"Roads and Bridges are our Future Power Plants"

Roads Australia 2023 Fellows

Research Paper
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Executive Summary

This research paper presents an innovation that we can introduce to our transport industry that will help us achieve Roads Australia policy objectives and open up opportunities for new streams of talent in the transport industry workforce. Our proposal is the integration of renewable energy power generating infrastructure into civil transport infrastructure and explores 'unlocking' the potential for energy capture in transport corridors and assets to power transportation and infrastructure, store for backup supply or re-distribute renewable energy back into the grid.

We investigated the types of renewable energy harvesting technology available in Australia and overseas, undertook a literature review of available research, industry consultation in the form of a peer group survey and interviews with subject matter experts across the industry to inform our recommendation that solar energy, to power microgrids located with transport infrastructure, is the most suited and ready to be deployed to the Australian transport industry. Integrating renewable technology directly into transport infrastructure, such as pavements and structures, is extremely difficult to quantify and there has been limited research in Australia to determine its true technical and operational feasibility.

We assessed risk, opportunities and constraints associated with the integration of renewable energy generation into transport assets and infrastructure and gauged industry appetite for adopting the recommendation from this research paper. We found that our proposal is likely to gain widespread support from transport agencies initially which will lend to widespread adaption across the industry. Other key identified risks and opportunities include the level of maturity and development of existing renewable energy harvesting technology, materials and transmission, and complicated integration considerations including the roles and responsibilities of government, asset owners and operators.

Successful integration of energy generation into transport infrastructure will require careful planning, investment, and collaboration among stakeholders to address these challenges and harness the opportunities. Renewable energy hubs will play a vital role in promoting sustainability, resilience, and economic well-being within communities, making them a key component of modern energy systems.

Our recommendations align and provide opportunity to deliver on Roads Australia policies such as **sustainability**, by helping drive further innovation capable of addressing climate change, **safety,** by providing secure renewable energy to power street lighting in remote areas previously deemed not cost effective to do so, and **transport reform,** recognising the need for transformational regulatory and technological reform to continue to drive value from Australian roads and the integrated transport network. This is very relevant in the renewable energy generation space given the need to employ new technology in the integration with roads and to integrate energy generating transport assets with existing utilities assets while meeting safety and regulatory requirements.

Our engagement with government subject matter experts identified that supporting government strategies, polices and incentives would be essential for the successful integration of renewable energy technology, and that government's role would most likely be partner, support and enable rather than build, own or operate any integrated renewable energy technology.

Our roadmap for implementation includes pilot sites and pilot projects to develop transport corridors and land for microgrids and the inclusion of renewable energy options in project delivery contracts respectively, with expansion of this program through new enabling government policies and strategies on an integration pathway that makes these practices business-as-usual for transport infrastructure.

The roadmap identifies three key streams to securing talent for the transport industry by; unlocking existing maintenance funds, generating revenue and re-deploying maintenance staff through leasing transport corridors and residual land for microgrids; enabling the mobility of an estimated 270 people each year from partnering between the transport and renewable energy industries; and attracting up to 170 new entry level talent graduates into the transport industry each year through appropriate recognition and publication of the benefits associated with renewable energy technology integration.

1. Project Definition

"Roads and Bridges are our Future Power Plants". Our proposal looks at how we can transform and modernise the transport industry thought the integration of renewable energy technology, supporting sustainability initiatives for a clean energy future, and attracting greater numbers of graduates and people looking for a career change.

Transport infrastructure such as roads, bridges, footpaths, road furniture, transport corridors, metro, light, and heavy rail assets occupy a significant footprint in urban and rural hubs that are under-utilised beyond conveying modes of travel in a contemporary and modern landscape. These civil assets have 'used' significant energy in their manufacture and construction, and 'store' a significant amount of 'trapped' energy. Material technology and innovation in the transport infrastructure space has been relatively incremental and the types of materials and construction practices have remained essentially unchanged for many decades.

"Transport remains the sector of energy use with the lowest share of renewables, with more than 95% of energy needs coming from oil and petroleum products and less than 4% from biofuels and renewable electricity in 2018." (SLOCAT, 2021)

Our proposal is the integration of renewable energy infrastructure into civil transport infrastructure and will explore 'unlocking' the potential for energy capture in transport corridors and assets to power, store and re-distribute renewable energy back into the grid. This will create a step change in transport infrastructure innovation, attracting material technologists, manufacturers, and constructors from the residential, commercial and industrial renewable energy sector to the transport sector.

This technology integration will also help to ensure future energy security within Australia supporting social, environmental and sustainability objectives that underpin future transport infrastructure construction, upgrades and renewal projects, speaking to the core of Roads Australia policy objectives, and may lead to a "return-on-energy-investment" measure to assess project options and material specifications for transport projects of the future. We will also explore the proposition that integration of renewable energy infrastructure would also attract the 'next generation' of transport industry practitioners based on the social, environmental and sustainability benefits of energy recovery via transport assets and corridors.

2. Objective

The 2023 Roads Australia Fellowship project poses the challenge:

'What is one technical innovation that we can introduce to our industry that will help us achieve RA policy objectives and open up opportunities for new streams of talent in our workforce.'

"The rate of consumption and demand for energy has far outstripped supply. Rising oil prices and dwindling reserves have led to global concerns about an impending energy crisis. On the other hand, there is energy all around us waiting to be tapped into. Space and cost are two of the biggest challenges with implementing sustainable energy harvesting solutions. The Bureau of Transportation Statistics reports that highways account for more than 1/3rd of the United States' energy consumption. Highways also take up a large amount of land. This very "problem" might be a solution in disguise." (Onio, 2021)

Our project proposal focuses on energy harvesting from new and existing civil and road infrastructure. The proposal explores integration and embedment of renewable energy technology, materials and infrastructure into transport infrastructure projects and assets that will bring new streams of talent from fringe industries and attract new talent from the positive social, environmental and sustainability outcomes of this innovation.

3. Scope

Our project investigates various energy harvesting technologies and seeks to make recommendations on the benefits, risks, challenges and opportunities for integration of the technology options into new and existing transport infrastructure. This research and investigation has enabled the production of a roadmap for implementation and integration of this renewable energy technology in the transport sector. The project scope required targeted research and investigation of the following areas:

- Literature review and case studies of energy harvesting technology that have been successfully tested overseas and could be ready for trialling in Australia.

- Literature review and case studies of energy harvesting technology that is being used in Australia in other industries or sectors that could be adapted for use within road and transport corridors.

    - This included identifying the possible workforce in those other sectors that could help implement that technology in the transport industry.

- Assessment of potential gaps in existing overseas or local energy harvesting technology that would require further development prior to application and use in road and transport corridors.

- Recommendations for policy makers and asset owners. Proposal for improved utilisation of existing transport infrastructure and for all new infrastructure projects to include green energy production, with an ideal future state to generate its own energy needs.

4. Research Areas and Opportunities

4.1 Energy Harvesting Technologies

There are four energy harvesting technologies that we have considered for integration of renewable energy technology and infrastructure into transport infrastructure.

We have identified two energy harvesting technology areas that are mature enough overseas and in Australia that have the greatest potential for application and benefits in the transport industry.

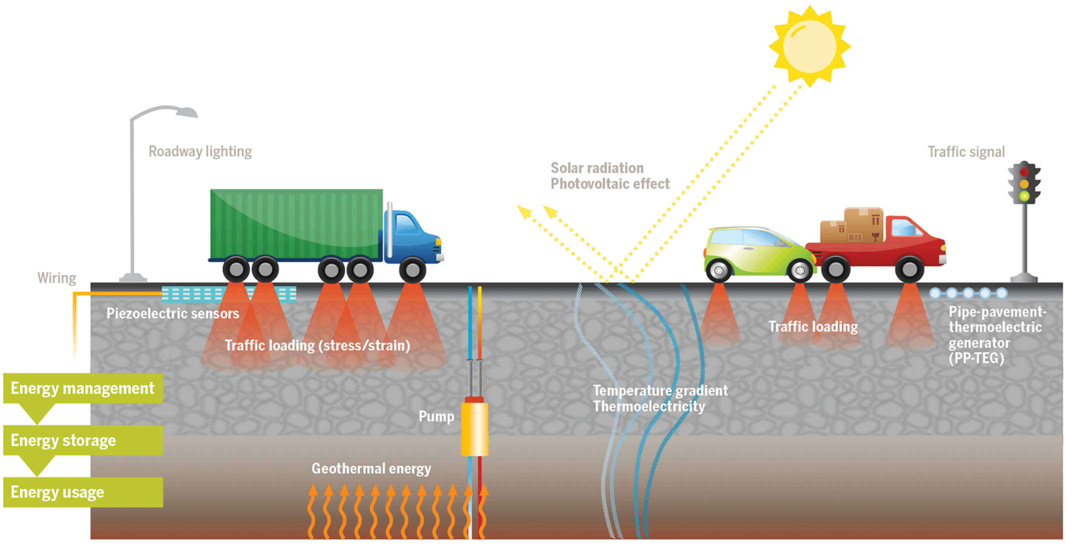


Figure 1 *Technologies that can turn roads and bridges into "power plants" (Rutgers, 2019)*

4.2 General Discussion on Technology Options

The rapid increase in energy demand has resulted in more dependence on fossil fuels, which leads to higher CO2 emissions every year. To overcome this problem, shifting from fossil fuel-based energy resources to renewable and sustainable ones is essential. One of the new research areas developed in this context is the harvesting of energy from urban infrastructures and, in particular, roads. A large amount of energy in the form of heat or kinetic energy is wasted annually on roads. (Zabihi & Saafi, 2020)

Recovering these local forms of energy as electricity would improve the energy efficiency of cities.

4.3 Technology Readiness Level Assessment (TRL)

We have used the TRL assessment to compare the different technologies. Originally developed and practiced by NASA, TRL is a systematic measurement methodology used to appraise technologies' maturity levels. It is categorized from 1, standing for having only the basic principles recognized and described, to 9, being fully developed, successfully tested and ready.

TRL Level	Description
1	Investigation of the fundamental principles of the technology
2	Technology's concepts are formulated
3	The concept of the technology is experimentally proven
4	The technology is validated in the laboratory environment
5	The technology is approved in a suitable environment
6	The technology is exhibited in a suitable environment
7	The technology's prototype is exhibited in an operational environment
8	The technology's system is finalised and qualified
9	The qualified system of the technology is approved in the operational environment

4.4 Summary of Technology Options

Mechanism	Advantages	Disadvantages	TRL	Trials
Electromagnetic: Mechanical system, converting kinetic energy into electrical energy using electromagnetic generators.	• High potential power output • Relatively low maintenance costs • Installed onto existing infrastructure	• Dependent on the weather (wind turbines) • Can influence traffic flow (speed bump)	7 4	• Wind Turbines – Alpha 311 Turbines • Speed bumps - Roller Electromechanical & Rack and Pinion Electromechanical
Piezoelectric: The electric charge that accumulates in certain solid materials such as crystals, certain ceramics.	• Good mechanical properties • Easy installation • Performance not dependent on weather	• Very low power output • Expensive fabulation and maintenance	3	• Evidence of 2 funded projects in USA
Photovoltaic: (PV) cell, commonly called a solar, a nonmechanical device that converts sunlight directly into electricity	• Average power output	• Dependent on the weather • Expensive fabrication and maintenance • Fragile and not mechanically • compatible with roads • Relatively low power output	9 7 4	• Wattway Pack (France) Installations in cycleways and footpaths • Solar Roadways (USA) installations in carparks • Solar Roadways (USA) Installation in carriageways.
Thermoelectric: Conversion of temperature differences to electric voltage	• Easy Installation	• Very low power output • Expensive fabulation and maintenance • Dependent on weather	2	• Research projects

4.5 Photovoltaic (Solar Roads):

Solar panels are well-known for converting solar radiation into electrical energy. They are compiled of several solar cells connected to each other in order to increase the electrical energy output of the whole panel. Solar cells are made of silicon-based crystals or, in more expensive types, made of scarcer materials such as gallium arsenide. Solar panels are widely used, especially in sun catching environments and on residential buildings' rooftops to generate off-grid electricity. The efficiency of these panels depends on a number of environmental factors, such as the weather conditions, production factors such as the type of solar cells and the surface area and condition of the panel. In addition to energy harvesting, one of the advantages of using solar panels on roads is the reduction of the urban heat island effect.

4.6 Working Prototypes include Footpaths, Cycleways, Carparks and Driveways)

4.6.1 Wattway Solar Road (Colas) based in France. (Colas, n.d.)

Wattway has considerably evolved since the concept was launched at the end of 2015. Thanks to feedback from some 40 trial sites in France and around the world, the new generation of panels is even more efficient and robust. The industrial innovations brought to the photovoltaic cells, in addition to a new full, aligned cell layout, have helped boost Wattway's energy performance by 21% per square meter. Panel strength and resistance have also been optimized thanks to a new design in the resin multilayer which encloses the cells. Finally, the electrical architecture has been redesigned to reduce the amount of wiring, and the electrical equipment needed to operate the solution was enhanced to ensure better performance.

Figure 2 – Examples of Wattway installations

Wattway Pack highlights and secures a path or pedestrian crossing. Just a few panels are enough to power the LED Bollards that are triggered by a presence detector or a dedicated programmer.

4.6.2 Solar Roadways, based in USA

Solar Roadways have many working examples of their product in commercial carparks, cycleways and residential driveways. Their latest large scale project has seen them working with the USDoD (Department of Defence) sponsored by the Air Force Research Laboratory.

Installation within a carriageway is considered close after Solar Roadways conducted a successful advanced loading test on their panels. The test saw the panels undergo a simulated 15-years of truck abuse in three months. A weighted (4.3 tonne) truck tire made over one million passes over six Solar Road Panels. There was some noted damage at the end of the trial, but it was not attributed to being caused by the weighted tire. (Newman, Coutu, Munna, Tschida, & Brusaw, 2020)

4.7 Electromagnetism:

Harvesting energy from roads using electromagnetism is categorised as a mechanical system, converting kinetic energy into electrical energy using electromagnetic generators. Depending on their energy transfer mechanism, these harvesters can be divided into rack and pinion, hydraulic and roller. Experimental and theoretical studies have been conducted on developing and testing each of these harvesting systems.

