ATKINS

Renewable Energy Generation and Distribution from Road Network Assets

Final Report

Scottish Roads Research Board

October 2017

TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Notice

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Document history

Job number: 5153405			**Document ref: 5153405-01**			
Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
0	Draft for Approval	HF	KA	HF		
0.1	Final Draft	HF	KA	HF	PM	13/06/17
0.2	Updated report	HF	KA	HF		07/07/17
0.3	Final Report	HF	KA	PM	GS	09/10/17
1.0	Combined Final Report	HF	KA	PM	GS	24/10/17

Client signoff

Client	Scottish Roads Research Board
Project	Renewable Energy Generation and Distribution from Road Network Assets
Document title	Combined Final Report
Job no.	5153405
Copy no.	Original
Document reference	5153405-01

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1 Introduction

1.1. Background to Study

Renewable energy providers view road authority assets as presenting useful opportunities to develop viable businesses. These assets include the road itself, roadside space, road/roadside structures such as lighting columns, underground duct and cable infrastructure and distribution network operator's cable heads. The renewable energy proposals include conversion of energy to electricity from one or combination of solar, wind, water, acoustic and vibration sources. Providers are aware of favourable political and policy context in Scotland, and often present their proposals with great enthusiasm and predictions of exaggerated outcomes.

Transport Scotland identified a need to develop a process for assessing proposals for renewable energy equipment (energy generating devices) for use in relation to the Trunk Road Network Asset. The process needs to consider such developments from inception to delivery, through evaluation and development. Such an assessment process should recognise existing processes within Scottish and UK Government and potentially in Europe. The process may also be of use to local authorities in Scotland, who receive similar approaches.

Accordingly, Atkins Limited was appointed by The Scottish Road Research Board (SRRB) to undertake research on behalf of Transport Scotland as part of the 2016-17 research programme.

1.2. Project Objectives

The project has the following objective, aims and proposed outputs:

The research objective is to:

- Develop a process that allows for a systematic evaluation of proposals and identifies the costs that will arise from the evaluation of the proposal.

The research aim is to:

- Develop a framework environment suitable for providing type approvals, trials sites and performance indicators.

The research output is to:

- Provide an application process to enable all proposals to be evaluated on a common basis.
- Provide a short guide for applicants explaining the practical considerations when installing renewable energy equipment on or adjacent to the road.

1.3. Workshop

During the project and based on discussions with the sponsor and industry representatives we identified that it would be helpful to explore the use of various techniques and the level of knowledge and understanding of all parties. A workshop was undertaken with representatives from Transport Scotland, the Trunk Road Operating Companies, SCOTS and the Scottish Futures Trust.

1.4. Structure of this Report

This report includes the following:

- Findings from the Desktop Study- see Section 2,
- Outputs from the Workshop – see Section 3,
- Development of the application process and associated guidance – Section 4 and
- Conclusions and Recommendations – see Section 5.

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2 Desktop Study

2.1. Introduction to Desktop Study

The primary aim of the desktop study was to identify current practices regarding renewable energy on the road network. The review considered literature published by Scottish Government, Scottish Futures Trust, UK Highway Authorities, Distribution Network Operators and any relevant case studies from renewable energy providers. We also considered current practices across different local authorities to broaden the focus of the study.

The following sections summarise the finding of the desktop study and identifies areas which may require further research.

2.2. Scottish Government

In 2011 the Scottish Government published '2020 Routemap for Renewable Energy in Scotland' which updated and extended the Scottish Renewables Action Plan 2009. This document presented actions which focus on targets, including a target of at least 30% overall energy demand from renewables by 2020. The Routemap commits the Scottish Government to develop new strategies for microgeneration.

The Routemap commits funding support for renewables including:

- **£13 million WATERS fund** – Wave and Tidal Energy: Research, Development and Demonstration Support fund for the development and testing of new prototypes in Scottish waters,
- **£10m Saltire Prize** for marine energy,
- **£70 million National Renewables Infrastructure Fund** to ensure Scotland reaps the huge financial benefits of offshore renewables. This fund is in addition to Regional Selective Assistance (RSA) and other funding available for companies,
- **The Scottish Biomass Heat Scheme**, which targets SMEs, has been crucial in maintaining momentum in the sector with over £2.6 million paid to 44 projects delivering 10 MW (thermal) of capacity, with annual CO2 savings of over 10,000 t CO2-equivalent and
- Since May 2007, **over 800 grants for community renewables, worth over £16M**, have been allocated under the Community and Renewable Energy Scheme (CARES) and the previous Scottish Community and Householder Renewables Initiative (SCHRI).

The Scottish Government, through CARES, for example, there is a detailed on-line process (CARES Toolkit) to allow communities to access funding for proposed micro-generation community schemes.

2.3. Transport Scotland Opportunities

Transport Scotland is a "participant" under CRC-EES Act 2010 – Carbon Reduction Commitment – Energy Efficient Scheme and committed to evidence reducing energy consumption from Trunk Road Network (TRN) Operations. Like other Scottish road authorities, Transport Scotland has developed a business case to introduce energy efficient street-lighting as a means of reducing energy consumption. However, available funding has not allowed this to progress as quickly as may have been anticipated.

