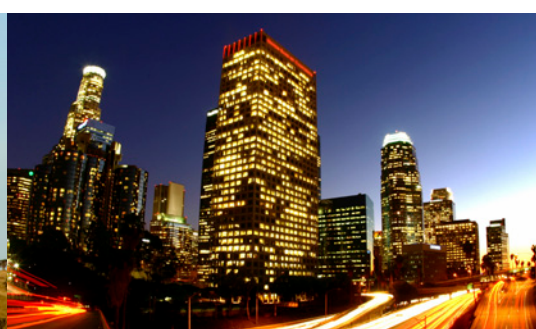


Australia's Future Grid

Evaluating whole-of-system options
for Australia's future electricity system

May 2012





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Executive summary

Australia's energy system is expected to undergo a major transformation over the coming decades. This transformation will involve all aspects of the nation's electricity chain.

In preparation CSIRO is convening an Australian-first, whole-of-system Future Grid Forum employing CSIRO's proven 'Futures Forum' capability. By applying this stakeholder-led methodology, the Forum's evaluation of future options will be profoundly influenced by the participating industry stakeholders. Participants will include electricity generators, transmission and distribution network operators, energy retailers, end-user customer representatives, regulators and government (state and federal).

Over a period of twelve to eighteen months, the Future Grid Forum will systematically evaluate all the major options available for Australia's future electricity system from an end-to-end perspective. Beginning with the most efficient pathway under current system settings as a point of reference the evidence-based process will progressively shortlist alternative options with the greatest potential to deliver secure, sustainable future outcomes at lowest system cost.

Importantly, it is expected that this Forum process will help shift the nation's energy debate to a more whole-of-system perspective encompassing the entire energy chain from generation through to the demand-side. By adopting the Energy White Paper's principle of energy productivity, the Forum will provide a roadmap to support investment resulting in sustainable, lowest cost outcomes for electricity users and inform considerations around new regulatory models. The process will complement and build upon the Energy White Paper and reviews carried out by the AEMC, Productivity Commission and others.

During the Forum process, a number of potential scenarios for Australia will be agreed on and explored by the participants. As examples only, the participants may choose to explore the following (or other) scenarios, supported by discipline experts to ensure robust and objective analytics:

- ◆ Status quo/counterfactual (based on current industry settings)
- ◆ High penetration of renewables
- ◆ High demand-side participation, including distributed generation
- ◆ Socially constrained / unconstrained technology adoption
- ◆ Australia as a clean energy importer (or exporter)
- ◆ Evolution under high uncertainty

CSIRO will coordinate the project and partner with selected groups, consultants and academics to deliver quantitative analysis dynamically informed through eight facilitated workshops over twelve to eighteen months.

The communication strategy for the Future Grid Forum will position the project outputs as a highly-credible, transformative road map for the Australian electricity system. The target audience is primarily industry and government, however, several outcomes will be of interest to the general public (particularly those focused on reducing electricity costs and greater customer participation).

The outcomes will be determined by the level of investment participants are prepared to make into the Forum. CSIRO expects that a budget of \$1-2 million is required to fulfil the entire project or a smaller \$0.5-1 million could provide reasonable order of magnitude assessments plus highlight future research needs. CSIRO and GE have already committed to fund the project with \$0.4 million.

CSIRO and GE now seek partners to join the Forum and contribute to the future of Australia's electricity grid. We are seeking Platinum (\$200K), Gold (\$100K) and Bronze (\$20K) members.



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Introduction

“A whole-of-system evaluation is needed if such a complex system is to be optimised for the future needs of the nation.”

Australia’s electricity system is expected to undergo a major transformation over the coming decades. This transformation will cover all aspects of the energy chain and the associated investment in the domestic electricity and gas system could exceed \$240 billion by 2030 .

With Commonwealth legislation in place mandating 20% of the nation’s electricity generation from renewables – the majority expected to come from intermittent wind resources – this transformation is already underway. In addition, opportunities for optimising the efficiency and future contribution of more traditional generation assets are being evaluated. At the same time, Australia’s transmission and distribution networks are facing significant pressure to limit new investments, maintain reliability and quality of supply, manage peak demand and integrate intermittent renewables at scale. On the demand side, new technologies such as electric vehicles, distributed storage and demand management could fundamentally change long-run demand patterns. In parallel, electricity retailers are considering what innovative new offerings and business models will be required to underpin and sustain this transformation.

