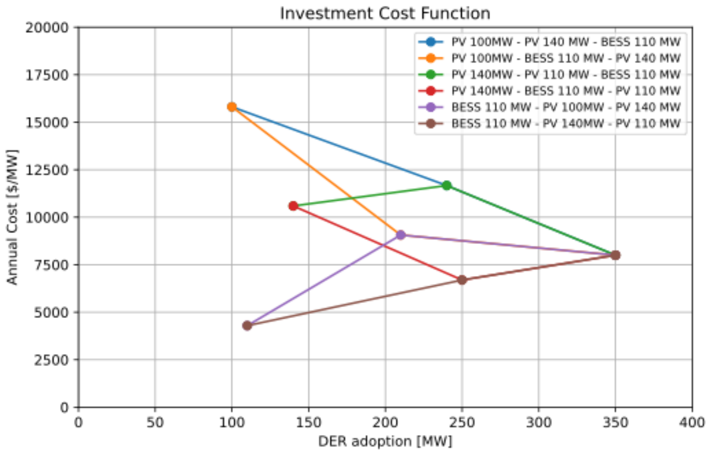


Figure 9 - Investment cost function when proactively planning distribution systems

3.5.2 Active network management as an investment function

Another key option when planning distribution systems is active network management (ANM) and CER orchestration. These would mean that DNSPs can make use of control schemes to operate the network, for instance, by curtailment of renewable generation, and controlling resources to solve some of the local issues that could be faced such as voltage rise and drops or congestions, and in turn, such control schemes could displace traditional investment such as network reinforcements. To showcase this, the same example of solar farms and BESS from 3.5.1 was analysed based on different degree of curtailment. As more curtailment was allowed, the investments needed were reduced, particularly when the solar units were connected. This scheme primarily impacted how much reactive compensation was needed to safely operate the network within the voltage limits, nevertheless, there was an opportunity cost associated with curtailing this energy that needed to be balanced with the investment cost. Currently DNSPs value curtailment using customer export curtailment value (CECV)[8]. In a whole-system planning framework where trade-offs between transmission and distribution investments are captured, it might be cost-effective to either reduce or increase curtailment within distribution networks instead of the “optimal” level of curtailment that would result from distribution planning using CECV.

[8] AER, Customer Export Curtailment Value, June 2022, https://www.aer.gov.au/industry/registers/resources/guidelines/customer-export-curtailment-value-methodology

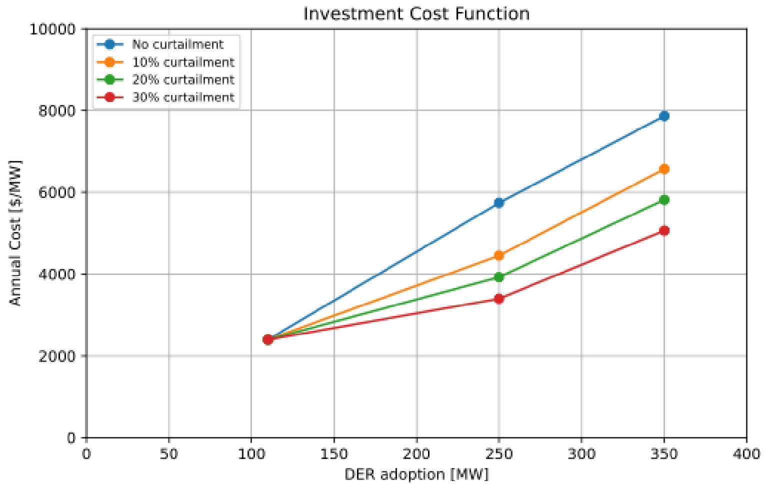


Figure 10- Impact of active network management in the form of curtailment

Furthermore, the orchestration of existing CER will also play a role in accommodating these medium-scale DER. If these resources can be properly controlled, they could unlock additional benefits when proactively planning distribution network and demonstrate how cost-effective additional distributed resources could be. Thus, over the optimal result from proactive planning presented in Figure 9, 75 MW of CER in the form of VPP[9] (as AEMO models CER orchestration in the ISP) were assumed and spread in the sample sub-transmission network according to the peak demand in each zone substation. The computed investment cost function is depicted in Figure 11. Note while controlling CER could have a huge impact in reducing infrastructure costs and allocating additional resources within distribution networks, the exact amount of CER orchestration will depend on the willingness of customers to be controlled.