Electromagnetic road energy harvesting systems have mainly been developed as speed bumps. They are also used in systems such as wind and water turbines.

Although a lot of systems have the potential of recovering at least a part of the wasted energy produced by vehicles travelling along a road, electromagnetic converters are potentially capable of capturing and generating a considerably higher amount of that wasted energy.

4.7.1 Rack and Pinion Electromechanical Energy Harvester

In these harvesters, the vertical movement of the road surface is converted into a rotational movement through a rack and pinion system connected to the surface. These harvesters are usually developed within a speed bump structure.

4.7.2 Hydraulic Electromechanical Energy Harvester

Unlike the rack and pinion system, in these harvesters, the load from the passing vehicles is transferred through a hydraulic medium to move a piston and spin the motor and the connected.

4.7.3 Wind Turbines

Already used successfully on buildings in the UK, Alpha 311 plan to mount 188 vertical axis wind turbines onto existing streetlights on the A442 main carriageway in Telford, United Kingdom, where they will harvest the airflow from passing vehicles. Streetlight mounted turbines are currently in testing phase. (Alpha 311, 2022)

Figure 3- An artist's impression of Installation of a wind turbine

4.8 Piezoelectric (Kinetic Roads):

Piezoelectricity is the electric charge produced by certain crystals when a mechanical stress is applied. First demonstrated in 1880 by the brothers Pierre and Jacques Curie, the piezoelectric effect has only begun to have practical applications in the past three decades.

Piezoelectric crystals can be embedded beneath a layer of asphalt. As cars drive over the road, the wheels exert a force that causes these crystals to deform and generate electrical energy. This energy can then be used to power streetlights or can be stored in batteries for later use.

In the United States, the state of California has invested USD 2.3 million to fund two independent projects with the aim of determining the viability of embedding piezoelectric devices in roads to harvest energy.

Another promising topic in this field is developing building materials which are capable of energy harvesting. In particular, cement-based piezoelectric and thermoelectric and energy storing composites are recently developed topics which have high potential for further improvements and future applications. Although their power output is relatively negligible compared to electromagnetic systems, their high compatibility with their host environment (the same material) is a significant advantage over other systems. (Zabihi & Saafi, 2020)

4.9 Thermoelectric:

The conversion of the thermal energy contained in roads to electricity is an emerging field of sustainable technology. Compared with electromagnetic and piezoelectric pavements, road thermoelectric generator systems (RTEGSs) have unique advantages, such as stable and continuous voltage output, reduction in high-temperature failures in pavements and prolonging of the pavement service life. At present, prototype Road Thermoelectric Generator Systems (RTEGSs) and their respective methods remain imperfect, and their power density is relatively low. (Yuan, et al., 2023)

4.10 Energy Storage:

Energy storage is an essential phase of harvesting energy after the conversion phases. Some suggestions of energy storage for road energy harvesting systems include super capacitors, big batteries and hydraulic energy storage. In the latter case, the energy is stored in the form of mechanical hydraulic energy, which will be converted to electrical energy once a threshold is passed. These facilities are often additional components of energy harvesting systems, taking place either within the mechanical module or as a separate module.

The most common form of storage being used for small scale generation are batteries, installed near the source of the generation and alongside the road or cycleway.

4.11 Transmission:

The large benefit of sourcing power from roads and transport infrastructure is that the generated power can be used within close proximity and therefore long-range transmission is not required. The generated power can be first considered for short circuits powering nearby lighting, security infrastructure and public supply for charging cars, e-bikes or phones.

If larger amounts of power are being generated, more than the need for the immediate environment, then this power can be connected to the electricity grid and distributed to households in the surrounding neighborhoods or transportation hubs for the recharging of electric busses and powering electric trains.

5. Risks & Opportunities:

We have identified several risks and opportunities associated with the proposed integration of renewable energy technology and infrastructure with transport infrastructure. This includes the level of maturity and development of existing renewable energy harvesting technology, materials and transmission to complicated integration considerations including the roles and responsibilities of government, asset owners and operators. This chapter explores some of these key considerations.

5.1 Risks

Technology Readiness:

Most energy harvesting solutions making use of roads are still in their early stages. Because much of the current research and development has been undertaken by private companies, there is limited public availability of data and costs remain high given the lack of mass production.

Standardisation and large-scale rollout:

At times, the arrival of renewable generation outpaces the changes in standards or regulation required to keep the power system reliable. The Australian industry could initially take guidance from the following international standards that are particularly relevant to zero-carbon power systems, which are maintained by IEC (International Electrotechnical Commission) and ISO committees and subcommittees:

IEC Technical Committee (TC) 47 develops International Standards for semiconductor devices including those that harvest energy.

IEC 62830-2:2017: Semiconductor devices - Semiconductor devices for energy harvesting and generation - Part 2: Thermopower based thermoelectric energy harvesting.

IEC TC 21: Standardization work for Batteries used to store electrical energy.

IEC TC 8 and its Subcommittee (SC) 8A: develops Standards for electricity supply systems, including the integration of power generated from renewable energy sources and fed into the electrical grid.

IEC TC 49: Standards for piezoelectric technology, which addresses piezoelectric, dielectric and electrostatic devices.

IEC TC 69: Electrical power/energy transfer systems for electrically propelled road vehicles and industrial trucks.

IEC TC 82: Solar photovoltaic energy systems

IEC TC 88: Wind energy generation systems

ISO/TC 180: Solar energy

A systems group, **SyC Smart Energy,** has recently been set up to provide systems level standardization, coordination, and guidance in the areas of smart grid and smart energy.

Space Constraints: Limited space in transport infrastructure like roads, railways, and airports can make it challenging to incorporate energy generation technologies effectively.

Cost: Initial investments in renewable energy technologies like solar panels or wind turbines can be expensive, making it a financial hurdle for integration.

Maintenance: Ensuring the ongoing functionality of energy generation systems in transport infrastructure requires regular maintenance, which can be costly and disruptive.

Efficiency: The efficiency of energy conversion and storage technologies must be optimized to make energy generation economically viable and sustainable.

Grid Integration: Coordinating energy generated from transport infrastructure with the wider energy grid can be complex and requires proper infrastructure and regulatory support.

Government and Industry Support: Engagement and support from transport and road agency would be required to successfully enable and incentivise the integration of renewable energy technology. New government policies and strategies may be required to support this change. This risk has been addressed in our Stakeholder Engagement chapter, identifying in-principal support.

Industry Service Providers: renewable energy suppliers are best positioned to build, operate and manage the supply of the energy harvested from the technology options integrated in transport infrastructure. There will need to be appropriate financial investment returns and/or incentives to ensure the viability of our proposal. This risk has been partially addressed in our Stakeholder Engagement chapter.

5.2 Opportunities

Sustainability: Integration can reduce the carbon footprint of transport infrastructure, contributing to cleaner and more sustainable transportation.

Energy Independence: Self-generation of energy can make transport hubs more resilient to power outages and reduce dependence on external energy sources.

Cost Savings: Over time, energy generation can offset initial investments and even generate revenue through excess energy sales to the grid.

Electrification: Supporting electric vehicle charging through integrated renewable energy can promote the transition to cleaner transportation.

Innovation: Integration can spur innovation in energy generation and storage technologies, leading to advancements in efficiency and effectiveness.

Social Inclusion: there is an opportunity to engage with minority groups and look for ways to provide targeted development to remote and indigenous communities.

Industry & Agency Energy Sustainability: With the ongoing migration of energy production shifting to renewable energy sources, there is a future concept that would propose all industries and agencies be able to produce energy to meet their own network demands and operational needs. The integration of renewable energy harvesting into transport infrastructure would be a positive step in securing the industry’s future energy demands.

Successful integration of energy generation into transport infrastructure depends on careful planning, investment, and collaboration among stakeholders to address these challenges and harness the opportunities.

6. Social Benefits

Renewable energy hubs offer numerous community benefits, promoting sustainability and economic development. Some of these benefits include:

Clean Energy Generation: Renewable energy hubs produce electricity from sources like solar, wind, and hydro, reducing greenhouse gas emissions and improving local air quality.

Energy Independence: Communities with renewable energy hubs can reduce their dependence on fossil fuels and centralized power sources, increasing energy security.

Cost Savings: These hubs often lead to lower electricity costs for residents and businesses, as renewable energy tends to have lower operating and maintenance expenses.

Job Creation: Building, operating, and maintaining renewable energy infrastructure can generate local jobs, boosting the community's economy.

Economic Growth: Renewable energy hubs attract investments and stimulate economic growth through the development of renewable energy projects, manufacturing, and research.

Community Engagement: Such hubs often involve local residents and organizations, fostering community engagement and cooperation in sustainable energy initiatives.

Energy Access: In regions with limited access to electricity, renewable energy hubs can provide reliable power, improving the quality of life and enabling educational and economic opportunities.

Grid Resilience: Renewable energy hubs can enhance grid stability and resilience, especially when combined with energy storage and smart grid technologies.

Environmental Benefits: By reducing reliance on fossil fuels, renewable energy hubs contribute to a cleaner environment and help mitigate climate change.

Technological Innovation: These hubs can serve as testbeds for innovative renewable energy technologies, driving research and development in the energy sector.

Education and Awareness: Renewable energy hubs can serve as educational resources, helping communities learn about and appreciate the benefits of clean energy.

Energy Export: Excess energy generated by renewable hubs can be exported to neighboring regions, creating revenue opportunities for the community.

In summary, renewable energy hubs play a vital role in promoting sustainability, resilience, and economic well-being within communities, making them a key component of modern energy systems.

7. Alignment with Roads Australia Policies

Our recommendations are aligned with and provide opportunity to deliver on the following Roads Australia policies:

Sustainability: integration of renewable energy generation into transport infrastructure will help the move to decarbonize by providing opportunities to encourage the move to zero emissions vehicles, will help drive further innovation capable of addressing climate change, and will help to address the environmental impacts of transport infrastructure.

Safety: transport infrastructure assets that generate renewable energy can be utilised to provide better road safety outcomes by providing power to street lighting in remote areas previously deemed not cost effective to invest in these areas as well as power sources for traffic control devices and variable message boards that can help save lives and reduce the road toll.

Transport Reform: This RA policy area recognises the need for transformational regulatory and technological reform to continue to drive value from Australian roads and the integrated transport network. This is very relevant in the renewable energy generation space given the need to employ new technology in the integration with roads and to integrate energy generating transport assets with existing utilities assets and whilst meeting safety and regulatory requirements.

8. Research Methodology and Approach

Our research approach was aligned to three main research methodologies:

8.1 Literature review

- Energy harvesting material technology and applicability/adaption to transport infrastructure, including integration into new build scenarios and modification of existing infrastructure to incorporate.
- Overseas and local tests, trials and implementation of energy harvesting technology in transport infrastructure scenarios, including pros, cons, lessons learned, gaps in policy, gaps in specification, etc.
- Technical publications from universities, government/authority, industry innovation, and applicability to Australian use.

8.2 Peers Network Surveys

- Develop a set of survey questions to share across industry and peer networks, encompassing various subject matter areas and demographic perspectives in the transport industry to seek feedback on the feasibility, opportunities and constraints for integration of renewable energy technology and the potential to attract existing fringe industry talent or new talent to the transport sector.

8.3 Interviews with Subject Matter Experts

- Interview Subject Matter Experts (SME's) in renewable energy technology sector and gauge current industry and market maturity for application of proposal
- Interview government transport and infrastructure agency resources such as policy makers and asset owners to understand appetite and capacity for change; and areas for consideration from their knowledge, experience and connections to research and consider in future roadmap.

9. Stakeholder Engagement

9.1. Peer Network Survey

A short online survey containing 6 questions was initiated by the project team to gauge the industry's thoughts on energy harvesting in new and existing infrastructure. Figure 4 illustrates the diversity of respondents who took part in the survey with a total of 91 surveys received with over 50% of respondents with more than 10 years in the transport industry.

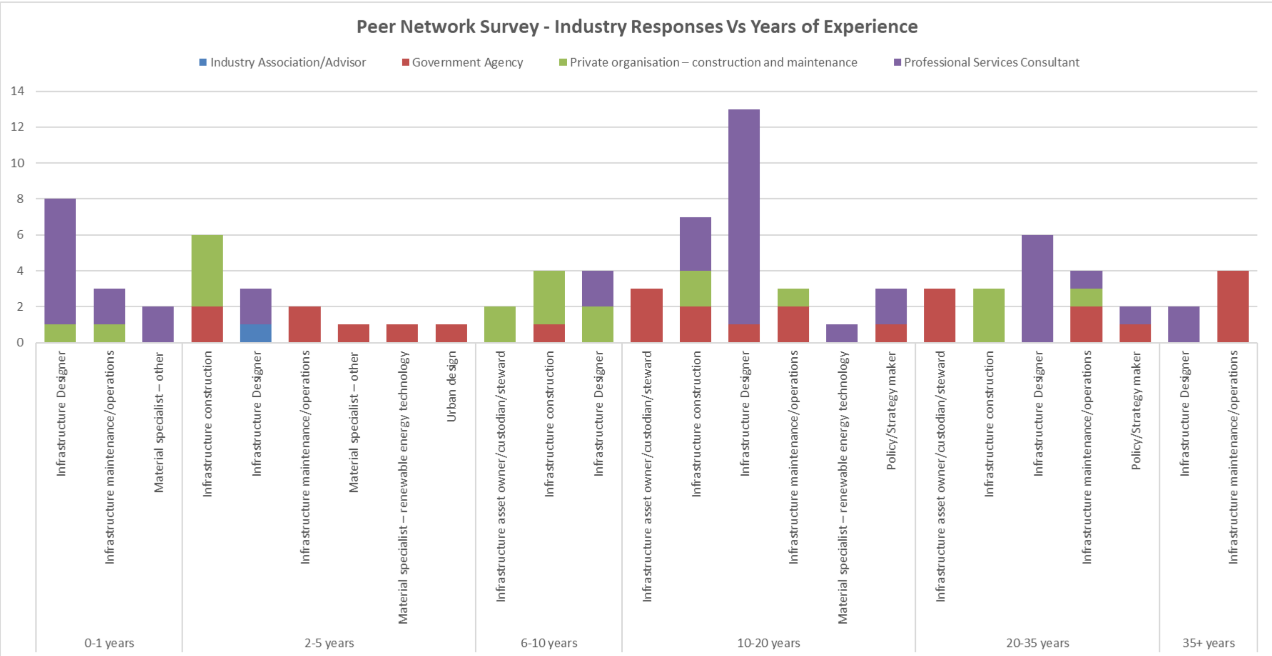
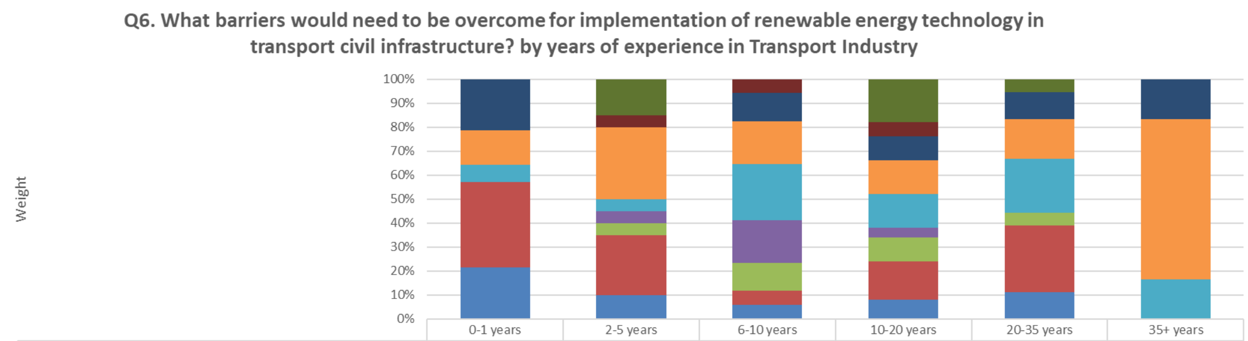