The Scottish Government is keen to promote the development of renewable energy in Scotland and developers are drawn to the perceived opportunities offered by the Trunk Road Network Asset. These include:

- Accessibility,
- Large numbers of energy consuming assets,
- Connectivity to the grid and
- Feed in tariff.

The business case for these proposals has been, by and large, based on the perceived return from feed in tariff with local distribution network operators (DNOs). Developers have not generally taken into consideration the requirements of operating in the particularly harsh environment of the Trunk Road Network.

Transport Scotland has received several proposals from developers wishing to implement and trial renewable energy generation apparatus within the Trunk Road Network. These have tended to be presented on an ad-hoc basis and require a significant resource input to consider the proposal. There is no clear path for developers to follow to engage with Transport Scotland.

As a result of Operational requirements on the Trunk Road Network Transport Scotland has taken up a number of renewable initiatives to facilitate the collection of traffic data and weather data from remote sites. To date the majority of these renewables installed on the Trunk Road Network have been localised wind turbines and solar panels attached to individual items, such as Vehicle Actuated Signs and Weather Stations.

2.4. Scottish Futures Trust

The Scottish Futures Trust (SFT) is an independent company, established by the Scottish Government with a responsibility for delivering value for money across public sector infrastructure investment. SFT operates at arm's length from the Government but works closely with the public sector to seek and deliver improved value for taxpayers.

SFT has a team of over 70 professionals working to increase the efficiency and effectiveness of infrastructure investment in Scotland. The team, drawn from public and private sector backgrounds, have a range of technical, legal and financial skills, and bring extensive commercial expertise in infrastructure financing, procurement and delivery into the public sector.

SFT published a Street Lighting Toolkit in 2015 to provide local authorities with the most up-to-date information to enable the preparation of robust business cases to invest in spend-to-save measures to phase in new LED lighting. Across Scotland, there are some 900,000 street lights costing local authorities £41m in annual electricity charges. These street lights also impact on the environment by releasing nearly 200,000 tonnes of CO2 into the atmosphere each year. By 2016/17 it is anticipated that some 250,00 will have been converted to LED since 2013.

2.5. Local Authorities

Local Roads in Scotland are maintained by the Local Authorities under the Roads (Scotland) Act 1984. The Local Authorities have generally focussed on reducing their energy consumption by increasing the use of LED lighting rather than utilising renewable energy products.

Similar to the Trunk Road Network, the use of renewables has been limited to localised wind turbines and solar panels attached to individual items, such as Vehicle Actuated Signs and Weather Stations.

3 Workshop Outputs

3.1. Approach and Methodology

A facilitated workshop was held in the Atkins office at 200 Broomielaw, Glasgow on 30 January 2017, to obtain wider industry views of the suggested processes. Invitees included,

- Transport Scotland,
- Atkins,
- Representatives from SCOTS,
- Representatives from the Trunk Road Operating Companies and
- Scottish Futures Trust.

This stage of the project comprised three distinct phases:

1. Preparation of Pre-Workshop documents to be sent to participants prior to the workshop date for information.

2. Issue of the documents to the relevant participants as identified and agreed with Transport Scotland. This provided background information to those that attended the workshop session.

3. The facilitated workshop was undertaken with the Stakeholders agreed at Phase 2. A record of the workshop was retained noting the details of those attending, the discussions and points made, examples of current practice and further areas to be considered.

3.2. Pre-Workshop Information

A workshop background note was prepared and issued to attendees prior to the workshop date. The purpose of this was to allow the attendees to prepare for the workshop, thereby maximising the benefits.

3.3. Workshop Outputs

Several key points were identified from the discussions and they are considered in the following sections.

- Technology Readiness Level (TRL),
- Working on the Road Network,
- Any process should allow developers to self-assess their proposals and should be transparent and
- CDM issues need to be considered, particularly with regard to maintenance of apparatus.

3.3.1. Technology Readiness Level

The attendees considered that a significant number of developers are bringing their products forward for road network trials at too early a stage in the development process.

It is proposed to utilise a Technology Readiness Level matrix to allow developers to demonstrate that their products have been progressed to a point that a sensible trial could be undertaken on the road network. Based on the table below, those products with a TRL of 7 or above may be considered suitable for trials. Devices that are considered to be at TRL5 or TRL6 may benefit from trials out-with the Trunk Road Network and consideration may be given by Transport Scotland to facilitate such trials.

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Table 1: Technology Readiness Levels[1]

TRL	Description
	Applied and Strategic Research
TRL 1	Basic Principles Observed and Reported
TRL 2	Technology concept and / or application formulated
TRL 3	Analytical and experimental critical function and / or characteristic proof of concept
TRL 4	Component and / or partial system validation in a laboratory environment
	Technology Validation
TRL 5	Component and / or partial system validation in a relevant environment
TRL 6	System / subsystem model validation in a relevant environment
	System Validation
TRL 7	System prototype demonstration in an operational environment
TRL 8	Actual system completed and service qualified through test and demonstration
TRL 9	Actual system proven in operational environment

3.3.2. Working on the Road Network

The attendees were of the opinion that most developers have not considered the harsh environment of the road network.

