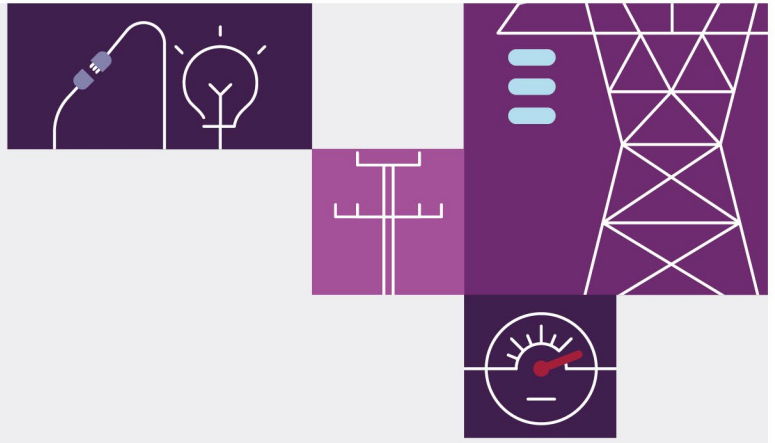


AEMO Connections Simulation Tool

October 2023

Project Overview and Lessons
Learnt





Important notice

Purpose

The purpose of this publication is to document the objectives, achievements and lessons learnt in relation to the implementation and initial operation of the AEMO Connections Simulation Tool.

This document fulfils AEMO's obligation under the ARENA Funding Agreement to provide a public report at the conclusion of the project.

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Acknowledgement

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Executive summary

This project aims to develop a Connections Simulation Tool (CST) to help developers, Network Service Providers (NSPs), and AEMO collaborate using common data sets to rapidly verify that prospective generators can be safely connected to the electricity network.

Connection applicants can utilise the CST to perform studies incorporating new plant models with the same large-scale power system model used internally by AEMO to assess connection applications. In doing so, connection applicants are able to better design their generating system and have increased confidence that the study outcomes will meet the required acceptance criteria. The objective is to significantly streamline the application process, reducing the risk, costs, and completion timeframe.

The implementation of the CST was a complex software development project which incorporated new capabilities, including:

- Implementation of cyber security measures that allowed AEMO to receive plant models (including executable files) via AEMO's public web portal, and
- Automation of the "on-demand" creation of virtual machines with preconfigured PSCAD applications.

Throughout the implementation of the CST, working groups, trial users and respondents to a request for Expression of Interest all indicated strong support for the CST, with 54 positive responses across a range of project types. Since the CST was launched in November 2022, 14 organisations have signed Service Access Agreements to enable the use of the CST, with two organisations actively using the CST currently.

The initial users have confirmed that the CST has benefited their connection applications, delivering:

- The ability to assess their new plant models connected to a full NEM model, and with AEMO's support assessed their model against project specific settings, measurements and faults
- AEMO cloud infrastructure and AEMO supplied PSCAD licences, avoiding the need to invest in their own systems.

AEMO continues to engage with industry to promote the benefits of the CST, and develop complementary tools and approaches.



Contents

Executive summary	3
1 Project Summary	5
2 Project Scope	7
3 Implementation	8
3.1 Minimum Viable Product (MVP)	8
3.2 Beta Version	8
3.3 Industry Trial	8
3.4 Launch Preparation	9
3.5 Launch	9
3.6 Post Launch	9
4 Lessons Learnt	11
4.1 Lesson 1: Industry need for better access to power system models to reduce the time and cost for connection approvals.	11
4.2 Lesson 2: Need for enhanced capabilities to provide more benefit to users.	11
4.3 Lesson 3: Uptake of the service	12
5 Transferability	13
5.1 Reuse of developed capabilities	13
5.2 Deployment in other jurisdictions	13
6 Conclusion and Next Steps	14
A1. Industry Feedback following Industry Trial (Aug 2022)	15
A2. Pre-launch Expressions of Interest	16
A3. Potential Enhancements	17
Glossary	18

Figures

Figure 1 Stakeholder Engagement	8
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1 Project Summary

Securing a new grid connection for renewables has become a barrier to the transition of Australia's energy system away from traditional energy sources.

The connection application process for renewables can be a complex process. With the exponential increase in connection applications in Australia's National Electricity Market (NEM) over the last 2-3 years, incentivised by the introduction of state and federal renewable energy targets, the power system has been inundated with connected technologies that are less predictable in output and highly responsive to power system changes.