Figure 4 – Summary of survey responses received

The survey, and the results of the peer survey which can be found in Appendix 1, can be summarised as follows:

- There is still a lot of work to be done in terms of integrating renewable energy technology into transport practices and, after doing so, the industry is going to be able to attract slightly more professionals from fringe industries.
- The majority of the survey participants believed that solar energy was the most suitable for integration into transport-related civil infrastructure.
- A large percentage of the industry also believe that there needs to be a lot of development in the renewable energy space before the industry is able to implement renewable energy into their day-to-day workstream. This indicates a lack of confidence in the effectiveness and applicability of currently available technology.
- There are mixed feelings with regards to the industry's ability to attract talent to join the transport community with very few believing that there would be a very high level of interest. The majority of the transport community seems to believe that the implementation of renewable energy technology in day to day work can attract a small number of people to join the industry.
- Three key pillars appear to be the main barriers to the adoption of renewable energy in the transport community:
    - Technological implementation limitations (this was flagged as the main issue by practitioners with over 35 years of experience)
    - Lack of supporting strategies and policies
    - Low awareness of renewable technology in the transport community



	0-1 years	2-5 years	6-10 years	10-20 years	20-35 years	35+ years
Other Comments		3		9	1	
Energy storage and transmission		1	1	3		
Limitations in existing renewable energy technology and materials	3		2	5	2	1
Challenges to adapt renewable energy technology and materials for application to civil infrastructure	2	6	3	7	3	4
Lack of awareness of renewable energy technology within the transport civil infrastructure industry	1	1	4	7	4	1
Lack of suitable skills and capabilities in the renewable energy industry		1	3	2		
Lack of suitable skills and capabilities in the transport civil infrastructure industry		1	2	5	1	
Supporting strategies, policies and incentives	5	5	1	8	5	
Limited resource availability	3	2	1	4	2	

Figure 5 – Perception of barriers based on age group

9.2 Stakeholder Interviews

Key to the success of our project proposal has been engagement with subject matter experts from various companies in both the energy harvesting and government planning and policy spaces.

The key contacts and feedback gathered from these sources is summarised below.

The following section adopts the perspectives of those involved in the planning, design and implementation of Solar Grid installations in Australia and Canada.

Nalin Pahalawatta - Energy – Planning and integration of PVs (Sydney, Australia)

An experienced practitioner with over 35 years' experience in the planning and design of Solar Farm Electrical Feeds and Systems in New Zealand and Australia.

- Recommends the deployment of microgrids for rapid uptake of more sustainable energy options in areas where there is heavy reliance on existing coal power energy supplier. Microgrids are a plug and play systems which can be adopted to any source of renewable energy.
- Microgrids can generate up to 4-5MW/2MWh battery system which has the potential to power up to 20 electric vehicles. The cost of implementing a microgrid is estimated in the order of $4-$5 million based on a reduced scale Solar Farm. The adoption of microgrids would help alleviate the issue of transmission and storage as the energy is to be used locally.
- This has seen widespread adoption across the world and is emerging in Australia Via Western Australia for use in remote communities and mining where the cost and challenges of implementing infrastructure is high to implement full scale Solar Farms or infrastructure to tie into existing energy sources. Examples were:
    - Kalbarri Microgrid (Local Community)
    - Agnew Renewable Hybrid Microgrid (Gold Mine)
- For rapid deployment of solar along existing road corridors where there has been a stagnant in deploying solar in remote access areas, government/industry it was suggested that Government should consider reviewing existing truck layover locations to see whether microgrid installations

can be adopted as a first step. The ownership/maintenance could be considered as part of the existing landowners' asset who may be able sell the energy back to the distribution network or in this case, locally at the service station. This potentially has the opportunity to contribute to the local community by supporting job growth and provide a new source of income stream in addition to energy security.

- Solar and wind are considered the most mature methods of all technology, however with the increase in material costs and scarcity of lithium and rare materials for batteries, alternative methods of sustainable energy sources are now starting to be investigated. One such technology is Solar Thermal Energy (concentrated solar) which collects solar heat arrays to heat molten salt. The advantage of this installation is that the molten salt during nighttime is able to store the heat for use. Such installations should be considered in Australia given sunny climatic conditions. These installations are seen used in Spain and Morrocco.
- There is an opportunity to investigate the reuse of end-of-life solar panels in road construction by separating glass materials from the rare earth semiconductor materials due given the finite resource availability. With increase in uptake of PVs, there is a need to ensure that the disposal of the panel is also dealt with.
- There is a need for more investment in startups, there is not enough funding to look into the technical issues/challenges specifically storage given the increase in material costs.
- The industry is very mature – specifically solar in Australia, however the Australian Government and regulations when compared to the rest of the world are draconian. Therefore, difficult for innovation.

Andrew McLean - Solar, Senior Engineer (design and construction) (Mississauga, Canada)

An engineer with over 10 years in the Solar Industry in Canada and through the world. He provides feedback to the design and construction of solar farms to achieve the optimum profitability.

- There is a potential to use recycled end-of-life solar panels in road construction, however further research is required into impacts of chemical leaching.
- His main recommendation is for industry to retain use of solar and wind as these are considered the most mature methods of all technology, all others are still requiring heavy investment in research and development.
- There are examples through the world where disused government land assets (i.e. rail corridors) have been converted into solar harvesting facilities and these should be considered when identifying new locations.

Mark Mitchell - Microgrid Global Lead (Vancouver, Canada)

A specialist Microgrid & Power System Specialist with a diversified background in power system controls and project management. He has extensive experience working with renewable energy and energy storage projects from conceptual studies to commissioning and operation.

- Outlined that in Canada due the Country's vastness and lack of infrastructure density, there are still several remote localities that depend on off-grid thermal plants to produce electricity using fossil fuels.
- During his career, he has widespread deployment and uptake of microgrids in Canada, particularly in these remote communities where the clean energy use has resulted in local economic development, and a renewed sense of community pride.

- Heavily advocates in areas where there is limited infrastructure to facilitate transmission and distribution, microgrids should be considered over other technologies.
- Advocate the government should engage with existing landowners (particularly indigenous communities)– in the form part of the decision-making process to be engaged in the early phases during the planning process. Where there is potential for social enterprise ownership.
- Recommends that with any proposed microgrid early engagement with local landowners and community is key as it is key to unlocking potential for social enterprise ownership.

Transport for NSW – “Voice of the Policy Maker and Asset Custodian” perspectives

The project team engaged with three leaders across Transport for NSW, ranging from planning and policy leads to sustainable infrastructure delivery leads and Asset custodians to gain an insight into the opportunities, challenges and areas for further research regarding the integration of renewable energy technology into transport infrastructure.

It is noted that the discussion items and themes may not be those of the organisation that each stakeholder represents.

Christopher Royal: Director, Sustainability, Safety Environment and Regulation

Chris Royal is the Director Sustainability within the Sustainability unit of Transport for NSW’s Safety, Environment and Regulation department. Chris leads develop of strategies, tools, policies and procedures for sustainability and climate change response across all of Transport for NSW and provides support to large capital projects delivered by Transport for NSW.

Chris considers that a cohesive strategy and approach across all transport infrastructure and assets would be required to successfully implement renewable energy harvesting and technology across the sector. Of the available renewable energy harvesting technology, solar is considered the most viable due to the maturity of the materials and capability, and relative ease of adaptation to different land areas and environments.

An opportunity exists to review the strategic approach to utilisation of residual land and/or retained road corridor owned by roads authorities. Prior strategies have investigated or pursued selling off land and there exists an opportunity to test if this land can be better utilised if retained. An optimum land use masterplan for infrastructure corridors would support a systematic assessment of all land owned by transport authorities and determine the best-value use.

Not all land is suitable to be sold as surplus, noting that some areas need to be retained for easements, regular maintenance access, buffers to adjacent land uses, and future road corridor options informed by strategic transport planning. An overarching land use masterplan would bring together various key stakeholder groups across Transport for NSW with various stakeholder perspectives, and lead to a unified approach to land management supported by all stakeholders with a values-based sustainability assessment a key requirement.

If residual land and road corridors are considered for renewable energy technology, maximising utilisation and consideration of roles and responsibilities is necessary. Would Transport installed and operate renewable infrastructure, or would they lease to independent renewable energy partners? Transport’s role could be to undertake land use planning development under the appropriate planning pathway, such as ISEPP, and then make the land available to industry to be developed with renewable energy technology. This would reduce the need to maintain a parcel of land that has minimal return on investment or customer outcomes.

There are more than 50 Transport assets that have medium to large photovoltaic energy harvesting solutions, spread across offices and various facilities, and Transport are investigating deploying electric vehicle charging hubs across Transport facilities. A policy that extends implementation of renewable energy harvesting across residual land or transport corridors may find support building off existing policies and strategies for utilisation of existing Transport assets for PV energy capture.

One of the highest costs for renewable energy sources within or in close proximity to high population centres is the land price. The use of retained public land could support industry growth without Transport taking on a new and higher risk function that may not be considered core business if Transport was to build, operate and maintain energy harvesting assets.

Some early investigations for utilisation of retained road corridor or land owned by Transport is in progress within the NSW Renewable Energy Zones. Barriers such as renewable energy skills and expertise in the transport industry leads to an initial view that roads agencies would not look to build, own or maintain renewable energy infrastructure, and rather support utilisation through provision of land for hosting of renewable energy infrastructure and supporting strategies, polices and land use assessment.

In summary, the development of a Transport Optimal Sustainable Land Use and Property Masterplan would provide an evidence-based high resolution graphical evaluation for the best long-term economic and sustainable use of all Transport land. This could include a:

- marginal abatement cost analysis of large-scale renewable energy generation and/or energy (battery) storage hubs,
- EV charging hubs,
- green hydrogen production and distribution hubs,
- large-scale land biodiversity offsets and revegetation,
- land and soil carbon credits,
- community hubs or precincts,
- community land-leasing (e.g. for community parks/gardens/reserves),
- active transport corridors such as cycling and walking paths and trails,
- lease or sale of land (with low residual value) that lowers ongoing OPEX maintenance burden (e.g. priority weeds removal).

David Kelly: Director Engineering Sustainable Infrastructure, Advanced Technical Services, Infrastructure and Place

David Kelly is the Director Engineering Sustainable Infrastructure within the Advanced Technical Services unit of Transport for NSW's Infrastructure and Place department. David works in the major capital projects space with an engineering and technical focus on improved sustainability and carbon reduction outcomes, leading sustainable infrastructure inputs into major transport delivery programs. David is also part of a national working group for de-carbonisation of infrastructure and involved in a national carbon assessment standard to support infrastructure programs.

A key focus area of David's role is carbon management in infrastructure, which he supports from an infrastructure delivery perspective, and many European nations are leading the way with supporting polices to reduce carbon and reduce cost as early as possible in the infrastructure lifecycle. To enable and support the integration of renewable energy technology into transport infrastructure, a detailed framework to quantify the benefits over a whole of life assessment for an infrastructure project would be beneficial. This could be via carbon cost analysis during business case preparation and review processes, and introduction of carbon values in the financial assessment process to challenge whether current infrastructure measures are sufficient to generate a change in scope and technology integration, essentially monetising the benefits and carbon natural assessment component.

David also informs the development of procurement and commercial aspects of major project contracts during delivery. An option for the integration of renewable energy technology could be to bring forward innovation via options in contracts, including terms relating to renewable energy harvesting such as a completed project to have a nominated amount of left-in-place energy harvesting on completion, supporting, and allowing industry to innovate to meet the requirement rather than specifying a certain technology type to be implemented. The inclusion of these contractual requirements could be supported by inclusion or adaptation into sustainability procurement standards, or similar, and would support innovative mechanisms in contracts even if the delivery model is rigid.

A likely suitable next step would be to pilot the inclusion of a renewable energy option on a project, where the tenderer nominates energy a harvesting method on an outcomes-based approach rather than prescriptive technology requirement, and review as a case study for alignment to Transport's Sustainable Infrastructure Program.

Rosemary Crowhurst: Director, Assets South, Regional Assets, Regional and Outer Metropolitan

Rosemary Crowhurst is the Director Assets South within the Regional Assets unit of Transport for NSW's Regional and Outer Metropolitan department. Rosemary leads the asset custodian and management functions, such as capital road, corridor and bridge renewal, upgrade and OPEX maintenance of state roads in the South Region of Transport for NSW stretching from the Illawarra south to the Victorian border and west across the Riverina.

Transport is preparing a Net Zero and Climate Change Policy, which has a identified a key recommendation and requirement to allocate the necessary resources to achieve the targeted outcomes. The potential inclusion of renewable energy harvesting technology within transport corridors and retained land assets may align to this policy, once published, and support the sustainability objectives.