While several studies and reviews have sought to evaluate various energy options, most have been carried out with a strong focus on specific parts of the electricity system and/or from the perspective of particular stakeholders. As demonstrated, for example, by the recent experience with increases in transmission and distribution charges, Australia’s electricity system cannot be analysed and optimised by examining its separate parts alone. Indeed a whole-of-system evaluation is needed if such a complex system is to be optimised for the future needs of the nation. This is especially so given the dynamic nature of looming industry challenges including the integration of intermittent renewables at scale, the gradual phase-out of high emission generation assets, gas price uncertainty and the adoption of electric vehicles.

Given the number and breadth of challenges ahead, CSIRO as the nation’s leading science and technology organisation, is convening an industry-led Future Grid Forum for Australia. Employing CSIRO’s proven ‘Futures Forum’ capability this will bring together recognised stakeholders from all major industry sectors in a series of events over a 12-18 month period. Together the Forum participants will conduct a facilitated, systematic and fact-based evaluation of the various options for developing Australia’s electricity system over the next four decades to 2050, supported by recognised experts in key disciplines.



1 Investment Reference Group, Report to the Commonwealth Minister for Resources and Energy, Department of Resources, Energy and Tourism, 2011

2 Refer Appendix A for additional information on previous CSIRO Futures Forums

Objectives and outcomes

“The report will play an important part in forming the foundation of Australia’s electricity system for the 21st century.”

For the first time, the Future Grid Forum will provide a whole-of-system perspective on Australia’s electricity supply chain well into the future.

Importantly, the Forum’s work will culminate with a high-profile, public report and launch event outlining the consensus analysis and recommendations. The robust new analytical processes, tools and frameworks developed and employed in this work will also provide valuable new capability for Australia well beyond the Forum itself. As such, it is expected that the Forum’s report and other outcomes will play a profound role in the foundation of Australia’s efficient, competitive, secure and sustainable electricity system for the 21st century.

At a high level, the objectives of the Future Grid Forum include:

- ◆ **Shift the energy debate to a whole-of-system evaluation of potential options.** Australia currently does not have the full capacity to rigorously analyse the long-term implications of changes to its energy system across the whole electricity value chain. Without this capacity it is simply not possible to accurately assess the full system cost impacts of much debated options such as, for example, high penetration renewables relative to the most efficient pathway under Australia’s current industry settings. This work will provide the first analytical framework capable of assessing the full system costs in a fact-based and robust way. It will thus provide the analytic foundation for evidence-based policy making and investment decisions that may exceed \$240 billion over the coming 20 years.
- ◆ **Objectively evaluate the options** by identifying and modelling a range of scenarios that address the key challenges and uncertainties. Once their system impacts are quantified (e.g. prices, emissions), closer analysis of the most important options will highlight key barriers to their implementation and potential mechanisms to overcome them.

- ◆ **Shape the debate of new regulatory models.** The Forum will also explore how different regulatory and operating models of the transmission and distribution systems may lead to different system cost outcomes. Regulatory issues will be considered at a high level for the purpose of fostering long-term co-ordination and integration. This process will draw upon and complement the existing, more detailed reviews being carried out by the AEMC, Productivity Commission and others³.

The planned outcomes of the Future Grid Forum include:

- ◆ **A Respected Coalition of Experts:** Bring together industry, government and regulators to systematically examine the merits of alternative options for the development of Australia’s future electricity system;
- ◆ **Whole of Electricity System Future Scenarios:** Construct a range of future scenarios articulating the main options for developing Australia’s electricity supply chain, including T&D regulatory mechanisms, to address national and global challenges over the next four decades to 2050;
- ◆ **New Analytical Framework:** Develop an integrated assessment framework capable of estimating the impacts across the value chain for the future scenarios;
- ◆ **Quantified Opportunities for the Nation:** Using the newly integrated analytical framework, quantify the delivered price of electricity, CO₂-e emissions, technologies adopted and landscape changes associated with each option;
- ◆ **Forged Consensus Solutions:** CSIRO’s extensive energy futures forum expertise will be applied to systematically work through the complex trans-sectoral issues and forge consensus solutions; and,
- ◆ **Published and Promoted Findings:** Publish a highly-credible, transformative road map for the Australian electricity system that presents the quantitative outputs and a shared view of the opportunities and challenges, accompanied by a transparent, evidence-based technical report.