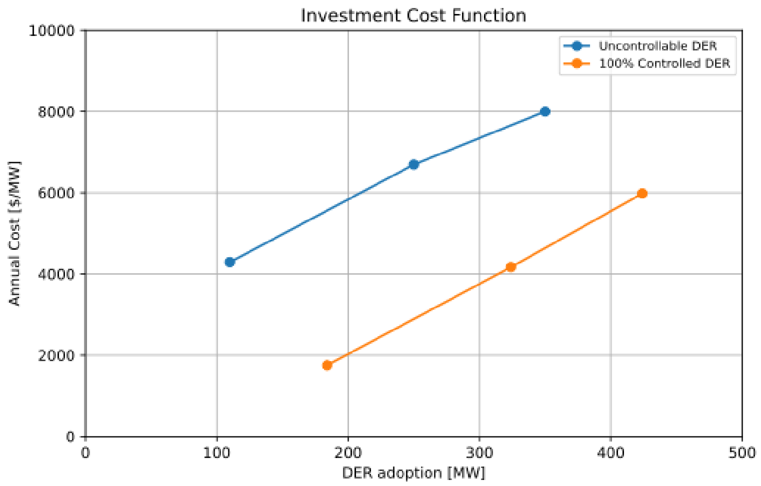


Figure 11 - Impact of orchestrating 75 MW of distributed batteries in the sample sub-transmission network

[9] A VPP is modelled as a storage device with 2.2 hours of duration. This is based on AEMO's inputs and assumptions for the ISP.

3.5.3 Trade-offs between large- and small-scale resources

A case study for the state of Victoria was analysed taking as reference year 2030, aiming at comparing the benefits of developing smaller-scale DER in sub-transmission against transmission augmentations that unlock developing large-scale solar, wind (on and offshore), and BESS within the 8 renewable energy zones (REZ, as defined by AEMO) considered for Victoria as seen in Figure 12.

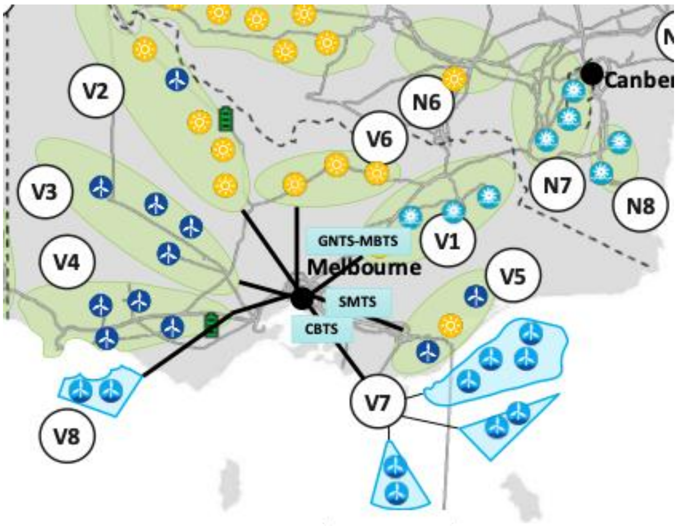


Figure 12 - Renewable energy zones in the state of Victoria

As illustrated in Figure 13, if decision-making over smaller-scale DER is neglected, 13.4 GW of transmission augmentations are needed, unlocking V4, V5, V6, and V7. This is to support the development of 100 MW of solar in V6, and 5.8 GW of wind in V4, V5, V6 and V7 (where offshore wind is developed), plus 4.1 GW of large-scale storage (4 hours) are built in V4.