The potential for inclusion of microgrids within road corridors and/or retained residual land would require review against the Roads Act to review what authority there is to pursue or not pursue. For freeways, the NSW Government is the roads authority for the full corridor, whereas local governments are the authority for roads reserves on other state roads, such as highways, and a supporting infrastructure policy may be able to allow microgrids were safe. Consideration should also be given to other potential land use options, such as cultural landscape management, when assessing the suitability and environmental planning considerations for land areas being investigated for the installation of renewable energy technology. There are potential transport corridors within the Illawarra that may be worthy of investigation for the viability of renewable energy technology integration, such as Memorial Drive or the M1 Princes Motorway.

The solar energy industry is mature and may therefore lend a policy and strategy position to partnering and enabling between government and industry, rather government agencies seeking to build and run their own microgrids. Transport could be an enable by leasing suitable road corridor areas or residual land and completing development planning and assessment for an industry provider to construct, operate and maintain solar energy harvesting infrastructure. There is currently negligible return on investment and low customer value outcomes maintaining residual land or land preserved for future road corridor; a leasing arrangement not only enables re-deployment of labour and resources; it may also generate funding to undertake other higher value maintenance and capital works that may have otherwise been underfunded or unfunded.

An important aspect would be to consider the philosophy of a government roads authority here; if we were to consider the government agency to be operating as a business, then there is the potential for unlocking and leasing land that can make money and re-inject into other initiatives as an industry organisational and financial sustainability measure, as well as the more traditional 'green' measures of sustainability. Typically, a government agency would not provide a service that can be provided at a level of maturity by the market – ethos is to fill a gap rather than compete, and therefore government's role here could be to provide a service that the market needs, such as affordable land leasing for microgrids within close proximity to cities and sources of demand, that would not restrict the future use of this land for transport infrastructure should land use assessment change as infrastructure planning and strategies develop.

Potentially the biggest challenge for the successful integration of renewable energy technology into transport infrastructure is the process of incorporating the technology into "business-as-usual". This could be seen at the key success for meeting long-term sustainability goals.

Key Themes identified from Transport for NSW SME's:

The following key themes were identified across the three different stakeholder discussions:

- Solar Energy is generally considered the most mature and readily adaptable renewable energy harvesting technology.
- Supporting Government strategies, policies and incentives would be highly important to meet the goal of integrating renewable energy technology in transport infrastructure.
- Government's role would most likely be to partner, support and enable rather than build, own or operate any integrated renewable energy technology.
- Government's role could most likely be to make available land for development of renewable energy technology via leasing residual road corridor or retained land and carrying out planning and assessment approvals.
- Government's role could likely be to ensure a commercial procurement framework include sustainability and carbon reduction targets based on integration of left-in-place energy harvesting on project completion.
- Government's role could likely be to review business case requirements for whole of lifecycle infrastructure assessment to monetise the benefits and carbon neutral assessment component with respect to renewable energy technology.
- The leasing of available and suitable transport corridors or retained and residual land would support unlocking resources for redeployment to higher customer value programs or works and generate revenue to support spending on programs that may otherwise have been underfunded (or unfunded).
- The roadmap to implementation for the integration of renewable energy technology into transport infrastructure could be best supported by:
    - pilot site/s for microgrids where government leases land to industry providers to build, operate and maintain,

    - pilot project to trial a renewable energy option in delivery contracts; where the contract would nominate a required level of energy harvesting to be left-in-place on completion, based on an electricity generation outcome rather than being prescriptive with respect to the renewable technology to be used.

- New talent to the transport industry could be sourced by:
    - releasing existing talent from management and maintenance of residual land to be re-deployed onto existing corridor management and maintenance functions.
    - renewable energy technical leads in major project delivery and surveillance for infrastructure projects, and attraction for mobilisation of talent from existing renewable energy organisations to transport industry organisations.
    - renewable energy technical staff within business case preparation and assessment.
    - attract new talent to industry with step-change shift to renewables and sustainability as core to road and transport corridors and projects.

Beca – Sustainability

Dr. Anumitra Mirti: Senior Associate Sustainability

Dr Anumitra Mirti has 20 plus years of experience in sustainability, climate resilience, project management, research and strategic environment and land use planning having worked in academia, private and government agencies both locally and internationally. At Central Coast Council she managed the strategic environment planning team that included ecological assessment for development applications, led the disaster resilience initiatives and emergency management planning project and provided sustainability and environmental management technical expertise across all council capital works and operational projects such as city planning, land use management and infrastructure projects. In her current role at Beca, she will be driving sustainability and climate resilience across BECA's projects both nationally in Australia and internationally.

- Recommended measuring sustainability benefits using carbon accounting tools and societal costs of the proposal. This could inform policy creation or commission further research;.
- Provided some good examples of sustainable transport practices that could benefit from renewable energy generation and/or provide opportunities for storage and transmission from both domestic and international case studies.
    - E-bike battery hubs across major urban areas in India – powered by renewable energy. These hubs recycle and replace batteries and provide a battery swap system to allow better efficiency and coverage for sustainable transport options permitting longer journeys.
    - Solar bus stops in Saudi Arabi which generate solar energy and used to power surrounding infrastructure such as interactive timetables, live public transport information, street lighting, and CCTV.
    - Liverpool City Council – roll out of smart lights i.e. solar powered street lighting that reports status such as faults and maintenance logs on an hourly bases.
    - Smart roads in City of Sydney local government area. These are roads that detect presence of vehicles and objects, forecast maintenance requirements and
    - Newcastle, Lake Macquarie and Hume Council – design of Circular Roads i.e. using circular economy design principles when designing new infrastructure.

- Recommended that carbon offsetting should be considered in all innovative solutions.
- Recommended updating technical specs with sustainability requirements – in order to support innovation.
- Also recommended create a raw materials passport for roads material infrastructure using a digital twin to track compliance with sustainability requirements such as carbon accounting.

10.Cost Assessment

The cost of integrating renewable technology into transport infrastructure, such as pavements and structures, is extremely difficult to quantify and there has been limited research in Australia to determine its true viability.

Illawarra Road Corridor Microgrid – A Theoretical Case

A key opportunity identified across our research and stakeholder engagement was the integration of solar microgrids within transport and road corridors and residual land owned by roads authorities.

600 kWp - Ground Mount Seasonal Tilt

Figure 6 - Re-purposed disused rail corridor into Solar Harvesting Farm (*German Solar Corporation, 2023*)

This aligns to the NSW Government's EnergyCo that identifies that "Upfront land-use planning and coordinated community consultation are central to Renewable Energy Zones and will help ensure a strategic approach to electricity infrastructure development." (EnergyCo, 2023)

The map below shows the location of the first five Renewable Energy Zones in NSW.

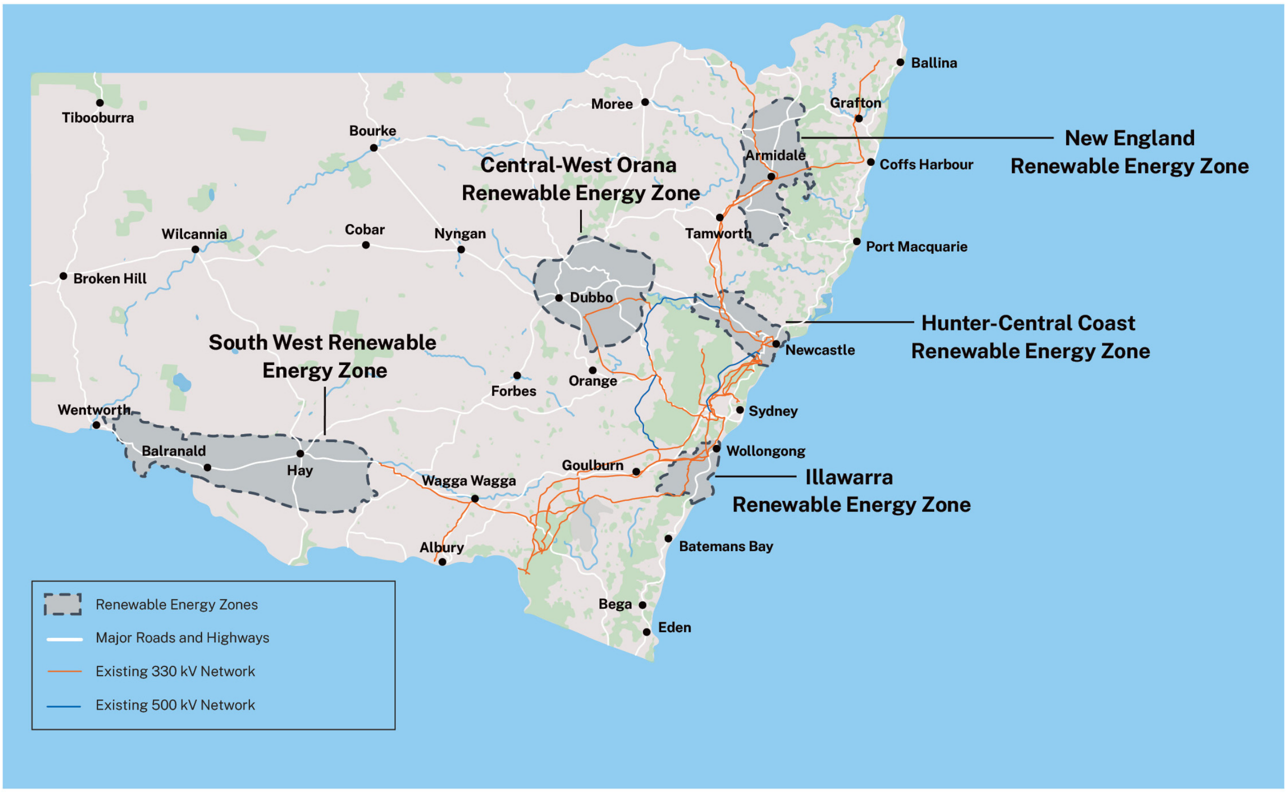


Figure 7 - Renewable Energy Zone Locations *(EnergyCo, 2023).*

There is a section of road corridor in Bulli, NSW preserved for a potential extension to the Memorial Drive road corridor located in the northern Illawarra, and within the Illawarra Renewable Energy Zone outlined above. A basic desktop assessment identifies approximately 2.8 hectares of cleared and un-developed land that could be utilised for a solar microgrid. Low height housing and vegetation adjacent to the land parcel would not restrict the viability of solar panel energy harvesting at this site.

Typical industrial and commercial land values in the Wollongong LGA range from about $500-1500/m2 (Valuer General, 2022). If we adopt a conservative approach of $750/m2, the total land value of this potential microgrid location could be considered in the order of $20M. Assuming a 0.25% yield, annual lease costs could be in the order of $50,000.

Typical maintenance costs for vacant land of this size, such as vegetation control and weed spraying, could be estimated at $0.50/m2 or $14,000. Assuming this occurs four times per year, annual maintenance costs could be in the order of $50,000/year. For this land parcel, the net benefit to Transport for NSW could be about $100,000 per annum based on an annual revenue of $50,000 and reduced maintenance costs of $50,000 per annum.

Generally, a one megawatt (MW) solar farm would typically occupy about 2-3 hectares of land (Energy Matters, 2023). This means that the Bulli parcel of land could be reasonably suitable for a one-megawatt solar farm, or microgrid.

A review of 13 large scale solar farms completed by MCG Quantity Surveyors identified that the investment costs per Watt to range from $1.34 - $4.00 (Mortlock, 2019), and again, for a conservative approach for a smaller scale site, if we adopt $4.00/Watt the cost to construct a one megawatt microgrid in Bulli would be in the order of $4M including land acquisition or leasing costs.

A one-megawatt microgrid could generate between 3,000 and 5,000kwh per day across the year with variable energy generation in winter and summer, and if we assume an average day over the course of the year is 4,000kWh and a commercial feed-in tariff of 10 cents/kWh (Independent Pricing and

Regulatory Tribunal, 2021) the microgrid could generate about $400/day or about $146,000/year. Assuming a service life of 25 years to total revenue from electricity generation over the life of the microgrid would be about $3.7M.

To ensure the proposed microgrid is economically feasible, support from renewable energy grants and programs, such as via the NSW Department of Planning and Environment or the NSW Climate and Energy Action, may be required to incentivise this development.

Figure 8 - An example of a solar microgrid adjacent to freeway in South Korea *(Bellini, 2021).*

11. Roadmap to Implementation

Based on our research of renewable energy technology, previous case studies and trials, and stakeholder engagement, we have identified a potential roadmap for the implementation and integration of renewable energy technology and infrastructure into transport infrastructure.

11.1 Renewable Energy Technology Type

Solar energy, harvested via photovoltaic panels, is currently the most developed and mature technology and infrastructure suitable for integration into transport infrastructure based on industry depth and successful small and large scale applications in Australia and overseas. The risk to reliability engineering and material technology is lowest and availability of industry providers indicates the potentially lowest technology cost option, while also enabling ease of removal of the solar infrastructure if unsuccessful. Wind turbines are likely the next most viable energy harvesting option for integration into transport infrastructure, with some evidence of successful trials in the UK.

Our roadmap recommends the adoption of solar energy technology, and potentially some localised trials of wind turbines, as the renewable energy technology type for initial integration with transport infrastructure and notes that, as the transport industry implements this integration, other technology types may follow based on industry incentives for innovation and development.

11.2 Leasing Transport Assets for Microgrids

A renewable energy microgrid is essentially a hub of energy harvesting infrastructure that connects to the state electricity grid and/or can store and supply power remotely when disconnected from the grid, which can be particularly beneficial for regional and rural communities. Solar microgrids can be applied at any scale and include the capability to be expanded later if required and space allows.

The Korean Government has announced a plan to deploy large-scale microgrid projects along their road network and highways, and give the opportunity for private companies to lease idle areas to deploy their projects. The Korea Expressway Corporation will "will offer surfaces on the slopes of the embankment of highways, the green areas around junctions, the rooftops of buildings, and parking lots" (Bellini, 2021) with a 20 year lease term where developers will be required to pay a usage fee.