The road environment can be quite hostile, and so careful attention should be given to the design and/or local siting of the device to overcome these dangers. As well as climatic considerations, design issues to be considered include:

- Gravel/stone throw from passing vehicles,
- Salt corrosion from gritting,
- Build-up of dirt from roads or animal activity,
- Turbulent air flow,
- Risk of theft or vandalism in remote locations and
- Difficulty in gaining access for inspection.

Most developers will not have considered the implications and cost of undertaking a trial on a live road network, including access, weather, health and safety legislation, planning consideration and maintenance. The cost associated in complying with these issues can be significant and could potentially negate the benefits gained from the device.

1. "Technology readiness levels (TRL)" (PDF). European Commission, G. Technology readiness levels (TRL), HORIZON 2020 – WORK PROGRAMME 2014-2015 General Annexes, Extract from Part 19 - Commission Decision C(2014)4995.

3.3.3. Self-Assessment

The attendees agreed that any process developed from this research project should allow developers to undertake an element of self-assessment to determine if their product is indeed ready for a trial on a live road network.

The basic premise is..'why does it need to be trialled on the road network now?' Evidence of trials undertaken on off-road locations should be provided, along with evidence of the results to back up the claims being made. This was considered to be critical to the process as experience has shown that developers claims based on lab testing can be somewhat exaggerated.

It was considered that it would be useful to provide potential applicants with an inventory of the equipment in use on the Trunk Road Network indicating energy consumption. Developers could then consider if their product could be utilised to enhance the existing energy provision.

3.3.4. Maintenance Considerations

For developers not familiar with operating on the road network it is unlikely that the maintenance and servicing of their product will have been considered. The attendees considered that any application process should include maintenance and servicing implications such as inspections, service visits, the need for traffic management to undertake these visits and the collection of data. For a trial to be worthy there needs to be a collection and evaluation of data to allow comparison of the actual power generation and that expected.

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4 Development of the Application Process and Associated Guidance

4.1. Introduction

The conclusion from the workshop was that an application process would be useful, both for developers and for roads authorities. Along with a background / guidance document it would allow developers to understand the various issues to be considered and overcome before proposing to undertake a trial on the road network.

It would in turn provide road authorities with the information required to undertake a meaningful consideration of the proposal. The process would be considered as a starting point for further discussions with the developer.

4.2. Risk of Working on the Road Network

As stated before the road environment is subject to extreme weather conditions and the developer will need to demonstrate that he has considered this in the design of his product. It would be helpful if the developer could provide robust evidence of previous trials, with emphasis on the conditions prevailing during the trial.

The developer will need to consider where the apparatus will be sited, how it is going to be placed, who is going to erect and maintain it, how often does it require maintenance and how it can be removed upon completion of the trial.

4.3. Energy Generation

The existing apparatus on the network has an existing power supply and information has been provided to developers on the types of apparatus and the energy consumption of the various assets. If a trial is to be considered the developer requires to demonstrate how his proposal can provide a supply that will be as reliable and as cost effective as the current power sources. It is recognised however that renewable sources may not currently be as cost effective and a higher cost ratio of up to 1.5 times the current cost may be considered during a trial phase.

The Roads Authorities are all bound by procurement laws and agreeing to a trial does not imply that the proposal will be adopted upon completion of a successful trial.

Some proposals may be reliant on the level of Feed in Tariff available and this brings its own challenges in relation to the road network. For example, in general street lighting is currently fed by an un-metered supply; any feed-in-tariff calculations will be reliant on demonstrating how much power is available after usage. If meters are therefore required to be fitted to measure usage the cost of these needs to be considered during the energy generation costings.

Setting out the method of generation will demonstrate the assumptions made by the developer. This is required to demonstrate why the devices is suited to work on the road network. For example, if the apparatus is reliant on sound energy, what volume of traffic is required to generate the levels required and over what period?

4.4. Costs

Through the application process the developer should consider why the product should be tested on a live road network. There is considerable expense involved to access the network, particularly if lane or carriageway closures are required. Again, evidence of trails undertaken in a similar environment, e.g. a car park, would assist in developing the case for a further trial.

Developers should be made aware that all costs of the trial, in general, will need to be borne by the developer

4.5. Application and Guidance

The application process will capture the information required by the Roads Authorities to allow a decision to be made regarding the readiness of the proposal for a site trial. It is not the purpose to consider the apparatus itself, only that it is sufficiently developed to consider a meaningful live trial. The process will therefore provide a time and cost saving for both the developer and for the Road Authority.

The guidance document has been produced with the intention of ensuring that the developer can complete the application by considering what information is required. This provides an element of self-checking and only sufficiently developed proposals will meet the guidelines. This document forms Appendix A to this report.

The guidance has been developed for use on the Trunk Road Network but can readily be adapted by the Local Authorities.

5 Conclusions and Recommendations

5.1. Conclusions

5.1.1. From Desktop Research

Below we present the conclusions of our desktop research:

- There is currently no process available for developers to suggest trials of renewable energy generating devices on the Trunk Road Network or Local Road Network.
- Consequently, approaches have traditionally been made to Roads Authorities on an ad-hoc basis.
- Developers do not necessarily have a good understanding of the road environment.
- The data provided by developers varies in quality and a considerable resource investment is required by the Roads Authorities when considering the approaches.