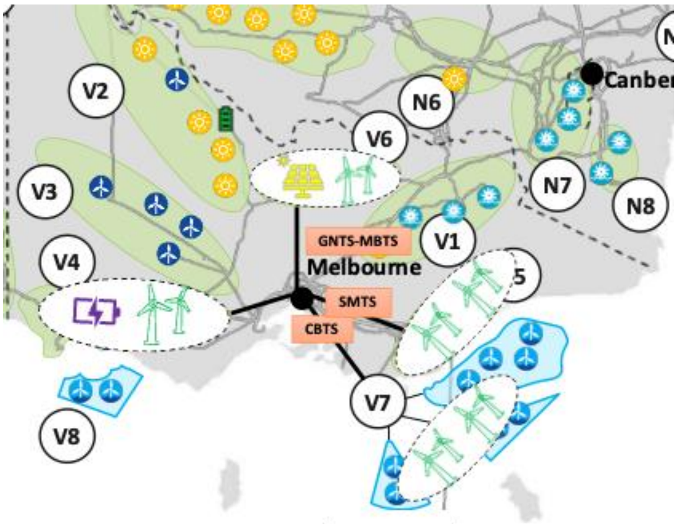


Figure 13 - Victoria's development with no decision-making over smaller-scale DER

On the contrary, as seen in Figure 14, once we unlock the possibility of investing in DER, the total transmission needed is only 8 GW, reduction of 5.4 GW, while developing 800 MW of solar, and 5.4 GW of wind, with only 3.5 GW of large-scale storage, representing a reduction of 600 MW. Therefore, from this simple case study it can be demonstrated that taking a whole-system decision-making perspective allows to develop resources across the system in a more efficient way, combining the development of large- and small-scale resources. As noted previously, these case studies are illustrative, research-based, and thus the input data and assumptions would need to be validated.

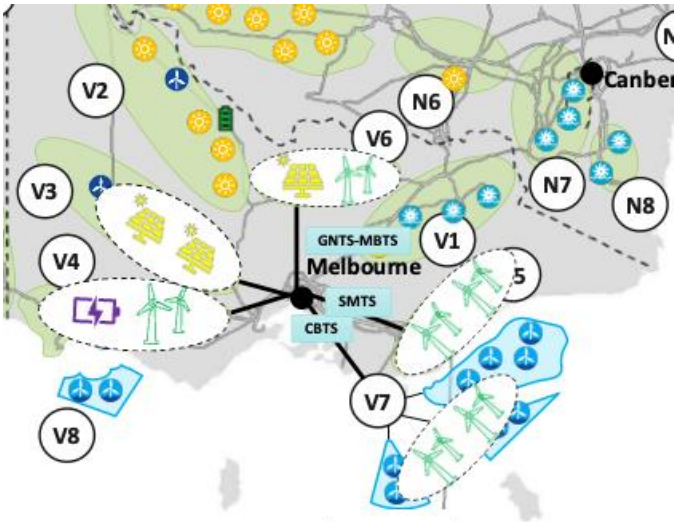


Figure 14 - Victoria's development including decision-making over smaller-scale DER

Moreover, one of the keys for this to happen is the hosting capacity of sub-transmission networks to accommodate larger DER. Depending on this, this adoption can be supported by proactive planning and considerations of non-network solutions such as ANM, reactive compensation, and even CER orchestration (not part of this analysis), reducing infrastructure costs within distribution networks. In turn, developing additional DER could avoid discussions over building transmission augmentations, which face deep uncertainties regarding construction times, costs, and social opposition.

3.5.4 Consequences of CER orchestration

Based on C4NET scenarios and, particularly, early outputs from WP 2.10, the modelling of storage within MV-LV networks (e.g., EVs and DHW) and how much of this is expected, was included in each sub-transmission network used in the modelling to analyse the effect of CER orchestration. However, this analysis does not consider the techno-economic impact within MV-LV networks of unlocking such CER capacity and orchestration, but this needs to be accounted for, to properly understand the investments and limitations deep into distribution systems, as there might be storage that is accessible upstream of the network but is constrained by network capacity and available only for local services.

Figures 15 and 16 illustrate the investment cost functions for reference years 2040 and 2050 respectively, using 0%, 25%, 50%, 75%, and 100% of CER orchestration as parametric approach for planning the sub-transmission networks, where all technologies increase the same percentage per iteration and it includes the controllability cost to unlock these resources. While the results indicate that the investment cost functions differ among sub-transmission networks due to topology and load differences, there are overall reductions in total annual investment costs (network and orchestration infrastructure) due to CER orchestration.