In the United States, an exit off a highway in Georgia was developed as a 1-megawatt solar installation within the overall interchange lane area. See Figure 9 below:

Figure 9 - An example of a solar microgrid adjacent to freeway in Georgia, USA. *(Descant, 2020).*

The NSW Government has identified five Renewable Energy Zones across regional NSW, and within these zones there are several key road and transport corridors that may be suitable for development with renewable energy microgrids.

Our roadmap for leasing transport assets for microgrids would seek to identify a pilot site/s for where government leases land to industry providers to build, operate and maintain renewable solar energy infrastructure. This would include:

- Identifying a suitable section of a road or transport corridor or residual land owned by Transport for NSW within the NSW Renewable Energy Zone; the parcel of land would ideally be in close proximity to energy demands such as a commercial, residential or industrial area.
- Completing planning and development assessment for the identified land that support development with renewable energy infrastructure (photovoltaic panels). Battery storage requirements, if any, would be considered based on local characteristics of the land parcel, such as reliability of the electricity grid, risk to impact during outages or natural disasters, and off-peak energy use demands.
- Leasing the identified land to a renewable energy industry provider for construction, operation and maintenance of the energy harvesting infrastructure, with connection to the mains electricity grid.

To determine the viability of leasing transport assets for microgrids, a framework for assessment of the pilot would be established prior to implementation and regularly reviewed during construction and operation. The framework may include:

- Assessing the 'do nothing' case, including the cost of maintenance of the existing land parcel and the value provided to the local environment and community.
- Identifying any impacts to road access or maintenance requirements to be considered in the development of the land with renewable energy infrastructure.
- Determining the land value and lease costs for measurement against industry tenders
- Reviewing the resources re-deployed to other road corridor and maintenance functions, and the benefits and works programs delivered with the revenue from land leasing.
- Reviewing the resources engaged from outside the transport industry required to deliver the pilot project.
- The safety and security of the identified land for ongoing maintenance and operations of renewable energy technology
- Feasibility assessment of the electricity utility adjustments and required to connect the micro grid to the mains electricity network and measure.
- Energy harvesting outputs and commercial viability of the microgrid.

The successful completion and operation of microgrid pilot site on leased road corridor would enable feedback into Transport for NSW land use planning strategies and policies, including alignment to a future Transport's Net Zero and Climate Change Policy, supporting wider roll-out of microgrids across transport and road corridors, and residual land parcels owned by Transport for NSW, increasing renewable energy harvesting across transport infrastructure throughout NSW as part of a masterplan for land use utilisation.

A final review of the pilot at an organisational and industry level for talent movements would identify if any new talent has moved into the transport industry because of the proposal, and what the projections of new talent would be on implementation of the larger scale program.

A basic desktop cost assessment of a microgrid installation in the northern suburbs of the Illawarra near Bulli has identified the potential financial viability for expansion of microgrid installations on leased road corridors and residual land when supported by other NSW Government initiatives and clean/renewable energy programs. Cross-agency and industry partnerships will be essential during the pilot phase to measure success and determine future policy, strategy and program requirements.

11.3 Renewable Energy Options in Project Delivery Contracts

It is common for road and transport infrastructure contracts to include clauses and options for innovation during the project delivery phase, enabling increased benefits and/or reduced costs or impacts during construction, maintenance and operation phases, however typically there is a heightened focus on the construction phase.

Our roadmap for integration of renewable energy technology into transport infrastructure requires a pilot project to trial a renewable energy option in the delivery contract. The contract would nominate that renewable energy harvesting must be left-in-place on completion for the operation phase of the project lifecycle with the type of renewable energy harvesting to be determine by the successful tenderer based on a target level of renewable energy generation.

The pilot project would include:

- A business case that considers the requirement for renewable energy technology to be integrated in the transport infrastructure project.
- A benefits analysis of the whole of lifecycle infrastructure project to monetise the benefits and carbon neutral assessment component with respect to renewable energy technology integration for the project.

- Be based on a draft commercial procurement framework that includes sustainability and carbon reduction targets consider the integration of left-in-place energy harvesting on project completion.
- Post-tender review to assess market capability to meet the requirements for renewable energy integration.
- Post-construction review to assess the benefits realisation aspect of renewable energy integration and electricity harvesting during the operation phase.

When these requirements are included in business case assessment criteria as part of a transport planning policy and incorporated into construction tenders, this will incentivise industry to deliver on the integration of renewable energy technology into transport infrastructure projects; and will bring the two industries, the transport industry and the renewable energy industry, to be working in close partnership and support the mobility of talent across the sectors.

It is expected that the renewable energy harvesting technology proposed by industry may initially be solar and wind turbine based on the maturity and tested nature of these materials and technologies, however, in time and through the implementation of this proposed procurement framework, it is expected industry innovation will occur to integrate other renewable energy types based on project specific requirements, such as site constraints, geographical conditions and transport infrastructure types.

The successful implementation of the pilot project would enable feedback into Transport for NSW's sustainability in procurement framework, or similar, for ongoing application and implementation across infrastructure programs and projects. A future state where these requirements are considered 'business as usual' will ensure that long-term sustainability measures and carbon reduction targets are met, along with the growth and development of talent within the transport industry.

11.4 Enabling Government Policies and Strategies

A key finding from our research, peer network survey and SME stakeholder interviews was the need for new or enhanced government policies and strategies to support the integration of renewable energy technology into transport infrastructure.

The following policy areas are recommended for review as part of our roadmap to implementation:

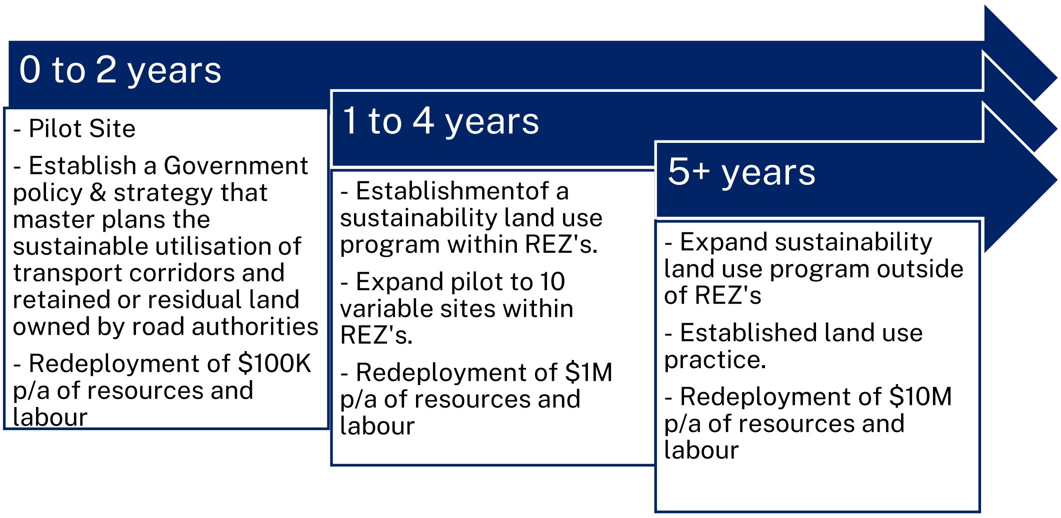
- A government policy and strategy that master plans the sustainable utilisation of road and transport corridors and retained or residual land owned by road authorities.
    - This policy could support the utilisation of road and transport corridors, or residual land, to be leased for the installation of renewable energy microgrids.
    - Based on the applicability of the NSW Roads Act with respect to use road corridors and infrastructure, this policy area is recommended to be addressed by the NSW State Government in consultation with other state government departments (such as DPIE), local government, and industry bodies and representatives.
- A government policy that supports a business case assessment and commercial procurement framework that includes sustainability and carbon reduction targets based on the integration of left-in-place energy harvesting on project completion.
    - This policy would support the innovation and growth in application of renewable energy harvesting integration with transport infrastructure projects.
    - This policy should support and enable innovation to expand the types of renewable energy harvesting technology that may be further developed in coming years and be suitable for integration into transport infrastructure in the future.

- Based on the lead role that the NSW Government has in transport planning, programming and delivery of infrastructure projects, this policy area is recommended to be addressed by the NSW State Government in consultation with the Australian Government (recognising their role in co-funding major infrastructure program), other state government departments, local government, and industry bodies and representatives.

11.5 Roadmap Timeline

Leasing Transport Assets for Microgrids

The following roadmap program outlines the alignment of supporting government policies and strategies with an initial pilot site, an expanded pilot program and pathway to establishing a long-term land use practice to lease transport assets for microgrids.

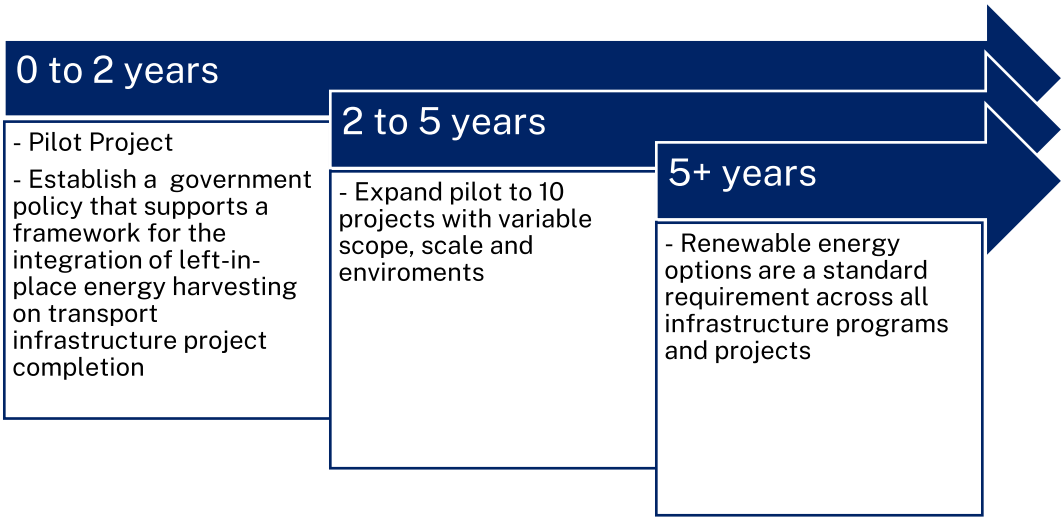


- 0 to 2 years
  - Secure funding for pilot site
  - Complete a Pilot Site Project
  - Estimated net revenue return of $100,000 p/a based on land lease and elimination of maintenance funds for vacant land. Redirection of maintenance resources to higher customer value works and programs.
  - Review and confirm feasibility and requirements for establishment of an ongoing land use program.
- 1 to 4 years
  - Establishment and implementation of a sustainability land use program that supports leasing of road corridors and retained land for microgrids across identified NSW Renewable Energy Zones
  - Expand program to about 10 varying sites across NSW to support wider testing and proof of application.
  - Estimated net revenue return of $1,000,000 p/a based on land lease and elimination of maintenance funds for vacant land. Redirection of maintenance resources to higher customer value works and programs. (assuming same estimated financial return of pilot site)
- 5+ years

- Expand sustainability land use program for utilisation of road corridors and retained land for microgrids across NSW, including outside of identified Renewable Energy Zones as an established land use practice.
- Estimated net revenue return of $10,000,000 p/a based on progressive expansion to 100 sites for land lease and elimination of maintenance funds for vacant land. Redirection of maintenance resources to higher customer value works and programs. (assuming same estimated financial return of pilot site)

Renewable Energy Options in Project Delivery Contracts

The following roadmap program outlines the alignment of supporting government policies and strategies with an initial pilot project, an expanded pilot program and pathway to establishing a long-term business case and procurement framework for the integration of renewable energy harvesting options in project delivery contracts.



- 0 to 2 years
    - Identify small-scale pilot project to trial renewable energy options in the project delivery contract. Consider this pilot project as a proof of concept.
    - Review pilot project and determine updates and amendments required to inform an update to the sustainability in procurement framework.
- 2 to 5 years
    - Implement updated renewable energy options in the project delivery contracts across 10 varying infrastructure projects to test and validate scalability and suitability across infrastructure projects.
    - Review projects and determine updates and amendments required to inform an update to the sustainability in procurement framework.
- 5+ years
    - Renewable energy options are a standard requirement across all infrastructure programs and projects for alignment to the sustainability in procurement framework.

Enabling Government Policies and Strategies

There are some existing government policies either in effect or under development that will support the required updates, amendments and alignment to deliver on the necessary changes to support our roadmap. We consider a 0-2 year horizon to prepare and finalise these policies and strategies to be suitable and achievable, that will also support inclusion of any findings and learnings from both the microgrid pilot site and pilot project with renewable energy options included in the contract terms.

11.6 Securing Talent for Transport Infrastructure

Our roadmap to provide security for future talent in the transport industry is based on three talent streams:

1. Unlocking Existing Capacity in the Transport Industry
    a. The leasing of transport corridors and residual land will enable re-allocation of existing land maintenance funds and labour resources to higher value or new works programs and activities.
    b. While initial capacity release will be low in the first two years under the pilot program period, it is projected that up to 70 maintenance staff could be released for redeployment within 5 years in New South Wales.
        i. While this appears a relatively low number, the value could be significant if the program is expanded to other Australian States and Territories, and local government areas where securing revenue and labour to undertake maintenance of transport infrastructure is challenging, particularly in regional centres and communities.
2. Enabling Mobility of Talent Across Partnering Industries
    a. There was an estimated 182,000 people engaged in the delivery of public infrastructure across Australia in 2021 (Infrastructure Australia, 2021) and an estimated 26,850 people employed in the renewable energy industry in 2019 (Gilfillan, 2023).
    b. The integration of renewable energy technology into transport infrastructure for major project delivery will require close partnership between technical and project management resources in both the transport and renewable energy industries.
    c. Assuming a conservative 1% mobility rate, there is the opportunity for about 270 people to move between the transport industry and renewable energy industry across Australia each year. While there is a risk of losing staff from the transport industry to the renewable energy industry, we consider there would be increased mobility from the renewable energy industry to the transport industry for the following reasons:
        i. The Transport industry is larger and more diverse, offering potentially greater employment and career development opportunities.
        ii. Transport infrastructure projects on a larger scale are typically located closely to cities and large urban centres, providing potentially more stable and attractive employment opportunities when compared to regional or remote major renewable energy projects.
3. Attracting New Talent to the Transport Industry
    a. In 2020 and 2021, enrolments at Australian universities in agricultural, environment and related industries course rose to about 17,000 compared to a consistent trend of about 14,000 enrolments in the same courses for the prior five years. The increase was predominantly related to a significant increase in women enrolling in these courses. For the same seven year period, enrolments in engineering and related technologies remained steady at about 67,000. (Department of Industry, Science and Resources, 2023)
    b. The sustainability, environmental and social benefits associated with integration of renewable energy technology into transport infrastructure is projected to attract new talent, in particular entry level talent, into the transport industry based on a demonstrable and fundamental shift in the recovery of carbon and energy during the operation lifecycle phase of infrastructure projects, with roads, bridges and corridors becoming future clean energy powerplants.
    c. We forecast our proposal, supported by appropriate recognition and publication of the benefits associated with renewable energy technology integration, could attract an uplift in about 1% enrolment movement from the environmental field to engineering and transport infrastructure, securing up to 170 new entry level talent graduates into the transport industry across Australia each year.