To identify and understand the interactions of connecting generation and storage plant with the power system, AEMO has developed a detailed four-state power system model.

The importance of maintaining the intellectual property of Original Equipment Manufacturers (OEMs) - in a time of high competition when new product versions are regularly released to address historical performance issues, provide greater responsiveness and flexibility or grid forming capabilities - has required AEMO to restrict access to and use of its detailed four state power system model. Essentially, this means that no connection applicants are able to use AEMO's four-state power system model when developing and testing the performance of their plant model.

This means that connection applicants are unable to fully understand and prepare for the interactions their plant model may have with the power system, as modelled by AEMO. This creates a highly uncertain environment for developers and investors during the connection application process. They have limited reassurance as to the potential success of their plant in demonstrating acceptable performance when incorporated into AEMO's detailed power system model as part of the connection application assessment process.

A world first, the Connections Simulation Tool provides developers, OEMs and consultants across the majority of the National Electricity Market (NEM) with the ability to run studies against AEMO's four-state model whilst protecting plant confidentiality.

The tool is an optional, fee-for-use service that is designed to be independent of, but support, the connection process. It enables users to independently use AEMO's four state model - the same model used by AEMO to assess a connection as part of the connection application process. This allows users to identify any issues that might arise in the project's interaction with the power system under different operating conditions - of the power system or newly connected plant.

Having identified any issues, users are then able to test potential solutions to these issues. This allows them to develop high-quality plant models in preparation for the connection application process. During this process, users are able to request the assistance of AEMO support staff in fully representing and understanding the behaviour of their plant model.

Because these plant models have been developed, tested and enhanced using the same model that AEMO will use in assessing connection applications, developers and investors can be confident that these plant models will require fewer approval iterations, reducing the time and cost to connect.

Commercial and technical confidentiality of all plant and network models represented within AEMO's four-state model is also preserved throughout the process.

The service aims to provide:

Greater Confidence in Studies

Connection applicants will be able to design their connecting plant better, accounting for performance and modelling issues that arise from integration to a more accurate representation of the NEM than would otherwise be available to them.

Faster Application Process

Utilising a full NEM power system model will provide applicants with data and insights that may reduce the risk of unforeseen performance or modelling issues arising in AEMO's and the NSP's detailed connection studies process and may reduce the number of iterations required to complete the connections process.

The approval process will, therefore, be streamlined, reducing risk, cost and time.

Further information, including a User Guide, an industry webinar and the pricing schedule, are available on AEMO's website at <https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/network-connections/connections-simulation-tool>.

2 Project Scope

AEMO developed the tool to allow connection applicants to perform studies that integrate their new plant models with the same large-scale EMT ¹power system model that is used internally by AEMO to assess connection applications. Without the CST, applicants are restricted to designing and testing many aspects of their plant in isolation against simplistic Single Machine Infinite Bus (SMIBs) model representations, without visibility of the plant behaviours that occur when integrated into a detailed representation of the power system.

The Connections Simulation Tool project scope included the development of three major functions:

1. EMT models and supporting automation tools configured such that users can test their own plant and its interactions with the full NEM model, without accessing the full NEM model and the confidential models therein
2. A web portal to enable the creation and management of users “Cases”, including upload of EMT plant models
3. A capability to create, on demand, a group of cloud-based virtual machines running the PSCAD models for each Case.

As well as preparation of:

4. A pricing model for the use of the CST on a cost-recovery basis
5. Tools to track engineering hours and usage, for monthly billing
6. Terms of usage, referred to as a “System Access Agreement”
7. Business processes and operational document for AEMO staff; and
8. User documentation for the CST service.

The CST functionality was developed in close consultation with industry stakeholders as described below.

Following consultation with Network Service Providers (NSPs), it was decided that the CST model seen by users would include their submitted plant and the Point of Connection (PoC). Neighbouring network elements and plants would not be visible.

¹ High resolution Electromagnetic Transient (EMT) studies are required to determine the behaviour of new plant and particularly for inverter based renewable resources. Information on the network connections process and modelling requirements are available on AEMO's website: <https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/network-connections>

3 Implementation

The project has extensively engaged with industry and ARENA. From early in the project, it was seen that the success of the Connections Simulation Tool required direct industry engagement. The project worked collaboratively with the industry and engaged with the industry groups described below to understand and address their needs in the solution.



Figure 1 Stakeholder Engagement

3.1 Minimum Viable Product (MVP)

Initially, an MVP version of the CST was developed to address the function (1) as described above. Three trial users tested the service, providing valuable feedback on the functionality, useability and draft documentation.