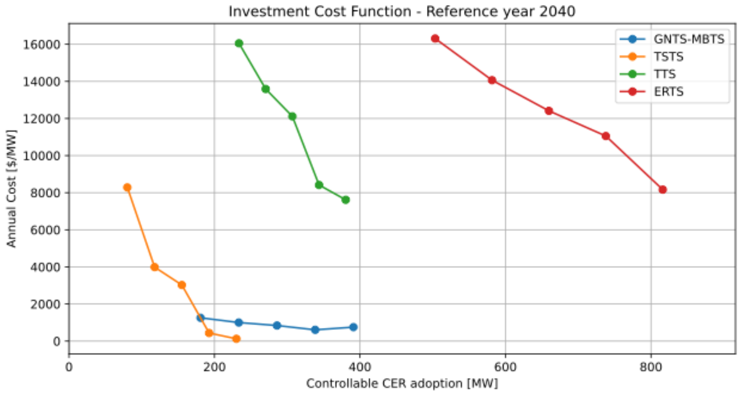


Figure 15 - Impact of CER orchestration on sub-transmission network planning, reference year 2040

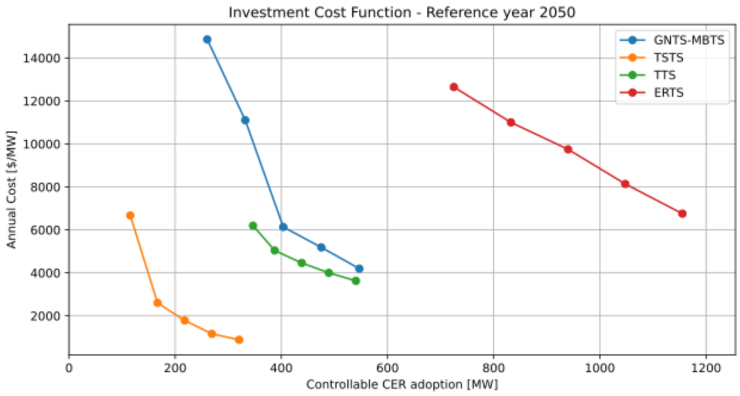


Figure 16 - Impact of CER orchestration on sub-transmission network planning, reference year 2050

4. Observations, insights, and key reflections for stakeholders

Through the evaluation of the work undertaken, C4NET has identified some observations, insights, and key reflections for stakeholders. Outlined below we have summarised these for DNSPs, AEMO, policy makers and researchers, with a section highlighting observations in relation to consumer outcomes. While these are summarised for stakeholder type, this section should be read as a whole to ensure cross-sectoral awareness.

4.1 DNSPs

The widespread deployment of small-scale assets (e.g., electric vehicles, distributed storage, distributed generation) in distribution networks is introducing additional uncertainty within power systems, but they also increase the potential controllability within distribution networks along with the ability of customers to take control over their own energy demand, opening new value streams for them. These new interactions and the transition from passive to active distribution networks are spreading decision-making across multiple levels, increasing the complexity of power system planning.

Current DNSP planning approach generally considers CER/DER as an inherent feature of analysed scenarios, as well as the limitations and investments needed within distribution networks to support such technologies. There are a few examples of flexibility introduced by aggregated CER/DER being pursued as non-network solutions to distribution network constraints. Joint planning between AEMO and DNSPs occur only at transmission connection asset level, and even then, the focus of the planning is primarily to do with maximum and minimum demand forecast and asset capability.

The project has gone much further to propose an integrated whole-system planning framework for transmission and distribution networks to capture the full value of CER/DER and conducted case studies to illustrate the benefits and practicality of the approach. The process involves DNSPs producing a parametric representation of the investments required (e.g., active network management, distributed storage, network reinforcements) to support DER adoption at multiple levels in distribution networks, communicating this from LV networks up to HV or sub-transmission level, allowing to hierarchically inform distribution investments for AEMO planners to consider within transmission planning frameworks, enhancing coordination.

In this sense, there could be trade-offs between the provision of local services and investments in network reinforcements, as DNSPs could plan distribution networks by minimising costs, leveraging CER orchestration to reduce investments, or even communicate future portfolios where additional investments are in place for this CER to provide services upstream the system at the national level (e.g., transmission system), which may not be the minimum cost solution for the distribution system but rather for the whole system (unlocking huge value at the transmission level). While the current regulatory framework does not prevent DNSPs considering other benefits (e.g. system benefits) in their investment decision-making, those benefits would need to be assured, and this can only be achieved through an integrated whole-system planning approach.