5.1.2. From Workshop

The key points from the Workshop are:

- A process involving an element of self-assessment would be advantageous to both developers and the Roads Authorities.
- The process requires to be transparent and provide developers with an opportunity to demonstrate why their apparatus is ready for a trial on a live road network. The information so provided will allow Roads Authorities to make an informed judgement as to the suitability for a trial at this stage in the development.
- The expected outcome from a trial needs to considered, data collected and reported and the outcomes shared with the Roads Authority.
- It is recognised that the Scottish Governments targets for renewable energy are an attractive proposition for developers and that it is extremely likely further proposals will come forward.

5.2. Recommendations

Based on our research we can make the following recommendations:

- Developers will continue to approach Roads Authorities with a view to undertaking trials of renewable energy generating devices on the road network.
- Guidance is required to ensure that Developers understand the implications of working on a live road network, the potential impact of the harsh environment on their apparatus and the cost implications of accessing and working on the road.
- A clear and easily understood process which allows developers to demonstrate how their apparatus deals with the harsh environment, how they have considered the installation, servicing and de-commissioning of the apparatus and how the energy is produced, stored and ultimately used will benefit both the Developer and the Roads Authority.
- The cost of energy production is of obvious interest but is not always the prime consideration in assessing a proposal. While an initial cost of 1.5 times greater than current energy prices would appear an appropriate level, it is recognised that this is likely to be unachievable on a small-scale trial. It should be borne in mind that not all benefits are related to the energy production, there may be other benefits such as an availability of power in a remote location where there is no grid connection.

5.3. Next Steps

The project outcome has established a process for both Transport Scotland and the local Roads Authorities to consider proposals from private developers to trial energy generating devices on the road network.

The next step will be to use this process to consider a proposal submitted by a Developer. Hence, if and when a Road Authority is approached to trial such a device or technique and decides to fully consider it, the process may be used. It is recommended that any such consideration is managed through SRRB on behalf of the individual Road Authority, subject to a successful bid for funding.

Appendices

Appendix A. Guidance for Developers

Executive Summary

The Scottish Trunk Road Network Asset includes over 52,000 electrical devices such as street lights, illuminated signs, traffic signals and illuminated bollards which are essential for road safety and to make journeys safer. To power these requires the consumption of over 32GWhpa of electricity, costing £3Mpa. Newer types of lighting are helping to reduce this cost, and it is possible that further cost savings may be possible through the wider use of renewable energy.

For Transport Scotland to identify candidate renewable energy products for use on the network, it is important that these are demonstrated as providing the level of power output claimed, reliably, safely, and within acceptable total lifetime costs. To help support this need, this document provides guidance to prospective suppliers of renewable energy products on the requirements for operating them on road networks in Scotland. It incorporates many lessons learnt from previous experience, and so should help developers to avoid common pitfalls.

1 Introduction

1.1. Background

The Scottish Trunk Road Network Asset includes over 52,000 electrical devices such as street lights, illuminated signs, traffic signals and illuminated bollards which are essential for road safety and to make journeys safer. (Appendix A1) To power these requires the consumption of over 32GWhpa of electricity, costing £3Mpa. Newer types of lighting are helping to reduce this cost, and it is possible that further cost savings may be possible through the wider use of renewable energy.

For Transport Scotland to identify candidate renewable energy products for use on the network, it is important that these are demonstrated as providing the level of power output claimed, reliably, safely, and within acceptable total lifetime costs. To help support this need, this document provides guidance to prospective suppliers of renewable energy products on the requirements for operating them on road networks in Scotland. It incorporates many lessons learnt from previous experience, and so should help developers to avoid common pitfalls.

It should be noted that Transport Scotland is not actively seeking candidates and does not have internal funding to directly support the development of renewable energy products. However, it may be able to offer support in kind for products that meet its needs. Transport Scotland is not under any obligation to procure any type of device, even if a field trial is considered to be a success. Transport Scotland is bound by standard Government procurement rules, and so if, following a successful field trial, a full installation was to proceed an open procurement competition would be required.

1.2. Methodology

To demonstrate performance, a field trial will usually be required. Field trials on the Trunk Road Network are expensive, and so prospective applicants are invited to complete a simple self-assessment checklist before approaching Transport Scotland

The purpose of the self-assessment is to allow developers to gauge the readiness of their proposal for a live trial on the Trunk Road network. The completed self-assessment should then be submitted to Transport Scotland.

2 Trunk Road Network

The following provides background information regarding the Trunk Road Network, the assets currently on the network and the practicalities to be considered in siting renewable energy generating devices on a live road.

2.1. Trunk Road Network

The Trunk Road Network, which includes motorways, connects Scotland's major cities, towns, airports and ports enabling the movement of people, goods and services and it is the Scottish Ministers' single biggest asset. The Trunk Road Network is hugely diverse, ranging from the ten-lane M8 in the centre of Glasgow to single carriageway sections in the west Highlands

The Trunk Road Network is 3,507 km (2,179 miles) long, including slip roads and roundabouts. It has a gross asset value of over £20.8 billion and represents 6% of the total Scottish road network. It carries 35% of all traffic and 60% of heavy goods vehicles.