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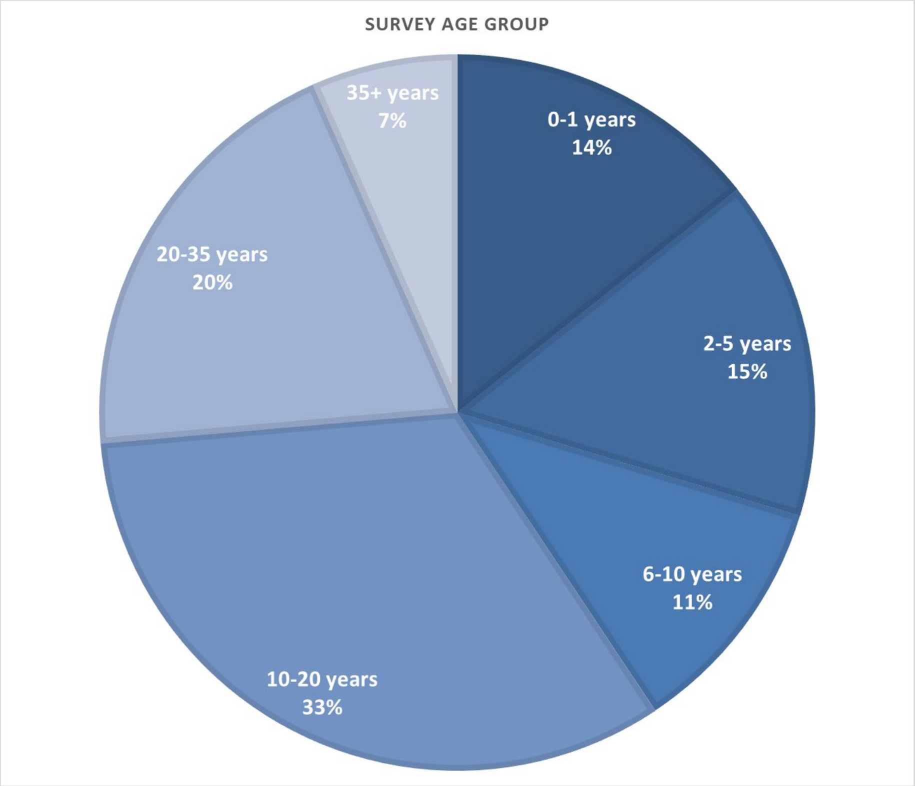
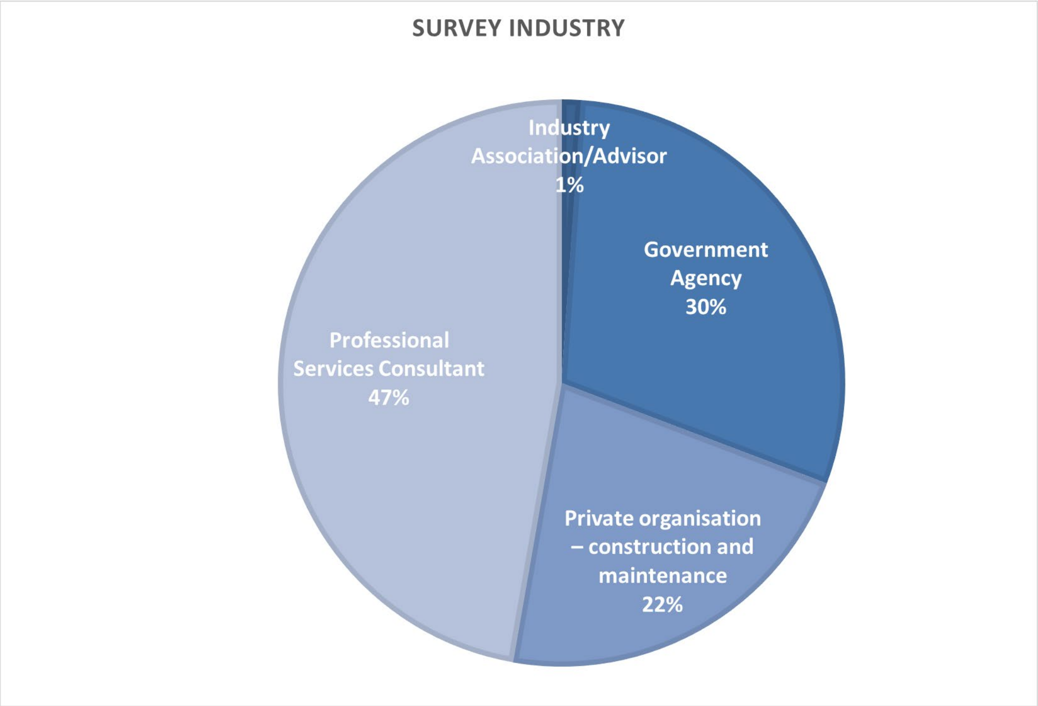
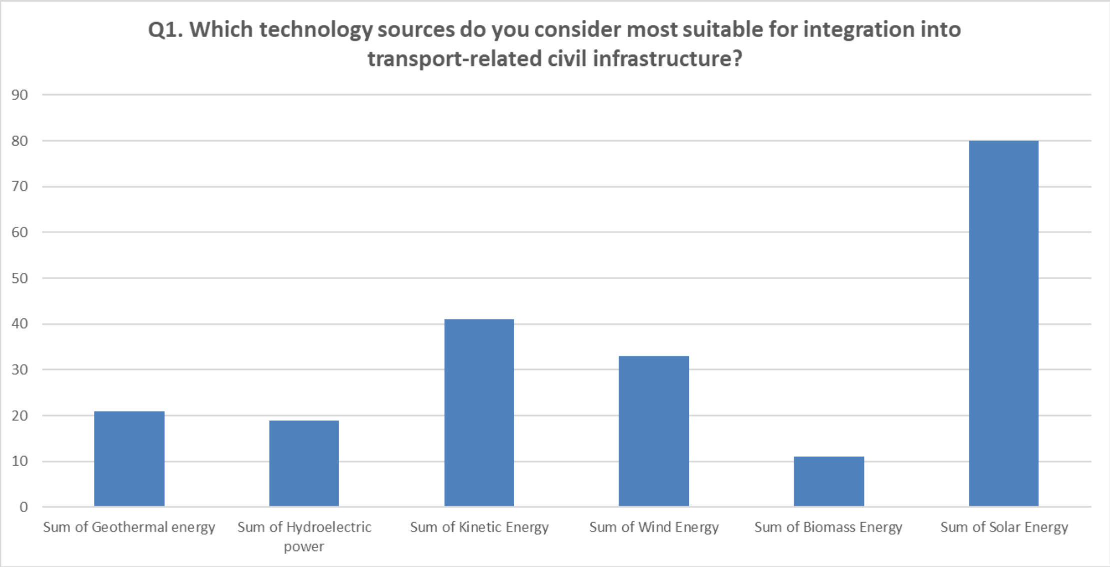
Appendices

Appendix 1: Survey Findings

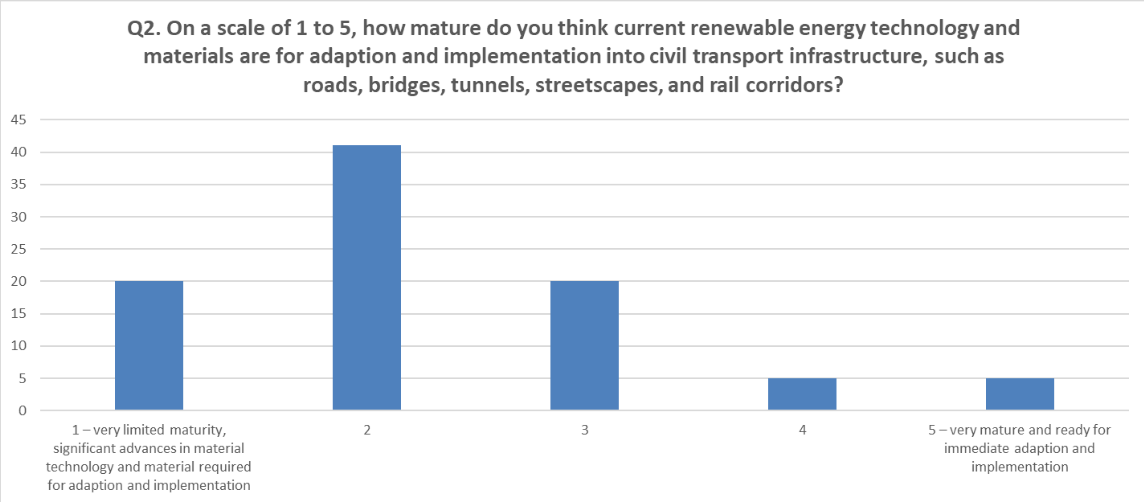
Respondent ID	Industry Association/Advisor	Government Agency	Private organisation – construction and maintenance	Professional Services Consultant	Grand Total
0-1 years			**2**	**11**	**13**
Infrastructure Designer			1	7	8
Infrastructure maintenance/operations			1	2	3
Material specialist – other				2	2
2-5 years	**1**	**7**	**4**	**2**	**14**
Infrastructure construction		2	4		6
Infrastructure Designer	1			2	3
Infrastructure maintenance/operations		2			2
Material specialist – other		1			1
Material specialist – renewable energy technology		1			1
Urban design		1			1
6-10 years		**1**	**7**	**2**	**10**
Infrastructure asset owner/custodian/steward			2		2
Infrastructure construction		1	3		4
Infrastructure Designer			2	2	4
10-20 years		**9**	**3**	**18**	**30**
Infrastructure asset owner/custodian/steward		3			3
Infrastructure construction		2	2	3	7
Infrastructure Designer		1		12	13
Infrastructure maintenance/operations		2	1		3
Material specialist – renewable energy technology				1	1
Policy/Strategy maker		1		2	3
20-35 years		**6**	**4**	**8**	**18**
Infrastructure asset owner/custodian/steward		3			3
Infrastructure construction			3		3
Infrastructure Designer				6	6
Infrastructure maintenance/operations		2	1	1	4
Policy/Strategy maker		1		1	2
35+ years		**4**		**2**	**6**
Infrastructure Designer				2	2
Infrastructure maintenance/operations		4			4
Grand Total	**1**	**27**	**20**	**43**	**91**


SURVEY AGE GROUP
0-1 years
14%
2-5 years
15%
6-10 years
11%
10-20 years
33%
20-35 years
20%
35+ years
7%

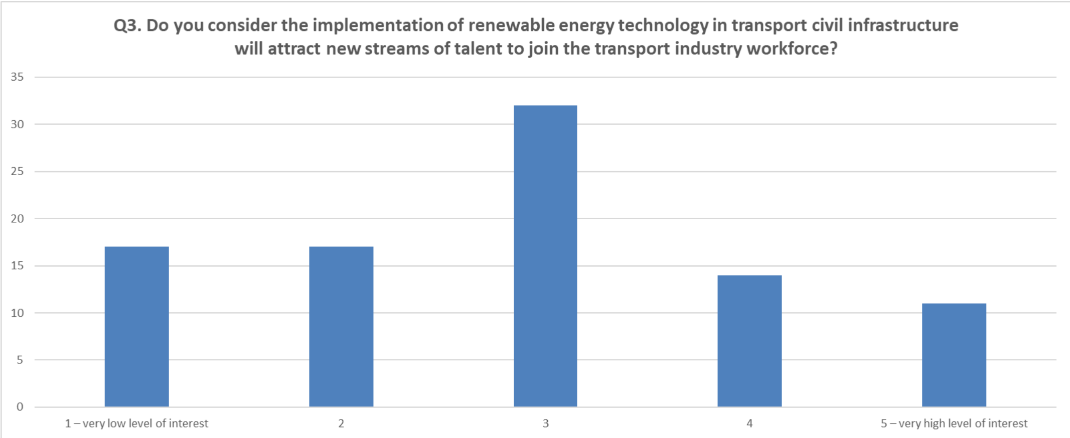

SURVEY INDUSTRY
Industry
Association/Advisor
1%
Government
Agency
30%
Private organisation
– construction and
maintenance
22%
Professional
Services Consultant
47%


Q1. Which technology sources do you consider most suitable for integration into transport-related civil infrastructure?
90
80
70
60
50
40
30
20
10
0
Sum of Geothermal energy
Sum of Hydroelectric power
Sum of Kinetic Energy
Sum of Wind Energy
Sum of Biomass Energy
Sum of Solar Energy