To produce the parametric representation, DNSP would need a deeper understanding of the limitations of their networks and the subsequent investments that would be needed to unlock distributed resources and operational flexibility (e.g., dynamic operating envelopes, equivalent models, ADN technologies etc.). It is recommended that DNSPs invest in the capability to produce accurate parametric representation that can be used in the proposed whole-system planning approach, including acquisition of accurate network data and potential trials of ADN technologies to gauge their technical/cost effectiveness.

4.2 AEMO

AEMO has begun to develop a methodology to integrate distribution network capabilities and opportunities for CER and DER within the ISP[10]. The proposed methodology in this research report is well aligned with the one proposed in this work package as it is based on a decentralised approach, where to account for distribution network constraints, AEMO will consider two main limitations: the operational constraints of CER due to distribution network limitations and constraints on the uptake of CER and additional DER. These constraints ensure that the distribution network, and possible augmentations, can support CER and more broadly, DER, integration without exceeding its capacity. The parametric representation and operational capability (in the form of NOE) proposed by this framework, developed by DNSPs, will provide the information as required by AEMO. In addition, feedback from AEMO will also assist DNSP's investment decision-making to unlock further the benefits of CER/DER.

AEMO's consideration and endorsement of the planning framework, together with DNSP acceptance and support, will be important to facilitate whole-of-system planning. It is recognised that the process of integrating CER/DER and distribution network consideration into whole-of-system planning will take time to implement and mature. In this regard, a roadmap for the evolution of ISP to reach the end goal is highly recommended.

4.3 Policy makers

The illustrative case studies demonstrate the potential huge benefits that come from aggregating and orchestrating CER/DER, not just for solving distribution network constraints but applicable for optimising transmission network investments including renewable energy zones, under the proposed whole-system investment framework.

[10] AEMO, "Draft ISP Methodology," 2025

The framework is applicable for the existing industry structure of de-centralised decision-making, with DNSPs performing planning for the distribution networks and AEMO planning for the transmission network. The form and way of communication and coordination between DNSPs and AEMO would need to be enhanced. Regulatory change may be required to the way investments in the sub-transmission network are valued/treated, particularly the combination of ADN functionality with DER that services both distribution and transmission needs.

It is recommended that policy makers give due consideration to the adoption of the proposed framework.

In addition, the case studies demonstrate coordination/orchestration of CER/DER can provide significant benefits when enabled by DNSP investment in ADN capability. However, apart from technology enablement, customer participation is key to achieving a high percentage of coordination. Policy makers can play a significant role in facilitating customer participation through market and policy developments.

4.4 Consumer

Consumers will ultimately benefit from any reduction of infrastructure costs through lower network charges. Many of the sub-transmission connection opportunities investigated in this project have no operational impact on consumers. While further savings to be gained from deeper integration at MV/LV level will require active customer participation, the degree of consumer engagement and participation will depend on their willingness to participate, and this will likely depend on having the appropriate incentives to do so.

4.5 Research

The project proposes the concept of NOEs to be developed for different voltage levels of the distribution networks. In the case studies, the NOEs are developed at the nodal interface (e.g. sub-transmission interface at a particular transmission terminal station) using optimal power flow algorithm. While the concept is relatively straightforward, the development of NOEs at the lower voltage levels, e.g. MV/LV, and the mechanism to “cascade” these NOEs to an upstream interface (e.g. sub-transmission interface) is not trivia. This can be a further research direction which will assist in the smooth uptake of the planning framework.