³ E.g. AEMC Power of Choice, and Transmission frameworks reviews; AEMO National Transmission Network Development Planning; Productivity Commission Electricity Network Regulation Inquiry.

Process and governance

“Forums are a proven process that CSIRO has successfully applied in the aviation, energy and fuels sectors.”

CSIRO’s Futures Forum process will consist of a structured series of eight facilitated workshops over approximately twelve to eighteen months. At the first workshop Forum participants will share knowledge through a series of presentations and discussions and then work together to define the scenarios and options to be examined by the modelling capability. At the second and third workshops modelling results will be presented and Forum participants will direct changes to the scenarios or model assumptions to improve and revise the model outputs. At the fourth and fifth workshops participants will provide a collective view of the challenges, opportunities and potential solutions (including policy and regulation options) for the electricity sector that have been identified during group discussions and in the modelling outputs. In the remaining workshops Forum participants will provide input to the draft written report that has been developed by the project secretariat to capture and communicate the Forum’s findings. Figure 1 below illustrates this process from start to finish.

The Forum will not seek to arrive at a consensus on specific recommendations for government policy or investment. However the process will deliver an agreed view of the various options to be considered - their regulatory barriers, risks, benefits and trade-offs, the action agenda required to move those options forward towards achieving an optimised electricity system and the roles of each stakeholder in achieving that goal. To deliver the quantitative analysis CSIRO will also partner with selected groups, consultants and academics as necessary.

Importantly, CSIRO has proven experience in the delivery of large, multi-stakeholder industry roadmap projects. In the case of the Future Grid Forum, CSIRO will coordinate the project supported by a steering committee that includes a representative from each of the Platinum and Gold participant organisations. As an industry-led process, a high level of consultation will also be maintained with all participants throughout. The core roles and responsibilities of Forum participants and the general functioning of the steering committee, are outlined in the Participant Agreement.

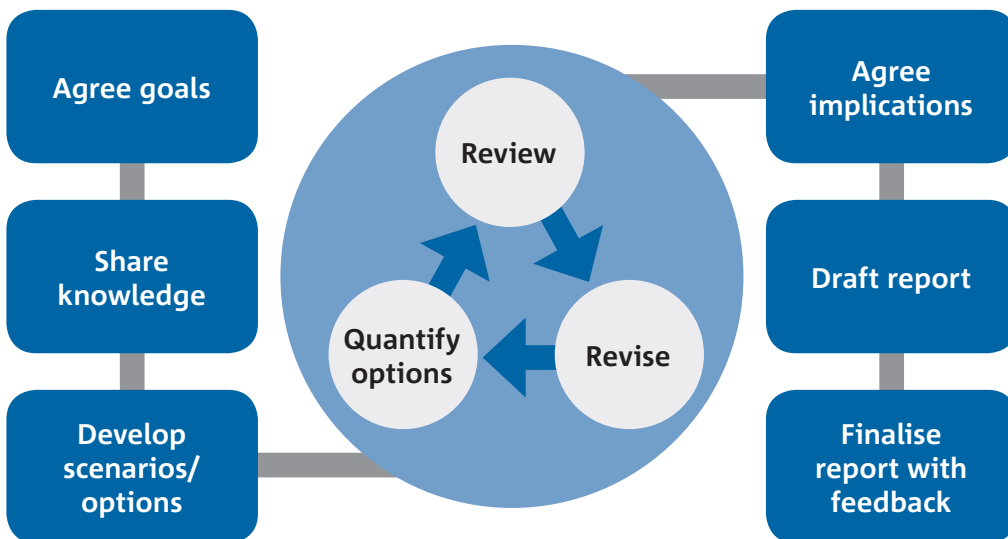


FIGURE 1: TYPICAL FORUM PROCESS SUCCESSFULLY APPLIED BY CSIRO

Participants

“The goal is to achieve a balance of interests across the entire electricity supply chain.”