3.2 Beta Version

The next development stage delivered a Beta version covering the major functions (1), (2) and (3) as described in Section 2 above. During the development, AEMO convened regular meetings with the Industry Working Group to demonstrate CST functionality and receive feedback that could be incorporated into the ongoing development of the CST.

3.3 Industry Trial

Six trial users, representing project developers, consultants and OEMs, were given access to the Beta version of the trial. During this pilot, the end-to-end process was tested:

- user accounts were created
- trial users submitted cases and provided "real-life" plant models via the web portal

- AEMO engineers configured the cases and created the PSCAD study environments on dedicated virtual machines for each user organisation
- users ran studies and received results
- Sample invoices were generated.

The users provided valuable feedback through regular meetings and a detailed survey. Key findings included the unanimous agreement that “The Connections Simulation Tool will be valuable to renewable plant developers and their collaborators” and did not highlight “anything fundamentally missing from the current solution that is required before it is released”.

3.4 Launch Preparation

Before launch, AEMO consulted with several stakeholders, sharing a proposed pricing model and the underlying assumptions, such as number of new and re-created cases per year and the duration of each Case. Feedback from an industry reference group resulted in adjustments to these assumptions and an updated pricing model. While final feedback from the reference group varied, all felt the pricing model was “workable”.

To gauge interest and prepare for a smooth launch, AEMO sought Expressions of Interest (EOIs) from potential users of the CST. As shown in the EOI Responses Summary in Appendix A2, there were 54 responses across a range of project types. Based on the strong response, AEMO organised sufficient staff and processes to manage the anticipated demand.

3.5 Launch

On 16 November 2022, AEMO launched the CST with industry and potential users through emails and industry forums. More broadly, a media release and social media content were issued, helping achieve widespread media coverage. (<https://aemo.com.au/newsroom/media-release/aemo-launches-world-first-generation-connections-tool>).

AEMO held an industry webinar in December 2022 to further promote the CST. The recording is available on AEMO’s website (https://aemo.com.au/-/media/files/electricity/nem/network_connections/connection-simulation-tool/connection-simulation-tool-industry-webinar-20221214_133113-meeting-recording.mp4?la=en&hash=DDA1C086BCDFBFB52BBCA8C409E8D39A). AEMO also presented to the Energy Systems Integration Group (ESIG) in March 2023.

3.6 Post Launch

In the first six months of operation, there have been at least 40 enquiries, which, by mid-2023, have resulted in 14 organisations signing Service Access Agreements, which enable access to the CST. This indicates strong buy-in to adopt the CST as a form of risk mitigation for future projects.

Two organisations have proceeded to create cases and actively use the CST to run studies. The first user used the CST for five weeks, and their experience is described in the case study below:

CASE STUDY

Project type:	Battery Energy Storage System (BESS)
User type:	OEM engineering team, engaged by project developer
Connection Application stage:	Enquiry
Reason for using the CST:	Evaluation of plant and model tuning in preparation for later FIAs
Studies performed:	Approximately 15 studies run over a 5 week period, testing several fault types.
Issues encountered:	Found interaction with model through the portal was slow and occasional disconnections from the tool.
Customer feedback:	“Can justify the use of the CST. The CST was really helpful for tuning models”. “Access to the wider network was helpful. The CST enabled studies that would not have been possible without the full NEM wide-area model”. “Yes, happy to use the CST again, preferably with IT issues resolved”

4 Lessons Learnt

AEMO has identified the following three key learnings from the development of the CST during the first six months of operation.

4.1 Lesson 1: Industry need for better access to power system models to reduce the time and cost for connection approvals.

Before the introduction of the CST, applicants have been unable to test plant models interacting with a full NEM model and have been forced to assess their models against simplified SMIB models. This has made it very challenging for applicants to fault-find and tune their models, creating a highly uncertain environment for developers, OEMs and investors when designing a project and preparing for the connection application process.

Unanticipated issues can introduce significant delays and costs into the connection application approval process, particularly if issues can only be solved by adding or redesigning physical plant assets. The CST enables users to identify these issues in the design phase of the project, before project budgets have been finalised and financial investment decisions made. This provides all parties – developers, OEMs and investors – an opportunity to better understand the plant's challenges based on its specific location, size and technology.

This provides for:

- more informed decisions about the plant's likelihood of success, and its potential return on investment
- greater flexibility in exploring solutions to address any issues identified, with dedicated support from AEMO technical experts
- an ability to test and tune solutions prior to submitting a connection application.