Appendix One

Researcher profile

Conducted by: University of Melbourne, Melbourne

Lead Researcher: Cristian Alcarruz Olivos

Research Team: Prof. Pierluigi Mancarella

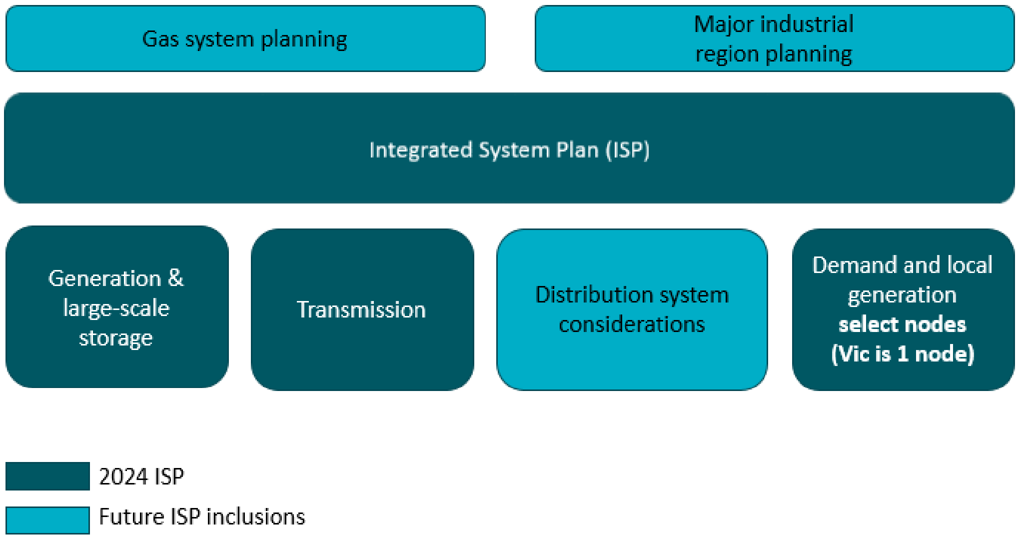
About C4NET

C4NET delivers multi-disciplinary solutions to the challenges the energy industry is facing. Working with complexity requires diverse skills, reliable data, and new approaches, which C4NET facilitates by bringing together governments, industry, and universities, creating new links across the sector.

Central to C4NET's program of work is the Enhanced System Planning (ESP) project, a significant and collaborative research project aimed at informing sub transmission level electricity planning beyond 2030, with a focus on building methodologies and approaches for bottom-up modelling and to highlight the opportunities presented through the distribution system and integrating Consumer Energy Resources (CER), to inform whole of system planning.

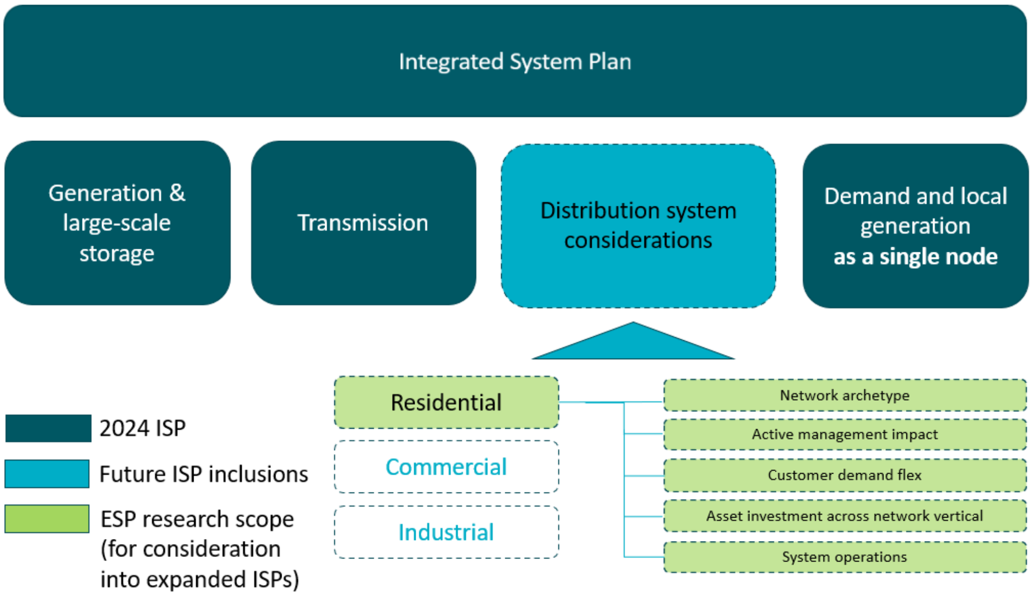
Appendix Two – Bigger picture integration with the ISP