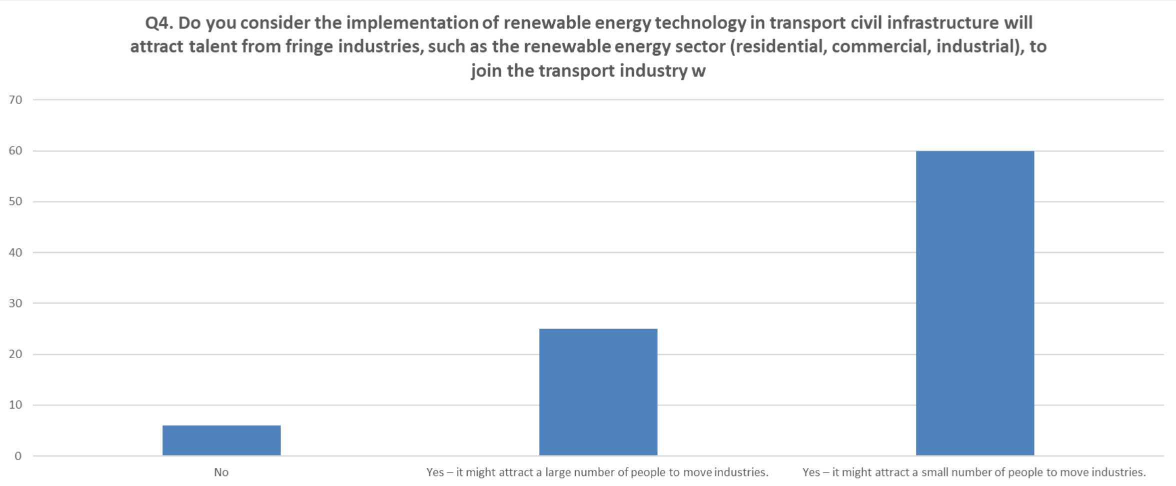
Row Labels	Column Labels 0-1 years (blank)	2-5 years (blank)	6-10 years (blank)	6-10 years Total	10-20 years Total	35+ years (blank)	Grand Total
Infrastructure asset owner/custodian/steward							
Government Agency							
Sum of Geothermal energy					1		1
Sum of Hydroelectric power					1		1
Sum of Kinetic Energy					2		2
Sum of Wind Energy					0		2
Sum of Biomass Energy					1		1
Sum of Solar Energy					3		5
Private organisation – construction and maintenance							
Sum of Geothermal energy			0	0			0
Sum of Hydroelectric power			0	0			0
Sum of Kinetic Energy			1	1			1
Sum of Wind Energy			0	0			0
Sum of Biomass Energy			0	0			0
Sum of Solar Energy			2	2			2
Infrastructure asset owner/custodian/steward Sum of Geothermal energy			**0**	**0**	**1**		**1**
Infrastructure asset owner/custodian/steward Sum of Hydroelectric power			**0**	**0**	**1**		**1**
Infrastructure asset owner/custodian/steward Sum of Kinetic Energy			**1**	**1**	**2**		**3**
Infrastructure asset owner/custodian/steward Sum of Wind Energy			**0**	**0**	**0**		**2**
Infrastructure asset owner/custodian/steward Sum of Biomass Energy			**0**	**0**	**1**		**1**
Infrastructure asset owner/custodian/steward Sum of Solar Energy			**2**	**2**	**3**		**7**
Infrastructure construction							
Government Agency							
Sum of Geothermal energy		0	0	0	2		2
Sum of Hydroelectric power		0	1	1	0		1
Sum of Kinetic Energy		1	0	0	0		1
Sum of Wind Energy		0	0	0	0		0
Sum of Biomass Energy		0	0	0	0		0
Sum of Solar Energy		1	0	0	2		3
Private organisation – construction and maintenance							
Sum of Geothermal energy		1	1	1	1		3
Sum of Hydroelectric power		1	2	2	0		3
Sum of Kinetic Energy		3	1	1	1		6
Sum of Wind Energy		1	2	2	0		3
Sum of Biomass Energy		0	2	2	0		2
Sum of Solar Energy		2	3	3	2		10
Professional Services Consultant							
Sum of Geothermal energy					1		1
Sum of Hydroelectric power					1		1
Sum of Kinetic Energy					1		1
Sum of Wind Energy					2		2
Sum of Biomass Energy					1		1
Sum of Solar Energy					3		3
Infrastructure construction Sum of Geothermal energy		**1**	**1**	**1**	**4**		**6**
Infrastructure construction Sum of Hydroelectric power		**1**	**3**	**3**	**1**		**5**
Infrastructure construction Sum of Kinetic Energy		**4**	**1**	**1**	**2**		**8**
Infrastructure construction Sum of Wind Energy		**1**	**2**	**2**	**2**		**5**
Infrastructure construction Sum of Biomass Energy		**0**	**2**	**2**	**1**		**3**
Infrastructure construction Sum of Solar Energy		**3**	**3**	**3**	**7**		**16**
Infrastructure Designer							
Government Agency							
Sum of Geothermal energy					0		0
Sum of Hydroelectric power					0		0
Sum of Kinetic Energy					1		1
Sum of Wind Energy					0		0
Sum of Biomass Energy					0		0
Sum of Solar Energy					1		1
Industry Association/Advisor							
Sum of Geothermal energy		0					0
Sum of Hydroelectric power		0					0
Sum of Kinetic Energy		0					0
Sum of Wind Energy		0					0
Sum of Biomass Energy		0					0
Sum of Solar Energy		1					1
Private organisation – construction and maintenance							
Sum of Geothermal energy	0		1	1			1
Sum of Hydroelectric power	1		1	1			2
Sum of Kinetic Energy	0		1	1			1
Sum of Wind Energy	1		1	1			2
Sum of Biomass Energy	0		1	1			1
Sum of Solar Energy	1		2	2			3
Professional Services Consultant							
Sum of Geothermal energy	2	0	0	0	3	1	7
Sum of Hydroelectric power	1	0	0	0	3	1	7
Sum of Kinetic Energy	6	0	2	2	7	0	17
Sum of Wind Energy	4	0	2	2	7	0	16
Sum of Biomass Energy	1	0	0	0	1	1	3
Sum of Solar Energy	7	2	2	2	10	1	28
Infrastructure Designer Sum of Geothermal energy	**2**	**0**	**1**	**1**	**3**	**1**	**8**
Infrastructure Designer Sum of Hydroelectric power	**2**	**0**	**1**	**1**	**3**	**1**	**9**
Infrastructure Designer Sum of Kinetic Energy	**6**	**0**	**3**	**3**	**8**	**0**	**19**
Infrastructure Designer Sum of Wind Energy	**5**	**0**	**3**	**3**	**7**	**0**	**18**
Infrastructure Designer Sum of Biomass Energy	**1**	**0**	**1**	**1**	**1**	**1**	**4**
Infrastructure Designer Sum of Solar Energy	**8**	**3**	**4**	**4**	**11**	**1**	**33**
Infrastructure maintenance/operations							
Government Agency							
Sum of Geothermal energy		0			0	0	0
Sum of Hydroelectric power		0			0	0	1
Sum of Kinetic Energy		1			1	2	4
Sum of Wind Energy		0			0	1	1
Sum of Biomass Energy		0			1	0	1
Sum of Solar Energy		1			2	3	7
Private organisation – construction and maintenance							
Sum of Geothermal energy	0				1		1
Sum of Hydroelectric power	0				0		0
Sum of Kinetic Energy	1				0		1
Sum of Wind Energy	1				0		2
Sum of Biomass Energy	0				0		1
Sum of Solar Energy	1				1		3
Professional Services Consultant							
Sum of Geothermal energy	1						2
Sum of Hydroelectric power	1						2
Sum of Kinetic Energy	0						1
Sum of Wind Energy	0						1
Sum of Biomass Energy	0						1
Sum of Solar Energy	2						3
Infrastructure maintenance/operations Sum of Geothermal energy	**1**	**0**			**1**	**0**	**3**
Infrastructure maintenance/operations Sum of Hydroelectric power	**1**	**0**			**0**	**0**	**3**
Infrastructure maintenance/operations Sum of Kinetic Energy	**1**	**1**			**1**	**2**	**6**
Infrastructure maintenance/operations Sum of Wind Energy	**1**	**0**			**0**	**1**	**4**
Infrastructure maintenance/operations Sum of Biomass Energy	**0**	**0**			**1**	**0**	**3**
Infrastructure maintenance/operations Sum of Solar Energy	**3**	**1**			**3**	**3**	**13**
Material specialist – other							
Government Agency							
Sum of Geothermal energy		0					0
Sum of Hydroelectric power		0					0
Sum of Kinetic Energy		1					1
Sum of Wind Energy		1					1
Sum of Biomass Energy		0					0
Sum of Solar Energy		1					1
Professional Services Consultant							
Sum of Geothermal energy	0						0
Sum of Hydroelectric power	1						1
Sum of Kinetic Energy	1						1
Sum of Wind Energy	0						0
Sum of Biomass Energy	0						0
Sum of Solar Energy	2						2
Material specialist – other Sum of Geothermal energy	**0**	**0**					**0**
Material specialist – other Sum of Hydroelectric power	**1**	**0**					**1**
Material specialist – other Sum of Kinetic Energy	**1**	**1**					**2**
Material specialist – other Sum of Wind Energy	**0**	**1**					**1**
Material specialist – other Sum of Biomass Energy	**0**	**0**					**0**
Material specialist – other Sum of Solar Energy	**2**	**1**					**3**
Material specialist – renewable energy technology							
Government Agency							
Sum of Geothermal energy		1					1
Sum of Hydroelectric power		0					0
Sum of Kinetic Energy		0					0
Sum of Wind Energy		0					0
Sum of Biomass Energy		0					0
Sum of Solar Energy		1					1
Professional Services Consultant							
Sum of Geothermal energy					1		1
Sum of Hydroelectric power					0		0
Sum of Kinetic Energy					0		0
Sum of Wind Energy					0		0
Sum of Biomass Energy					0		0
Sum of Solar Energy					1		1
Material specialist – renewable energy technology Sum of Geothermal energy		**1**			**1**		**2**
Material specialist – renewable energy technology Sum of Hydroelectric power		**0**			**0**		**0**
Material specialist – renewable energy technology Sum of Kinetic Energy		**0**			**0**		**0**
Material specialist – renewable energy technology Sum of Wind Energy		**0**			**0**		**0**
Material specialist – renewable energy technology Sum of Biomass Energy		**0**			**0**		**0**
Material specialist – renewable energy technology Sum of Solar Energy		**1**			**1**		**2**
Policy/Strategy maker							
Government Agency							
Sum of Geothermal energy					0		1
Sum of Hydroelectric power					0		0
Sum of Kinetic Energy					0		1
Sum of Wind Energy					0		1
Sum of Biomass Energy					0		0
Sum of Solar Energy					1		2
Professional Services Consultant							
Sum of Geothermal energy					0		0
Sum of Hydroelectric power					0		0
Sum of Kinetic Energy					1		2
Sum of Wind Energy					2		2
Sum of Biomass Energy					0		0
Sum of Solar Energy					2		3
Policy/Strategy maker Sum of Geothermal energy					**0**		**1**
Policy/Strategy maker Sum of Hydroelectric power					**0**		**0**
Policy/Strategy maker Sum of Kinetic Energy					**1**		**3**
Policy/Strategy maker Sum of Wind Energy					**2**		**3**
Policy/Strategy maker Sum of Biomass Energy					**0**		**0**
Policy/Strategy maker Sum of Solar Energy					**3**		**5**
Urban design							
Government Agency							
Sum of Geothermal energy		0					0
Sum of Hydroelectric power		0					0
Sum of Kinetic Energy		0					0
Sum of Wind Energy		0					0
Sum of Biomass Energy		0					0
Sum of Solar Energy		1					1
Urban design Sum of Geothermal energy		**0**					**0**
Urban design Sum of Hydroelectric power		**0**					**0**
Urban design Sum of Kinetic Energy		**0**					**0**
Urban design Sum of Wind Energy		**0**					**0**
Urban design Sum of Biomass Energy		**0**					**0**
Urban design Sum of Solar Energy		**1**					**1**



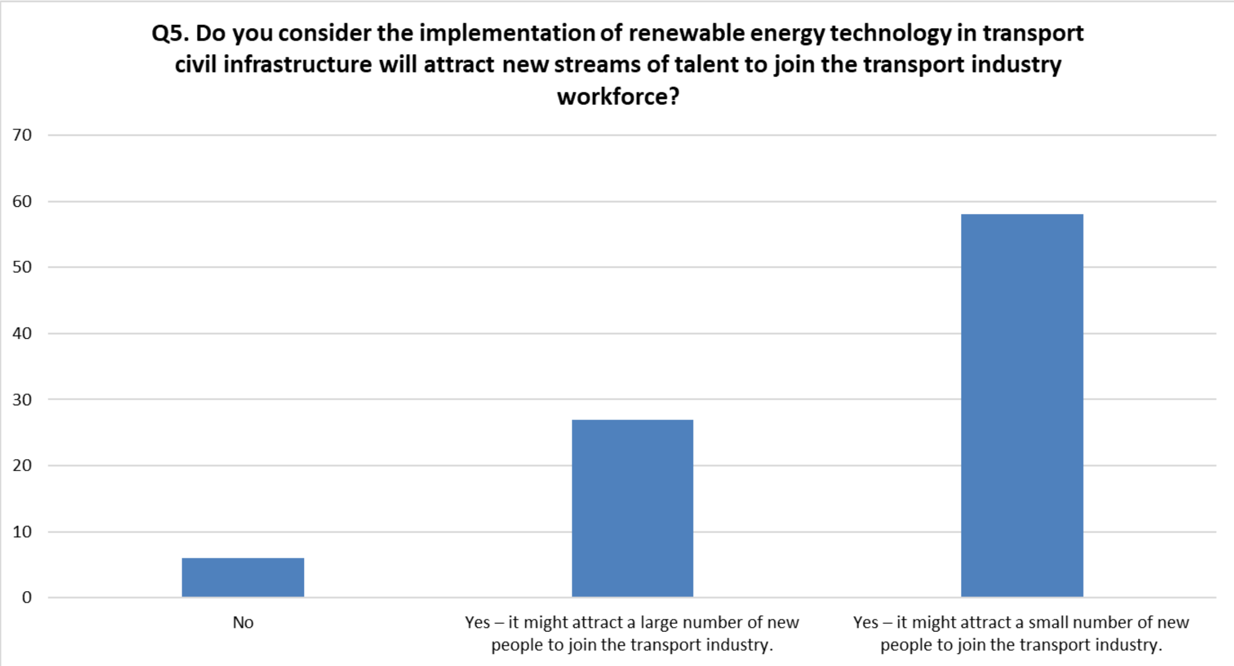
Respondent ID	0-1 years	6-10 years	10-20 years	20-35 years	2-5 years	35+ years	Grand Total
1 – very limited maturity, significant advances in material technology and material required for adaption and implementation	**2**	**4**	**4**	**5**	**4**	**1**	**20**
2	**9**	**2**	**15**	**9**	**4**	**2**	**41**
Government Agency			**3**	**4**	**2**	**2**	**11**
Infrastructure asset owner/custodian/steward				1			1
Infrastructure construction			1		1		2
Infrastructure Designer			1				1
Infrastructure maintenance/operations			1	2		2	5
Material specialist – other					1		1
Policy/Strategy maker				1			1
Private organisation – construction and maintenance	**1**	**2**	**2**		**1**		**6**
Infrastructure asset owner/custodian/steward		1					1
Infrastructure construction		1	2		1		4
Infrastructure maintenance/operations	1						1
Professional Services Consultant	**8**		**10**	**5**	**1**		**24**
Infrastructure construction			1				1
Infrastructure Designer	5		8	4	1		18
Infrastructure maintenance/operations	1						1
Material specialist – other	2						2
Policy/Strategy maker			1	1			2
3	**2**	**3**	**5**	**3**	**5**	**2**	**20**
Government Agency		**1**	**2**	**1**	**2**		**6**
Infrastructure asset owner/custodian/steward			1	1			2
Infrastructure construction		1			1		2
Infrastructure maintenance/operations					1		1
Policy/Strategy maker			1				1
Industry Association/Advisor					**1**		**1**
Infrastructure Designer					1		1
Private organisation – construction and maintenance		**1**	**1**	**1**	**2**		**5**
Infrastructure construction		1			2		3
Infrastructure maintenance/operations			1	1			2
Professional Services Consultant	**2**	**1**	**2**	**1**		**2**	**8**
Infrastructure Designer	2	1	2			2	7
Infrastructure maintenance/operations				1			1
4			**3**	**1**		**1**	**5**
Government Agency						**1**	**1**
Infrastructure maintenance/operations						1	1
Professional Services Consultant			**3**	**1**			**4**
Infrastructure Designer			2	1			3
Material specialist – renewable energy technology			1				1
5 – very mature and ready for immediate adaption and implementation		**1**	**3**		**1**		**5**
Government Agency			**1**		**1**		**2**
Infrastructure asset owner/custodian/steward			1				1
Material specialist – renewable energy technology					1		1
Professional Services Consultant		**1**	**2**				**3**
Infrastructure construction			1				1
Infrastructure Designer		1					1
Policy/Strategy maker			1				1
Grand Total	**13**	**10**	**30**	**18**	**14**	**6**	**91**