Within the Trunk Road Network there are a significant number of devices that require electricity to function and a summary of the main asset types is shown in Table 1 (refer to Appendix A for a further detailed breakdown).

Table 1: Summary of Main Trunk Road Electrical Assets

Asset Type	Number	kWh pa
High Mast Lighting Columns	3,082	5,353,464
Standard Lighting Columns	25,988	29,247,443
Illuminated Signs	13,686	1,612,870
Illuminated Bollards	2,824	175,416
Traffic Signals	3,195	432,704

2.2. Risks and key factors affecting the Road Network

2.2.1. Design of Devices and Local Siting to Withstand Road Conditions

The local road environment can be quite hostile and aggressive and apparatus designed to be placed on the Trunk Road Network requires to be robust. Careful attention should be given to the design and/or local siting of the device to overcome the environmental risks highlighted below.

- Gravel/stone throw from passing vehicles,
- Salt corrosion from gritting,
- Build-up of dirt from roads or animal activity,
- Turbulent air flow,
- Risk of theft or vandalism in remote locations and
- Difficulty in gaining access for inspection.

2.2.2. Impact on the Environment

The device might also impact the road environment, and so all possible risks to the road users and the adjacent environment will be considered by the road authority before giving permission for a device to be installed by the side of a road. The following aspects require careful consideration including the development of any risk mitigation measures.

- How much of a distraction will it be for the driver?,
- Will it affect the road surface?,
- What if a vehicle hits the product?,
- Will it disrupt any wildlife corridors?,
- Noise levels?,
- Drainage issues?,
- Maintenance liability? and
- Impact on Ride Quality?

2.2.3. Siting on the Trunk Road Network

Working on the Trunk Road Network will always incur additional costs compared to simpler sites where access is easy and requires no special permissions. Selecting the right location within the boundary of the land around a road is important, as it will make a big difference to the lifetime operating costs:

- Devices installed on land that does not require any lane closures over its life will have the lowest cost of operation,
- Devices installed on the edge of the road that will require lane closure for installation and maintenance will incur higher on going costs and
- For safety, no trial devices will generally be permitted in the central reservation or any other traffic islands between lanes. Similarly, no trial devices will generally be permitted to be mounted over the road, for example on a bridge or gantry.

This means that devices that rely on a feature of the road for operation, such as the passing of cars over or close to a generating source, will be disadvantaged by these higher siting costs.

Some devices might have additional hazards that also influence siting, such as the risk of blade throw from wind turbines.

2.2.4. Lane Closures

Access to install equipment may involve closing a lane of the carriageway or even the entire road. If additional access is required to undertake servicing and maintenance of the apparatus further closures may be required.

The costs of closing a carriageway lane will vary depending on location, duration, proximity to junctions, if it can be combined with other work, and time of day. If required, hire of temporary traffic control equipment should also be included. If access is needed on a periodic basis, such as for maintenance inspection or repair, then these additional lane closure costs should be accounted for.

2.2.5. Legislative Requirements

There are many general and road specific codes that applicants need to be familiar with and comply with where appropriate, including but not limited to

- Health and Safety at Work etc. Act 1974,
- Construction (Design and Management) (CDM) Regulations 2007,
- Disability Discrimination Act 2005,
- BS7671:2008 Requirements for Electrical Installations (IEE Wiring Regulations, Seventeenth Edition),
- Electricity at Work Regulations 1989,
- Roads (Scotland) Act 1984,
- Transport (Scotland) Act 2005,
- Road Traffic Regulation Act 1984,
- Traffic Signs Manual Chapter 8,
- Traffic Signs Regulations and General Directions (TSRGD) 2016,
- The New Roads and Street Works Act 1991,
- Traffic Management Act 2004,
- European Directive 2011/92/EU and Town and Country Planning (EIA) (Scotland) Regulations 2011,
- Microgeneration Certification Scheme Accreditation,
- 2008 Ambient Air Quality Directive (2008/50/EC),
- Air Quality Standards (Scotland) Regulations 2010,
- Part IV The Environment Act 1995,
- Environmental Protection Act 1990,
- Land Compensation Act 1973,
- Noise Insulation Regulations 1975 and 1996,
- Water Supply (Water Quality) (Scotland) Regulations 2001,
- European Landscape Convention,
- Wildlife and Countryside Act (as amended) 1981,
- Conservation (Natural Habitats, &c.) Regulations 1994,
- Management of Electronic Traffic Equipment – A Code of Practice, Sept 2011, UK Roads Liaison Group,
- Well-Managed Highway Infrastructure – A Code of Practice, Oct 2016, UK Roads Liaison Group,
- Trunk Road Operating Company Procedures – Transport Scotland – Development Management,
- Local Authority Planning Guidelines and
- Temporary Traffic Management Design to Chapter 8 of the TSRDG.