The Future Grid Forum ideally includes representation from generators, transmission and distribution networks, energy retailers and customers as well as government and regulators. The goal is to achieve a balance of interests across the entire electricity supply chain (including a range of views about Australia’s energy future) and maximise the value that each participant receives by sharing the costs of the analysis.

Companies are generally preferable to industry associations since they are better able to articulate a specific view. Both the regulation and policy arms of government would be desirable, including both federal and state representation.

Following are a range of potential participants invited by CSIRO.

TABLE 1: EXAMPLE LIST OF ENERGY CHAIN STAKEHOLDERS

ENERGY CHAIN SECTOR	COMPANIES	ASSOCIATIONS
Generation	Macquarie, Origin, Delta, Stanwell, etc	NGF, ESAA
Transmission	Powerlink, ElectraNet, TransGrid, etc	ENA, Grid Australia, ESAA
Distribution	Ergon, Ausgrid, Western Power, SP AusNet, etc	ENA, ESAA
Retail	Origin, AGL, TRUenergy, etc	ERAA, ESAA
Customers	Rio Tinto, BHP Billiton, etc	EUAA
Suppliers	GE, IBM, Landis & Gyr, etc	
Non-government Organisations	ACOSS, CUAC, St Vincent de Paul, Smart Grid Australia, ClimateWorks, WWF	

TABLE 2: EXAMPLE LIST OF GOVERNMENT STAKEHOLDERS

ARM OF GOVERNMENT	DEPARTMENT OR AGENCY
Regulation	AER, AEMC, AEMO
Policy	RET, DCCEE, State DOEs, BREE

By including all relevant stakeholders as participants, the Forum will provide an opportunity for constructive and open debate. Importantly, this will provide a catalyst for developing a shared, view of the challenges as well as the potential synergies and ‘sweet spot’ opportunities for the nation.

Potential scenarios

“A whole-of-system evaluation is needed if such a complex system is to be optimised for the future needs of the nation.”

The specific options and scenarios to be analysed will be agreed upon by the forum participants. No options will be excluded. The participants will have several opportunities to develop and revise the scenarios and ensure they represent a balanced set of options. Some options and scenarios that could be explored are outlined in Table 3 below as **examples only**. The table also provides the analytical approaches necessary to credibly evaluate them.

TABLE 3: POTENTIAL AREAS OF FUTURE GRID CONSIDERATION AND THE ANALYSIS REQUIRED

POTENTIAL OPTION TO BE EXPLORED	ANALYSIS REQUIRED TO CREDIBLY EVALUATE
Status quo / counterfactual	Project the most efficient, cost-effective electricity system pathway and technology mix for continuation of the current system that includes existing policy settings Comparison of portfolio of renewables intermittent output with demand load profiles
High penetration of renewables	Analysis of output potential of ‘baseload renewables’ - geothermal, solar thermal with storage, and biomass Analysis of potential of large scale electrical and thermal storage options
Australia as a clean energy importer (or exporter)	Impact of natural gas export parity pricing in Australia Demand for and relative cost of current and future low emission electricity supply from (and to) SE Asia Cost, efficiency and feasibility of high voltage transmission lines
High demand-side participation, including distributed generation	Characterisation of the cost and performance of energy efficiency, fuel substitution and distributed generation options inclusive of distribution system requirements Alternative demand growth and load profiles under different levels and types of demand side participation Likely and managed EV recharging profiles and levels
Socially constrained / unconstrained technology adoption	Potential social limits to technology adoption – wind setback rules, CSG contribution to gas supply, nuclear power, CCS Impact of social limits on quantity and/or costs of electricity from affected technologies
Evolution under high uncertainty	Estimated impact of uncertainty on investment in transmission, distribution and generation infrastructure Characterisation of options for reducing uncertainty (e.g. renewable precincts), scale efficient network extensions

Analytical framework

“At least seven major tools will be required to perform a systematic analysis of the electricity supply chain.”

The analysis techniques to deliver the outputs will include a mix of high and low *temporally* (30-minute to 40-years)⁴ and *spatially* (square km to regional/country) aggregated simulation tools. It is believed that at least seven major tools will be required as outlined in Table 5 below. Where feasible, we will draw on existing tools and approaches.