Feedback throughout the project from trial users, the Stakeholder Reference Groups, surveys, and the initial operational user have all validated these benefits. Furthermore, the strong response to the pre-launch Expression of Interest indicates significant support for tools that provide access to detailed EMT power system models.

4.2 Lesson 2: Need for enhanced capabilities to provide more benefit to users.

Feedback from stakeholders has indicated that enhancements to the CST will benefit users.

This feedback suggests the highest priority enhancement should be increased network visibility, whereby users can interact with network elements beyond just the Point of Connection for the tested plant. This extended network visibility would significantly expand the ability of the user to make changes to their study scenarios and their study outputs within the tool without AEMO-side intervention. This allows users additional ability to investigate their impact on the wider network, and allows them much greater flexibility in the application and study of any proposed solutions to issues found. The initial arrangement results from industry consultation and seeking to balance security, commercial sensitivity, and creating a valuable solution.

A summary of the enhancements identified for possible future release of the CST are shown in Appendix A3.

4.3 Lesson 3: Uptake of the service

The table below notes the key themes identified by stakeholders when asked about their use of the CST.

Feedback from stakeholders	AEMO action
<p>Developers have experienced unanticipated higher plant development costs due to global inflation, skilled labour shortages, and higher insurance costs. These issues have caused developers to delay their projects to either redesign or refinance them, delaying the connection application process.</p> <p>In some cases, the costs identified above have translated into potential CST users cutting down on optional costs such as using the CST.</p>	<p>AEMO is reviewing the fee structure of the CST to balance upfront costs against ongoing costs for use of the tool.</p>
<p>Plant model development delays, such as in scenarios of OEM or NSP driven changes. Some registered CST users are impacted by such changes, leading them to delay the use of the CST.</p>	<p>N/A</p>
<p>An initial hurdle has been the legal review of CST agreements taking a long time for certain organisations, which has meant some projects progressing beyond the need for CST.</p>	<p>Now that these organisations have their CST agreements set up, they should be equipped to readily use the CST for their next projects.</p> <p>AEMO is also investigating any avenues for making the CST agreement negotiation a simpler process in future.</p>
<p>CST requires additional functionality to make it more valuable for proponents, as noted in Section 4.2. The key additional functionality highlighted has been greater visibility of the surrounding network and closely located plant.</p>	<p>Appendix A3 provides the enhancements being considered by AEMO in a future release of the CST, with network visibility being the highest priority item.</p>
<p>CST users can be unaware of all the benefits that can be achieved by using the CST.</p>	<p>AEMO continues to promote the CST's benefits in its discussions with developers, OEMs and consultants. AEMO is also promoting the use and benefits of the CST in international forums and with international market operators.</p>

5 Transferability

5.1 Reuse of developed capabilities

The building of the CST platform required the development of a number of software tools. Of the various tools, two can potentially be re-used by AEMO's engineering teams, including those that assess connection applications:

1. The ability to upload power system models (incorporating executable code) via AEMO's web portal, while adhering to enhanced cybersecurity requirements targeted to meet the updated Security best practice guidelines
2. The ability to create "on-demand" cloud-based virtual machines to run PSCAD studies using preconfigured power system models
3. A robust and collaborative model management platform for storing and maintaining the wide-area PSCAD EMT models
4. The security and legal procedures for allowing external party access to systems that are adjacent to, and which interact with, AEMO internal systems.

5.2 Deployment in other jurisdictions

There has been interest in AEMO's experience in developing the CST and possible deployment from Western Power, as well as international network operators such as National Grid. One international system operator would consider using a CST-like application as a mandatory step in their connection applications.

6 Conclusion and Next Steps

The CST can provide considerable value to industry, reducing the risk and cost of connection projects, as well as reducing the likelihood of delays and unanticipated issues in connection application processes. Feedback from initial operational and trial users indicates that the CST provides material value in minimising project risk and increasing project confidence.

The CST provides access to AEMO's PSCAD wide area model, powerful Azure Cloud virtual machines, PSCAD licences, and access to AEMO Engineers to support connection studies. These capabilities are largely proprietary in nature to AEMO and provide a unique value proposition for developers and OEMs.

Recognising this, there are a number of enhancements, as described in section 4.2, that AEMO is considering implementing to improve the usability and effectiveness of the CST. AEMO will continue to enhance the CST to deliver greater network visibility and ease of use, and offer the CST service to project developers, OEMS and their consulting engineers.