2.2.6. Requirement for Field Trials

The high cost of installation, inspection and de-commissioning of devices means that field trials should not generally be undertaken until the device is at an advanced stage of design. On the Technology Readiness Level (TRL) classification adopted by the European Commission[1] of product development, it would be unlikely that any product at less than TRL 7 would be ready for field trials on the Trunk Road Network (see Table 2 below).

As an example, for some devices TRL 7 might correspond to having successfully undertaken tests over a representative period in a car park. Products that are already at TRL 8 or 9 will have lower risk, and be closer to market, and so will be more likely to be offered a field trial.

Devices that are considered to be at TRL5 or TRL6 may benefit from trials out-with the Trunk Road Network and consideration may be given by Transport Scotland to facilitate such trials.

Sufficient instrumentation should be fitted to the device at field trial stage in order that the performance can be assessed over a range of operating conditions. It is recommended that this information can be viewed remotely, in near real time.

Table 2: Technology Readiness Levels

TRL	Description
	Applied and Strategic Research
TRL 1	Basic Principles Observed and Reported
TRL 2	Technology concept and / or application formulated
TRL 3	Analytical and experimental critical function and / or characteristic proof of concept
TRL 4	Component and / or partial system validation in a laboratory environment
	Technology Validation
TRL 5	Component and / or partial system validation in a relevant environment
TRL 6	System / subsystem model validation in a relevant environment
	System Validation
TRL 7	System prototype demonstration in an operational environment
TRL 8	Actual system completed and service qualified through test and demonstration
TRL 9	Actual system proven in operational environment

1. "Technology readiness levels (TRL)" (PDF). European Commission, G. Technology readiness levels (TRL), HORIZON 2020 – WORK PROGRAMME 2014-2015 General Annexes, Extract from Part 19 - Commission Decision C(2014)4995.

2.2.7. Insurances

It is essential that adequate insurance is in place to protect against claims arising from any aspect of the field trial.

The insurances noted in Table 3 will be required to be provided by the developer, for the lifetime of the trial, i.e. from installation until de-commissioning.

Table 3: Insurances

Event	Cover	Period
Professional Indemnity Insurance	FIVE MILLION POUNDS STERLING (£5,000,000) each and every claim without limit to the number of claims	To be maintained for the duration of the Trial and for 12 months from Completion of the trial
Public Liability	TEN MILLION POUNDS STERLING (£10,000,000) in respect of each claim, without limit to the number of claims	To be maintained for the duration of the Trial and for 12 months from Completion of the trial
Employee Liability	FIVE MILLION POUNDS STERLING (£5,000,000) in respect of each claim, without limit to the number of claims	To be maintained for the duration of the Trial and for 12 months from Completion of the trial

2.2.8. Restoration Bond

When a device is being trialled on the Trunk Road Network the developer may be required to provide a Restoration Bond. The purpose of this is to ensure that funds are available to restores the site to its original condition following completion of the trial. This requirement will be considered on a case by case basis.

3 Energy Generation

3.1. Grid Connected or Stand Alone

Renewable energy has a lower carbon footprint during operation, and is useful in locations with no mains alternative. But for a renewable energy device to be attractive, it needs to offer an overall proposition that is at least similar in terms of cost and ongoing attention, to that of mains powered devices. These sometimes hidden advantages of mains powered equipment will typically include the following:

- Resource not location dependent
- Little roadside maintenance required
- Easily understood by all operatives
- Availability of power is good
- Negligible decommissioning costs
- Power not weather dependent
- No need for energy storage
- Long lifetime
- Low attractiveness to theft

If an electricity network connection point is available, then it is recommended that the renewable energy system is connected to this. This is because it provides a secure supply at times of low renewable energy generation, which is essential for ensuring safety on the road network. It will also avoid the cost of fitting batteries to store energy at times of insufficient power generation. Where a grid connection is available any electricity generated that is surplus to requirements can be exported, potentially providing an income to the developer and to Transport Scotland.

Fitting a dedicated electricity meter to the renewable energy source will enable any applicable financial support to be claimed, irrespective of whether the electricity is used by Transport Scotland or exported to the electrical network. The amount paid per unit of electricity by the electricity supplier is likely to be considerably less than what Transport Scotland pays for units that it purchases. This means that self-consumption of generated electricity gives the biggest financial return to Transport Scotland but may deter developers as their returns may be diminished. In some cases, this might serve as a limit to the capacity of renewable energy generation equipment installed.

3.2. Off Grid Products

Where a mains connection to power electrical apparatus on the Trunk Road Network is financially prohibitive, then some form of off-grid supply is needed. This is commonly some type of renewable energy device, such as wind or solar power and occasionally fuel cells or small scale hydro systems may be used. All such sites will require some form of battery storage to power the apparatus when the renewable device is not operating. For temporary schemes, a diesel generator or portable battery set are also popular.

In off grid situations, the renewable energy source will be carefully selected to meet the load requirements. It might be directly integrated with the product, such as a small solar panel fitted on the equipment enclosure, or be installed close to the product. Any field trial on the road network would usually be on this basis, helping to demonstrate operation in real-life conditions, and to ensure that the device is matched well to the requirements of the product it is powering.