It is important to note that the functionality of the simulation tools will be integrated by CSIRO to address the specific system option to be explored (as some options will require greater analysis of different parts of generation, transmission, distribution and the demand-side systems than others). Figure 2 below indicates how some of these tools will be integrated.

TABLE 5: TOOLS REQUIRED TO PERFORM SYSTEMIC ANALYSIS OF THE ELECTRICITY SUPPLY CHAIN

NAME	PRIMARY FUNCTION	STATUS
National weather prediction	Provide climate data	Existing
Long term generation investment model (e.g. ESM, MARKAL)	Project long term optimal generation mix, emissions and prices	Existing
Global electricity technology cost model (e.g. AETA)	Project change in electricity generation technology costs	Existing / AETA update in progress
Spot Market Model (e.g. PLEXOS, Prophet)	Dispatch least cost generation subject to transmission constraints	Existing / to be augmented with transmission network expansion planning tool
DNBP / Power flow model	Project the required distribution system augmentation	Existing / to be augmented with non-standard augmentation options
Distributed Energy opportunities model	Project optimal use of distributed generation, energy efficiency and demand management options	Partially constructed
Bottom-up energy demand model (e.g. EE-MAP concept)	Project future demand profiles from building/ equipment level analysis subject to adoption of distributed energy	Partially constructed

⁴ Sub 5-minute timescale analysis to address intermittency effects and ramp rates will be addressed by CSIRO’s Future Grid University Cluster (refer Appendix B).