Performance issues raised by the initial user have already been addressed. This is expected to benefit the experience of subsequent users of the tool.

To enhance user value, AEMO will:

- Engage with NSPs to review the user's visibility of the network adjacent to the Point of Connection, and key network interactions
- Where possible, implement the enhancements identified in Appendix 3. Those identified as having high user value will take precedence, particularly introducing greater network visibility (noted above) and network equivalency
- Review the pricing model for the CST to rebalance upfront and ongoing costs to users.

AEMO will continue to promote the unique benefits of the CST:

- during ongoing discussions with developers, OEMs and consultants,
- in network and market operator collaboration and research forums (both domestic and international)
- at domestic and international conferences.

A1. Industry Feedback following Industry Trial (Aug 2022)

Pilot period: 25/7 – 3/9
Survey date: 16-18 Aug



Connections Simulation Tool Industry Feedback

This report covers weekly feedback meetings and a survey that was received from 6 external users across all organisations

Trial users see value in the tool and consider the solution ready

Agreement with statement “The Connections Simulation Tool will be valuable to renewable plant developers and their collaborators”

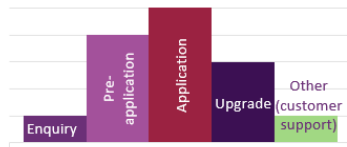


“Is there anything fundamentally missing from the current solution that is required before it is released?”

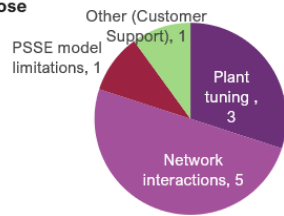


Predicted Usage Pattern

Phase



Purpose



When: Overnight and weekdays
Duration: 1-3 weeks
Location: Global

Expected usage primarily for connections applications and upgrades aligning to the early project assumptions

Solution Feedback

Overall the solution had a positive ratings. N/A ratings can be attributed to:

- One organisation was unable to run studies as their set up was not compatible with the pilot security steps.
- Some users did not complete requested tasks.
- One member from each organisation was sent invoices.

User access management

Creating cases

Viewing and updating cases

Running studies

Closing cases

Ease of use

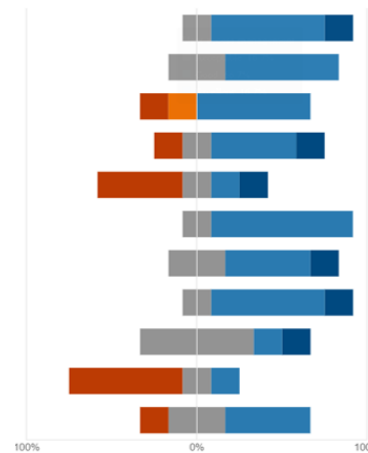
System Navigation

Terminology and language

Support (mailbox and guides)

Billing process

End to end process

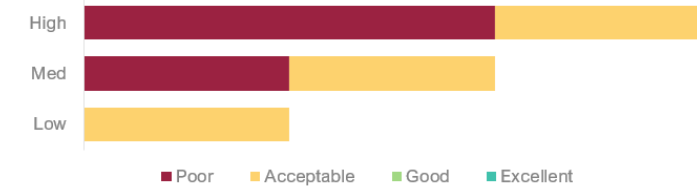


Legend: N/A, Poor, Acceptable, Good, Excellent

Due to a security risk an interim measure was introduced for access during the pilot. As this is not part of the R1 solution related feedback is not included.

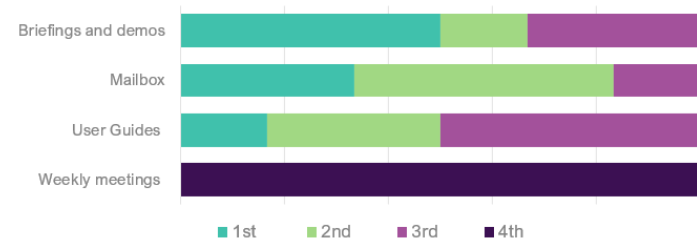
Performance

Runtimes were rated low. Most users will not have run studies against the four state network which will take longer than individual plant studies. This will be managed through expectation setting