Most forms of renewable energy have an output power that is inherently variable and unpredictable. It is therefore important to consider the longest time for which there will be no output from the device, and what means will be used to span this gap in operation. In general, this will be from battery storage which can be charged directly from the renewable energy source. In addition, total shutdown due to factors such as snow or ice should be accounted for.

Currently the market for off grid products is led by small wind turbines and solar panels. To help gauge the competitiveness of new products, it is a good idea to benchmark the performance and features of new products against these or other established technologies.

4 Submitting an Application

The submission requires the applicant to complete four sections:

- About the Product
- Energy Generation
- Field Trials
- Costs

The following sections provide guidance to assist in completing the application. The text boxes that ask for detail are restricted to 150 words, however supporting documentation can be referenced by including a link to a web-site if appropriate.

4.1. About the Product

This section provides an opportunity to describe the developer, the proposal and an operational summary.

4.1.1. The Developer

Criteria 1a, 1b and 1c require details of the developer / company making the application.

4.1.2. The Proposal

This section seeks detailed information on the proposal and all sections 2a to 2g should be completed and supporting evidence provided, referenced where appropriate. Criteria 2b requires justification that the proposal is developed enough to warrant being trialled on the road network.

4.1.3. Operational Summary

Section 3 requires the developer to provide results of any previous trial (3a) which will reinforce the Technology Readiness Level claimed in 2b. Consideration of the operation of the product during any trial will require to be evidenced at 3d and any on-going maintenance and servicing requirements will be considered in the answer to 3e.

4.2. Energy Generation

This section provides an opportunity to describe the energy generated and the site conditions required to maximise the outputs.

4.2.1. Energy Generation

The estimated annual energy amount generated by a single device should be referenced at 1a, with supporting evidence required in 1b.

Energy generation is calculated as:

Energy generated = Rated Output Power x Average daily operating hours x Average load factor during generation time.

Worked example

A device with a rated Output of 1kW, operating an average of 6hrs per day, with an average load of 40%, will generate 1kW x 6hrs x 40% = **2.4kWh per day**.

In this context the ‘Average Load Factor’ is the load on the energy generating device and is a measure of the proportion of the peak output that the device may operate at.

The approach will depend on the type of device:

- For established technologies, use existing reference works.
- For new technologies, the starting point should be a robust calculation of system input power, and an estimate of energy losses in each component. The difference is then the available output energy.

Any assumptions made in the calculation must be clearly referenced and justified in 1c.

4.2.2. Site Conditions

The developer must provide details of the ideal site conditions required to generate the energy in 1a – 1c above. This will determine the location of the device on the network, taking into account any conditions previously noted. The requirement for traffic management to install the apparatus is also to be considered in 2c.

4.2.3. Road Asset Operation

Appendix A provides details of the existing electrical assets found on the Trunk Road network, including the energy consumption figures. In Section 3 the developer should indicate which assets are intended to be powered by the proposed apparatus (3a), the number of hours that the apparatus will provide energy to the asset (3b) and if storage is required for periods when the asset is not requiring power (3c).

4.3. Field Trials

This section provides an opportunity to describe the purpose of the proposed field trial, the site location, access requirements and data collection.

4.3.1. Experience

The developer must provide evidence of undertaking appropriate field trials and sharing the results of those trials (1a and 1b). This information is required to demonstrate the TRL of the proposal.

4.3.2. Trial Purpose

For a trial to be meaningful there must be a measurable outcome. The information requested in 2a and 2b will determine how this will be achieved.

4.3.3. Performance

The developer is required to provide a summary of the key system performance data in 3a

4.3.4. Site Feasibility Work

In section 4a the developer must provide details of any experience of working on a live road network. This information should include locations, traffic volumes, access arrangements, traffic management utilised and lessons learned.

4.3.5. Access Survey

In section 5 the information required relates to the proposed trial site, considering the installation, maintenance & servicing and decommissioning stages of the trial.

4.3.6. Site Visits

The developer is required to provide a summary of the purpose of any on-going site visits envisaged during the trial. This should include but is not limited to servicing, maintenance and data collection.

4.3.7. Site Telecoms

The developer is required to provide details of how he intends obtaining data from the trial site. The information to be included in section 7a should include the frequency of data collection.

4.4. Costs

This section considers the cost of producing the energy generated.

4.4.1. Development Costs

The developer must provide evidence of detailed costings to develop the product, including parts, patents and insurance requirements. Evidence of insurances should also be provided.

4.4.2. Installation Costs

The installation costs required in section 2 are broken down into 3 areas, covering the installation costs, traffic management costs and any connection charges.

Provision should be made for electrical isolation of individual generation sources. This is to ensure safety during servicing, and to enable isolation in the event of damage. Depending on location, this might mean that a TS approved roadside enclosure will be required.

Similarly, there should be a means to prevent mechanical generating devices from moving.

Remote reading meters are recommended to avoid repeated visits to the road network, and to identify at an early stage if there are any problems with devices. For field trials, multiple meters can be useful to pinpoint performance of different devices, but for regular operation it may be sufficient to just have one commercial meter for a whole array of devices.