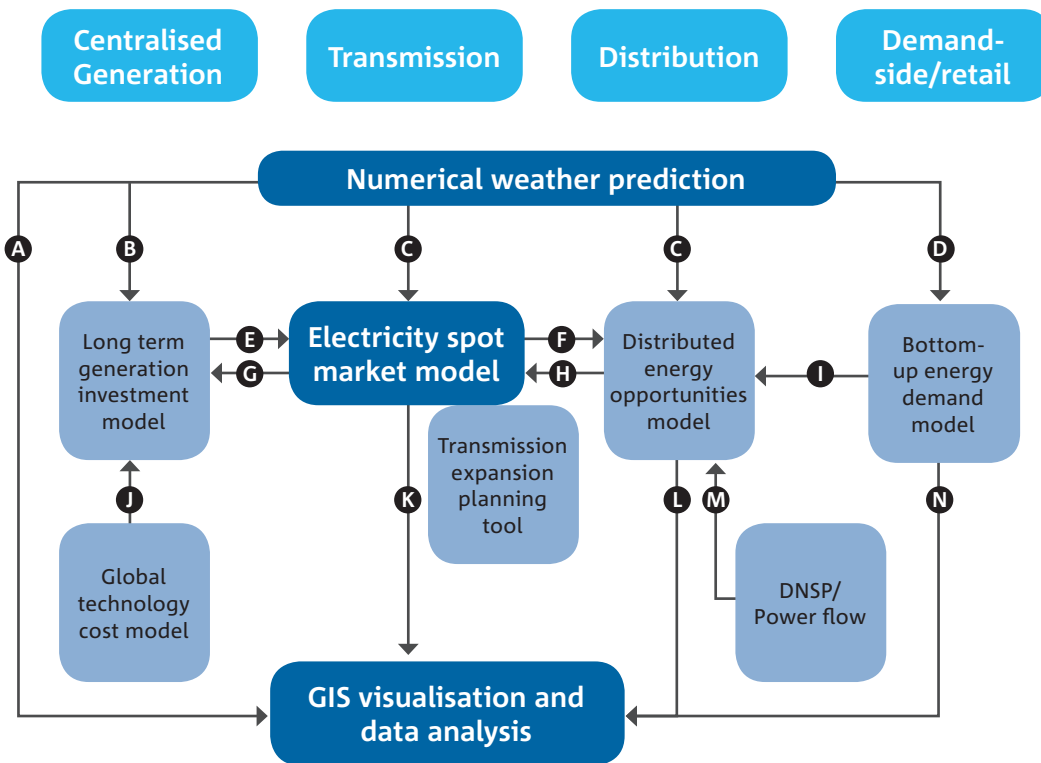


FIGURE 2: ANTICIPATED ANALYTICAL TOOLS AND INFORMATION FLOWS

LEGEND

- | | |
|--|--|
| <p>A Location of climate-driven renewable energy resources</p> <p>B Solar radiation; temperature; wind speed</p> <p>C Fine temporal scale generation profiles for solar, wind, wave; climate driven demand profiles</p> <p>D Climate zones information</p> <p>E Technology mix</p> <p>F Fine temporal scale retail prices</p> <p>G Modified technology mix boundary conditions; cost of transmission build</p> <p>H Modified demand based on uptake of distributed generation, energy efficiency and demand management</p> | <p>I Demand by building stock and end user; effect of energy efficiency and other building energy management on demand profile</p> <p>J Change in electricity generation costs</p> <p>K Location of existing and new generation and transmission infrastructure</p> <p>L Location of distribution system constraints; augmentation</p> <p>M Cost of distribution network augmentation; distribution system boundary conditions</p> <p>N Location of demand by type, intensity and potential rate of change</p> |
|--|--|

Outputs

“The outputs of the Forum will be determined by the level of investment - \$1-2 million is required to provide a roadmap with strong buy-in and robust technical findings.”

The quantity of outputs of depth of analysis will be determined by the investment the forum participants are prepared to make. We expect that a budget of \$1-2M is required to evaluate the major options in a credible manner. However, a smaller project of \$0.5-1M could provide reasonable order of magnitude assessments plus highlight future research needs.

CSIRO and GE have already committed to fund the project with \$0.4M. The final amount of funds available will not be known until all participants have responded to their invitations. Depending on the response it is envisaged the project will be able to deliver three likely levels of outputs and outcomes as set out in Table 4.

For each of the options, key variables will be calculated from a whole-of-system and national perspective over the next four decades to 2050:

Retail Price Projections: Projected retail electricity prices under a range of credible alternative system options;

System Cost Projections: Projected costs associated with investment and operation of electricity generation, transmission and distribution;

CO₂-e Projections: Greenhouse gas emissions under alternative system options;

System Visualisation: Visual depiction of the evolution and growth of demand-side participation, transmission infrastructure, renewable resources and power generation infrastructure over time;

Technology Scenarios & Profiling: Illustration of scenarios or projections of technology adoption in electricity generation and demand-side participation;

Policy and Regulatory Options: Evaluation of policy and regulatory mechanism options for generation, transmission and distribution.

TABLE 4: PROJECT OUTPUTS AND OUTCOMES UNDER DIFFERENT SCALES

OUTPUT OR OUTCOME	\$400K (CSIRO AND GE FUNDING ONLY)	~\$1M (TARGETED COALITION)	~\$2M (BROAD COALITION)
Project impact	Interesting report. Limited buy-in from non-participants in industry and government	Roadmap with industry and government buy-in	Roadmap with strong buy-in and greater robustness of technical findings
Summary and technical report	Yes	Yes	Yes
No. of scenarios / policy options	3	6	6 + sensitivities
Modelling and analysis	Full model suite but: Local demand projections based on pro rata of aggregate state node only	Full model suite plus: Residential and commercial demand based on LGA level building stock and equipment model Transmission/generation plans tested against near worst case DSM cases extrapolated from CSIRO regional modelling or existing literature	Full model suite plus: Transmission/ generation plans tested for robustness to several probability of exceedence cases Simulation of DSM: building air conditioner control, vehicle to grid and DG aggregation within building stock and equipment model Alternative climate scenarios

Communications

“On the strength of our brands we will communicate a highly-credible, transformative road map for the Australian electricity system.”

Participants will co-develop and agree to a communication plan that is operational throughout the Forum process. While the final report is a key tool, the communication plan will also use a variety of approaches to target different audiences and progressively release project learnings and outputs. Also, given much of the target audience are themselves participants in the Forum, CSIRO’s experience is that the Forum will begin to have impact on the national debate well before its conclusion.

The communication strategy will position the project outputs as a highly-credible, transformative road map for the Australian electricity system. The target audience is primarily industry and government, however, several outcomes will be of interest to the general public (particularly those focused on reducing electricity costs and greater customer participation).