Shift towards whole of system planning



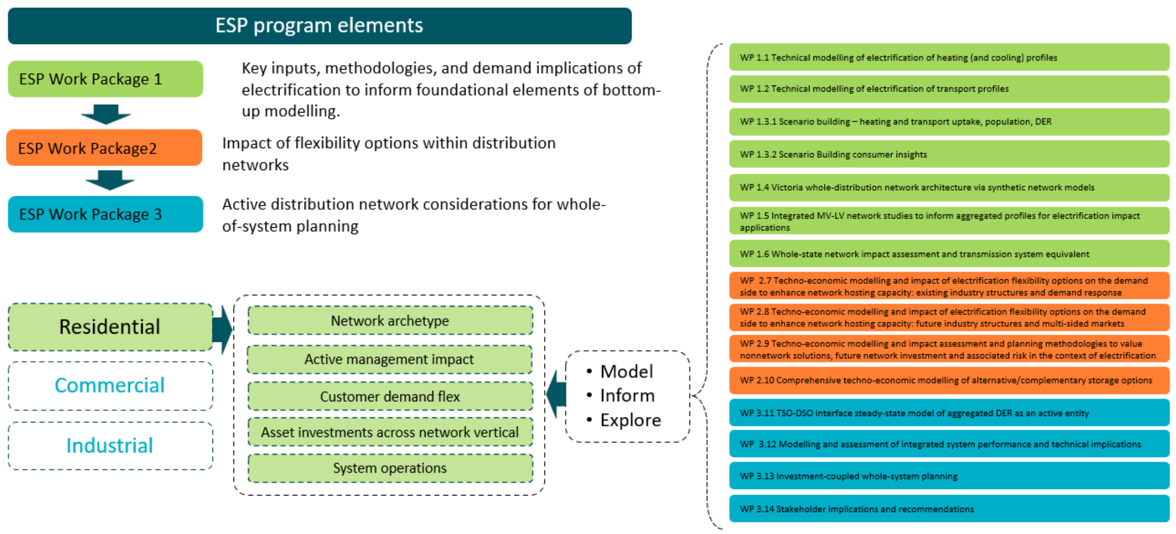
The Energy and Climate Change Ministerial Council (ECMC) accepted the recommendations of the review of the ISP which target transformation of the energy system as a whole, with particular reference to gas system planning, major industrial region planning and distribution systems.

Distribution system components of whole of system planning

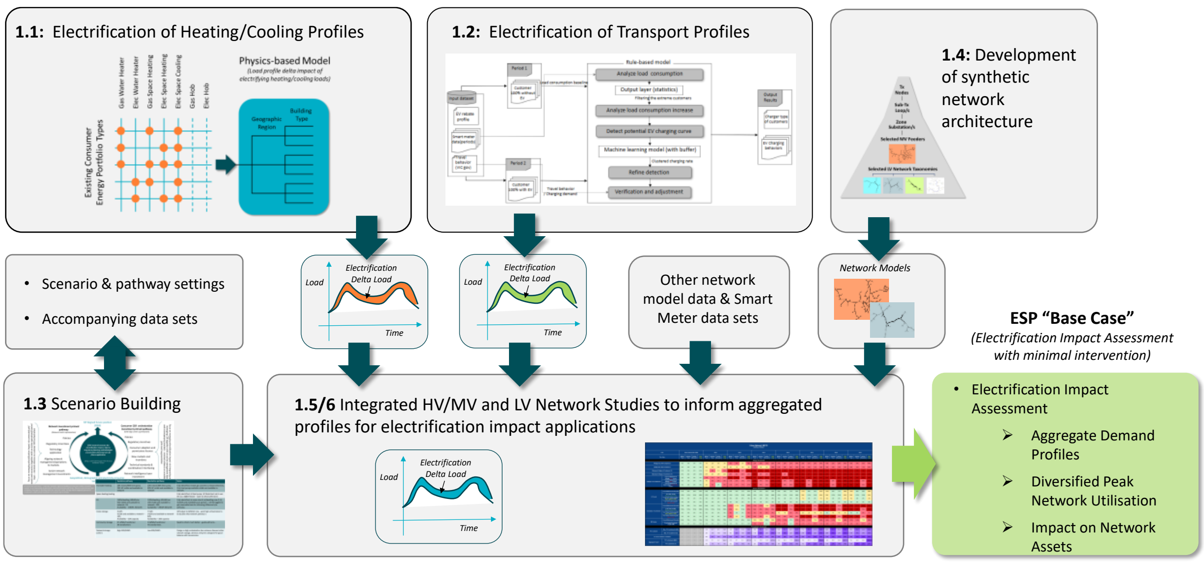


The ESP was scoped to be deliverable with the resources and time at hand to inform feasibility of broader application. It focussed on the more complex areas around residential and low voltage assets of the distribution system, with an application across Victorian networks with methodologies applicable to any region in the NEM.