Support channels

The planned support channels have been validated



A2. Pre-launch Expressions of Interest

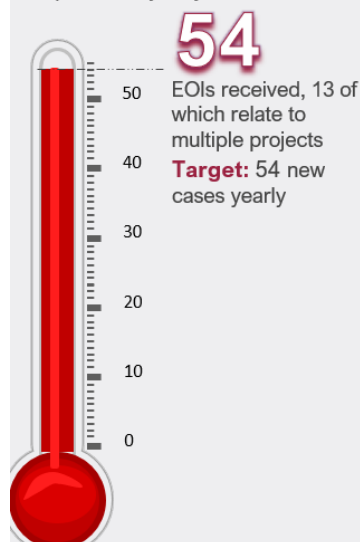
Expressions of Interest Connections Simulation Tool

Expressions of interest opened on 19th July and has demonstrated strong industry interest in using the tool.

Information relevant at 2nd Nov 2022

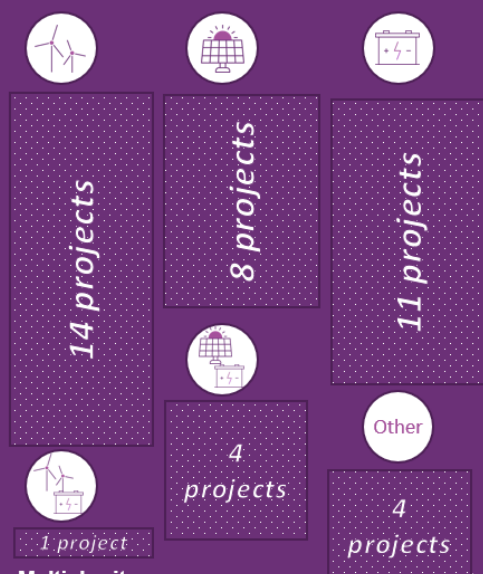


EOIs Received
Expressions of interest cover the over 65% predicted yearly demand



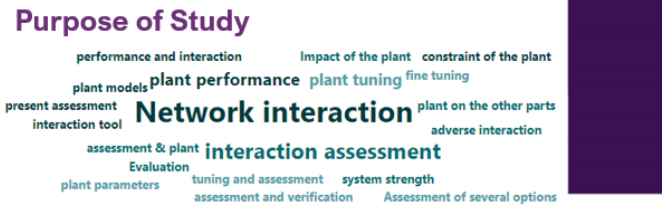
Notes:
1. The following information is currently not provided to industry users: Cost of service, Service commencement date
2. The form was published prior project delays that impact the scheduled of release 1
3. Awareness of the EOI form was through 1) direct email, 2) article in State of the System 3) article in the AEMO newsletter.

Plant/Project
Demand covers on a broad range of projects.

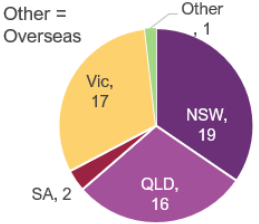


Multiple sites:
13 submissions referred to multiple projects across sub-transmission system, FFI Studies, Welcon Tech DER grid connection projects, Future projects, Various wind, solar and BESS projects, Consulting supporting connections across the NEM, Generic project to evaluate tool, Electricity Market Impact Studies

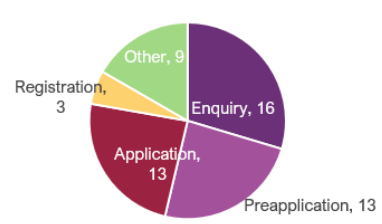
Organisations



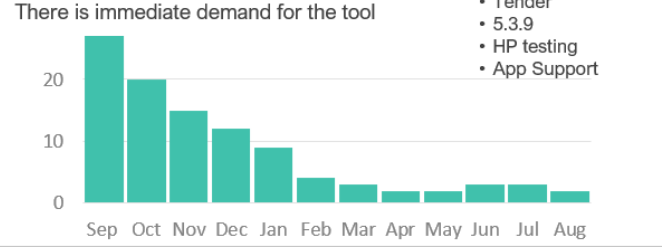
Project Locations



Project Phase



Desired Timing



A3. Potential Enhancements

Connections Simulation Tool R2 Enhancement Priorities



Glossary

This document uses many terms that have meanings defined in the National Electricity Rules (NER) or are commonly used in the electrical engineering community. Some abbreviations may be specific to this document only.

Term	Definition
CST	Connections Simulation Tool
EMT	Electromagnetic Transient
MVP	Minimum Viable Product
NSP	Network Service Provider
OEM	Original Equipment Manufacturer
PSCAD	A software tool used to run EMT studies