This will require the production of simple, plain language messages backed by credible analysis. Given that the questions that the project addresses often involve spatial analysis (e.g. interactions between resources, infrastructure and customer participation) there is high potential for production of engaging visual or interactive products via a dedicated online presence. Major sponsors who contribute to the development of the analytical outputs will have the opportunity to brand the outputs.



Options for participation

Forum participants will help fund the project by each contributing a participation fee. The fee for most participants will be justified on the basis that it will be an order of magnitude less than if they were to commission the project on their own.

The original Platinum sponsors initiating this project are CSIRO and GE. We now seek additional Platinum, Gold and Bronze sponsors to join the Forum and contribute to the future of Australia’s electricity system. A description of the various participant types and contributions follows.

The collected fees will be used to fund the following activities and expenses:

- ◆ Project management / secretariat
- ◆ Application of a suite of models, some development (see Appendix A)
- ◆ Meeting facilitation
- ◆ Workshop venues and catering
- ◆ Communications activities

TABLE 6: FUTURE GRID PARTICIPATION OPTIONS

PARTICIPANT TYPE	ROLES & RESPONSIBILITIES
Platinum: \$200K	Recognition as project foundation partner, steering committee member, project management contribution, workshop participation, management of and contribution to project deliverables and reports and a leading role in the communication of outcomes.
Gold: \$100K	Project steering committee member, workshop participation, review of project deliverables and contribution to project report and communication of outcomes.
Bronze: \$20K	Workshop participation, review of project deliverables and contribution to project report
Gratis: \$0K	To participate at the same level as Bronze (or above) member but with the fee waived as they lack the financial means but are necessary to provide balance or special input to the group

Appendix

APPENDIX A – Previous CSIRO Futures Forums

Sustainable Aviation Fuels Forum

With emissions reduction and fuel security in mind, Australia and New Zealand's main aviation players approached CSIRO Energy Transformed Flagship to work collaboratively on a study that would help plan a sustainable future for aviation fuels. This world-first study brought together representatives from the Australian and New Zealand aviation industry in 2010, with the study culminating in May 2011 with the release of its report.

<http://www.csiro.au/en/Outcomes/Energy/Powering-Transport/Sustainable-Aviation-Fuels-Road-Map.aspx>

Future Fuels Forum

Against the backdrop of awareness about the environmental impacts of fossil fuel use, peak oil, fuel security and climate change the Future Fuels Forum was convened to identify scenarios that could drive Australia to 2050. The work of the Future Fuels Forum culminated in July 2008 with the release of its report.

<http://www.csiro.au/Outcomes/Energy/Future-Fuels-Forum.aspx>

Energy Futures Forum

The Energy Futures Forum brought together industry and community groups in a scenario planning exercise exploring potential futures of the Australian stationary energy (static energy generation facilities) and transport industries. Running over a two-year period the Forum applied advanced modelling to develop future energy scenarios to identify potential energy industry and technology pathways and highlighted potential impacts to society, the environment and the economy. The work of the Energy Futures Forum culminated in December 2006 with the release of its report.

<http://www.csiro.au/Organisation-Structure/Flagships/Energy-Transformed-Flagship/Energy-Futures-Forum.aspx>

APPENDIX B – Related CSIRO activities

The Future Grid Forum resides within CSIRO's broader Future Grid Program. Some other related and complementary projects underway within this program include:

Future Grid University Cluster

This is an opportunity to partner with key Australian universities to harness their unique expertise in certain areas and expand the breadth and depth of system analysis. Under this project, CSIRO is currently seeking expressions of interest in power systems analysis, market modelling skills, alternative approaches to network development and policy and regulatory aspects.

Inner City Energy Map Project

CSIRO is collaborating with a group of Australian inner suburban councils to create and field-test a new model for identifying and evaluating distributed energy opportunities (distributed generation, energy efficiency and demand side response) for achieving significant emission cuts at an urban scale.

CONTACT US

t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

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Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation.

FOR FURTHER INFORMATION

CSIRO
ENERGY TRANSFORMED FLAGSHIP
Mark Paterson
m 0459 841 006
e mark.paterson@csiro.au
w www.csiro.au/energy