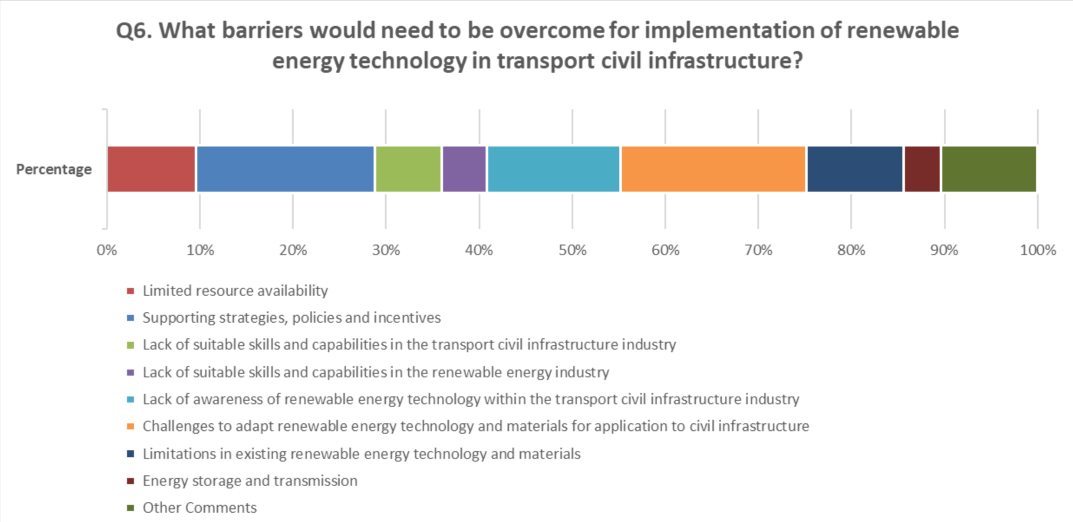
Respondent ID	Column Labels						
Row Labels	0-1 years	10-20 years	20-35 years	2-5 years	35+ years	6-10 years	Grand Total
1 – very low level of interest		4	7	2	1	3	17
Government Agency		1	2	1	1	1	6
Infrastructure asset owner/custodian/steward			1				1
Infrastructure construction		1		1		1	3
Infrastructure maintenance/operations			1		1		2
Private organisation – construction and maintenance			4			2	6
Infrastructure construction			3			1	4
Infrastructure Designer						1	1
Infrastructure maintenance/operations			1				1
Professional Services Consultant		3	1	1			5
Infrastructure construction		1					1
Infrastructure Designer		1	1	1			3
Policy/Strategy maker		1					1
2	1	7	2	5		2	17
Government Agency		2		2			4
Infrastructure asset owner/custodian/steward		1					1
Infrastructure construction		1					1
Material specialist – renewable energy technology				1			1
Urban design				1			1
Private organisation – construction and maintenance				3		2	5
Infrastructure asset owner/custodian/steward						1	1
Infrastructure construction				3			3
Infrastructure Designer						1	1
Professional Services Consultant	1	5	2				8
Infrastructure construction		1					1
Infrastructure Designer	1	3	2				6
Policy/Strategy maker		1					1
3	7	10	5	4	4	2	32
Government Agency		3	2	2	3		10
Infrastructure asset owner/custodian/steward		1	1				2
Infrastructure maintenance/operations		1		1	3		5
Material specialist – other				1			1
Policy/Strategy maker		1	1				2
Private organisation – construction and maintenance	2	2		1		1	6
Infrastructure construction		2		1		1	4
Infrastructure Designer	1						1
Infrastructure maintenance/operations	1						1
Professional Services Consultant	5	5	3	1	1	1	16
Infrastructure construction		1					1
Infrastructure Designer	3	4	2	1	1	1	12
Infrastructure maintenance/operations	1						1
Material specialist – other	1						1
Policy/Strategy maker			1				1
4	4	6	2		1	1	14
Government Agency		2	1				3
Infrastructure asset owner/custodian/steward		1					1
Infrastructure maintenance/operations		1	1				2
Private organisation – construction and maintenance						1	1
Infrastructure construction						1	1
Professional Services Consultant	4	4	1		1		10
Infrastructure Designer	2	4	1		1		8
Infrastructure maintenance/operations	1						1
Material specialist – other	1						1
5 – very high level of interest	1	3	2	3		2	11
Government Agency		1	1	2			4
Infrastructure asset owner/custodian/steward			1				1
Infrastructure construction				1			1
Infrastructure Designer		1					1
Infrastructure maintenance/operations				1			1
Industry Association/Advisor				1			1
Infrastructure Designer				1			1
Private organisation – construction and maintenance		1				1	2
Infrastructure asset owner/custodian/steward						1	1
Infrastructure maintenance/operations		1					1
Professional Services Consultant	1	1	1			1	4
Infrastructure Designer	1					1	2
Infrastructure maintenance/operations			1				1
Material specialist – renewable energy technology		1					1
Grand Total	13	30	18	14	6	10	91



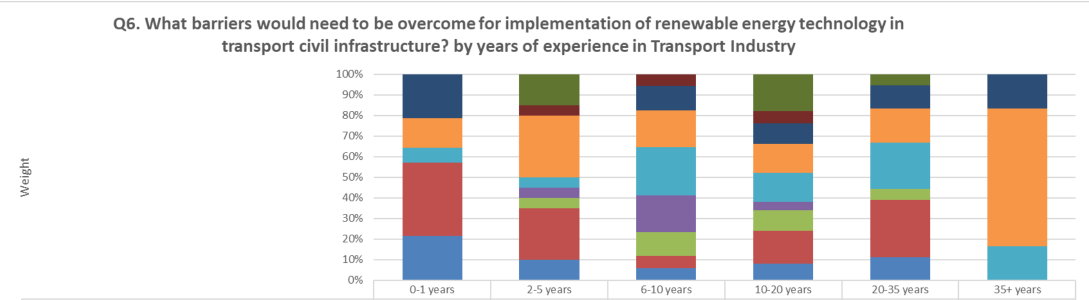
Count of Respondent ID	Column Labels						
Row Labels	0-1 years	10-20 years	20-35 years	2-5 years	35+ years	6-10 years	Grand Total
1 – very low level of interest		4	7	2	1	3	17
Government Agency		1	2	1	1	1	6
Infrastructure asset owner/custodian/steward			1				1
Infrastructure construction		1		1		1	3
Infrastructure maintenance/operations			1		1		2
Private organisation – construction and maintenance			4			2	6
Infrastructure construction			3			1	4
Infrastructure Designer						1	1
Infrastructure maintenance/operations			1				1
Professional Services Consultant		3	1	1			5
Infrastructure construction		1					1
Infrastructure Designer		1	1	1			3
Policy/Strategy maker		1					1
2	1	7	2	5		2	17
Government Agency		2		2			4
Infrastructure asset owner/custodian/steward		1					1
Infrastructure construction		1					1
Material specialist – renewable energy technology				1			1
Urban design				1			1
Private organisation – construction and maintenance				3		2	5
Infrastructure asset owner/custodian/steward						1	1
Infrastructure construction				3			3
Infrastructure Designer						1	1
Professional Services Consultant	1	5	2				8
Infrastructure construction		1					1
Infrastructure Designer	1	3	2				6
Policy/Strategy maker		1					1
3	7	10	5	4	4	2	32
Government Agency		3	2	2	3		10
Infrastructure asset owner/custodian/steward		1	1				2
Infrastructure maintenance/operations		1		1	3		5
Material specialist – other				1			1
Policy/Strategy maker		1	1				2
Private organisation – construction and maintenance	2	2		1		1	6
Infrastructure construction		2		1		1	4
Infrastructure Designer	1						1
Infrastructure maintenance/operations	1						1
Professional Services Consultant	5	5	3	1	1	1	16
Infrastructure construction		1					1
Infrastructure Designer	3	4	2	1	1	1	12
Infrastructure maintenance/operations	1						1
Material specialist – other	1						1
Policy/Strategy maker			1				1
4	4	6	2		1	1	14
Government Agency		2	1				3
Infrastructure asset owner/custodian/steward		1					1
Infrastructure maintenance/operations		1	1				2
Private organisation – construction and maintenance						1	1
Infrastructure construction						1	1
Professional Services Consultant	4	4	1		1		10
Infrastructure Designer	2	4	1		1		8
Infrastructure maintenance/operations	1						1
Material specialist – other	1						1
5 – very high level of interest	1	3	2	3		2	11
Government Agency		1	1	2			4
Infrastructure asset owner/custodian/steward			1				1
Infrastructure construction				1			1
Infrastructure Designer		1					1
Infrastructure maintenance/operations				1			1
Industry Association/Advisor				1			1
Infrastructure Designer				1			1
Private organisation – construction and maintenance		1				1	2
Infrastructure asset owner/custodian/steward						1	1
Infrastructure maintenance/operations		1					1
Professional Services Consultant	1	1	1			1	4
Infrastructure Designer	1					1	2
Infrastructure maintenance/operations			1				1
Material specialist – renewable energy technology		1					1
Grand Total	13	30	18	14	6	10	91



Respondent ID Row Labels	Column Labels 0-1 years	10-20 years	20-35 years	2-5 years	35+ years	6-10 years	Grand Total
No		2	2	1	1		6
Government Agency		1	1		1		3
Infrastructure asset owner/custodian/steward			1				1
Infrastructure construction		1					1
Infrastructure maintenance/operations					1		1
Professional Services Consultant		1	1	1			3
Infrastructure construction		1					1
Infrastructure Designer				1			1
Policy/Strategy maker			1				1
Yes – it might attract a large number of people to move industries.	6	10	3	3	1	2	25
Government Agency		3	2	2			7
Infrastructure asset owner/custodian/steward		1	1				2
Infrastructure construction		1					1
Infrastructure Designer		1					1
Infrastructure maintenance/operations				1			1
Policy/Strategy maker			1				1
Urban design				1			1
Private organisation – construction and maintenance	1	2		1		1	5
Infrastructure construction		1		1		1	3
Infrastructure Designer	1						1
Infrastructure maintenance/operations		1					1
Professional Services Consultant	5	5	1		1	1	13
Infrastructure construction		1					1
Infrastructure Designer	4	4	1		1	1	11
Infrastructure maintenance/operations	1						1
Yes – it might attract a small number of people to move industries.	7	18	13	10	4	8	60
Government Agency		5	3	5	3	1	17
Infrastructure asset owner/custodian/steward		2	1				3
Infrastructure construction				2		1	3
Infrastructure maintenance/operations		2	2	1	3		8
Material specialist – other				1			1
Material specialist – renewable energy technology				1			1
Policy/Strategy maker		1					1
Industry Association/Advisor				1			1
Infrastructure Designer				1			1
Private organisation – construction and maintenance	1	1	4	3		6	15
Infrastructure asset owner/custodian/steward						2	2
Infrastructure construction		1	3	3		2	9
Infrastructure Designer						2	2
Infrastructure maintenance/operations	1		1				2
Professional Services Consultant	6	12	6	1	1	1	27
Infrastructure construction		1					1
Infrastructure Designer	3	8	5	1	1	1	19
Infrastructure maintenance/operations	1		1				2
Material specialist – other	2						2
Material specialist – renewable energy technology		1					1
Policy/Strategy maker		2					2
Grand Total	13	30	18	14	6	10	91



Results by User Group



	0-1 years	2-5 years	6-10 years	10-20 years	20-35 years	35+ years
Other Comments		3		9	1	
Energy storage and transmission		1	1	3		
Limitations in existing renewable energy technology and materials	3		2	5	2	1
Challenges to adapt renewable energy technology and materials for application to civil infrastructure	2	6	3	7	3	4
Lack of awareness of renewable energy technology within the transport civil infrastructure industry	1	1	4	7	4	1
Lack of suitable skills and capabilities in the renewable energy industry		1	3	2		
Lack of suitable skills and capabilities in the transport civil infrastructure industry		1	2	5	1	
Supporting strategies, policies and incentives	5	5	1	8	5	
Limited resource availability	3	2	1	4	2	