ESP alignment with distribution system components of whole of system planning



The 'base case' for residential electrification impact assessment, the flex options and relativity to other investment options



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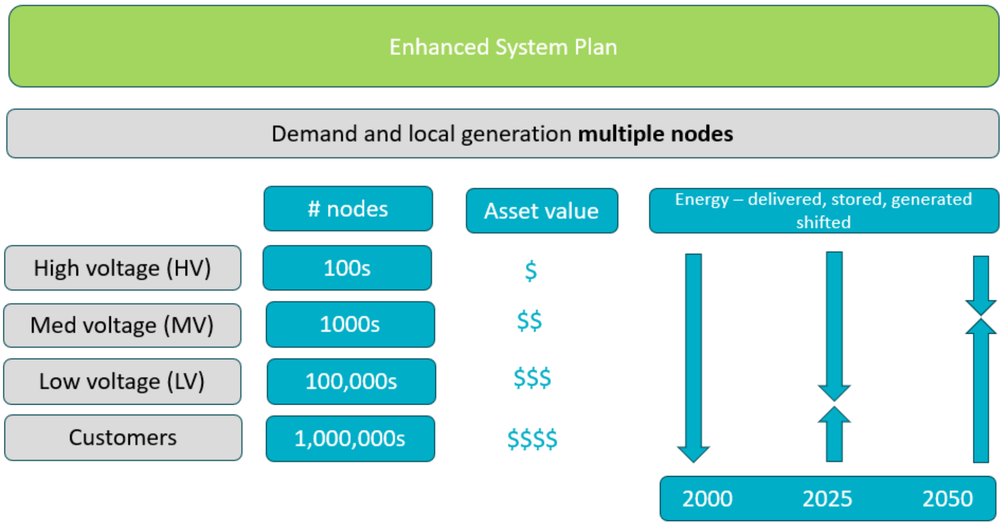
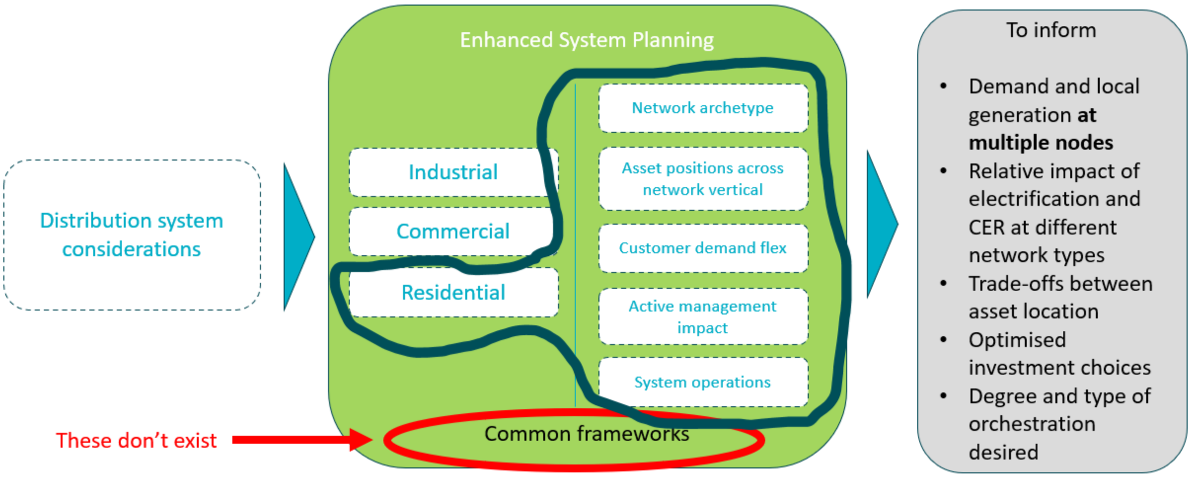
Elements needed to meaningfully inform distribution system aspects in whole of system planning



Methodological gaps in whole of system planning



Appendix Three – ESP project and research partners