Street lighting on the road network is generally unmetered. The developer will need to demonstrate what agreements are in place with the electricity provider to reduce the energy bill commensurate to the amount of energy generated.

The cost of connection to a network connection point varies widely. If the cables need to cross land owned by third parties, the costs can be extremely high and might make the installation unviable.

4.4.3. Recurring Costs

The recurring costs required in section 3 relate to those costs to be incurred during the trial period, which will generally be for a minimum of 12 months.

The cost of servicing and spare parts should be included in the calculation of costs. Items requiring attention vary from device to device, but will typically include:

- Bearings.
- Seals.
- Equipment fans.
- Fan filters.
- Lubrication of Moving parts.
- Electronic equipment.

Frequency of visits will vary, and should be estimated wherever possible with reference to similar equipment. It is useful to distinguish items that can be changed in the field from those that need to be returned to base.

4.4.4. Decommissioning

Similarly the costs for decommissioning the trial and reinstating the site should be included in section 4.

4.4.5. Power Generation

In section 5, specific values must be submitted relating to rated output, average daily operating hours and average load factor during generating time. The developer must provide supporting evidence for each of these values and justify any assumptions made.

4.4.6. Levelised Cost of Energy

There are many different approaches to calculating the cost of generated energy, but for simplicity and transparency the Levelised Cost of Energy method shall be used. This method calculates the average cost of electricity over the product lifetime by dividing the total lifetime costs of ownership by the lifetime electricity generated.

Total Lifetime Cost of ownership = Product price + Delivery + Installation and Commissioning + Service (time and spares) + De-commissioning + Traffic Management (total).

Total Lifetime Electricity Generated = kWhpa x Lifetime (years)

Levelised Cost of Energy = Total lifetime cost of ownership / Total lifetime electricity generated

Worked Example

Product Price	£5,000	
Delivery	£200	
Installation & Commissioning	£2,000	
Service (time and spares)	£1,000	
De-commissioning	£800	
Traffic Management (total)	£3,000	
Total Costs	**£12,000**	
Lifetime generated electricity	**40,000kWh**	(20 years at 2,000kWhpa)

Levelised cost of energy = 30p/kWh

4.4.7. Funding

The developer must provide evidence that funding is available for the full cycle of the trial. This is from installation to final decommissioning and reinstatement of the site.

5 Conclusions

Transport Scotland recognises the importance of renewable energy generation and that the Trunk Road Network may provide an opportunity for trial sites. This has to be considered in the operational context of the Trunk Road Network.

It should be recognised that the environment alongside the Trunk Road Network is harsh, with extremes of weather, noise, vibration and loose debris all potentially impacting on any roadside apparatus.

The information that developers are required to provide to Transport Scotland is detailed in this Guidance Report and will ensure that proposals are considered in an equitable manner. Providing the information will demonstrate that developers have considered all the issues required to undertake a trial on the Trunk road network.

Appendix A1. Trunk Road Electrical Assets

Trunk Road Electrical Assets by Type

		Scottish Power - DNO			SSE/Hydro - DNO		
		Qty	Calculated Circuit Watts	kWh (EAC)	Qty	Calculated Circuit Watts	kWh (EAC)
Roadside Electrical Assets (REAs)							
Road Lighting HID range of Circuit Wattage	**<140**	1,405	43	210,573	313	80	87,462
	141-250	4,261	179	3,139,985	2,573	178	1,787,256
	251-350	6,605	300	8,156,801	3,701	301	4,335,194
	351-480	4,926	447	9,011,509	58	449	101,408
	>481	8	672	22,246	0	0	0
Road Lighting LED range of Circuit Wattage	**<100**	527	77	165,095	2,003	69	538,262
	101-150	772	131	412,456	332	135	174,264
	151-200	355	171	240,350	538	176	361,040
	>200	228	219	203,664	97	213	80,306
Various	**Illuminated Signs**	10,717	20	1,441,186	2,969	14	171,684
	Illuminated Bollards	1,921	16	121,162	903	15	54,254
	Traffic Signals	648	13	63,686	2,547	33	369,018
	Weather Stations	46	98	40,324	67	100	58,496
	Other - Control Gear etc.	2,044		289,857	2,175		68,704
		34,463		**23,518,894**	**18,276**		**8,187,347**
	High mast columns	2,964		5,272,399	118		81,065
	Standard columns	16,445		21,747,334	9,543		7,500,109
	14w Fluorescent Sign Light	6,071	14	351,087	868	14	47,360
	16w Compact Sign Light	972	16	63,173	1703	16	105,874
		7,043		**414,260**	**2,571**		**153,234**
	Cabinets - cable heads	836	1	21,494	532	1	6,320

Traffic Scotland - Intelligent Transport System

	Scottish Power - DNO			SSE/Hydro - DNO		
	Calculated			Calculated		
		Circuit	kWh		Circuit	kWh
	Qty	Watts	(EAC)	Qty	Watts	(EAC)
Variable Message Signs	1,031	552	2,238,847	47	778	324,386
Traffic Counters	620	31	134,714	25	38	8,243
Comms Equipment	1,424	80	809,508	108	41	34,249
CCTV cameras	257	175	519,646	20	127	22,266
Cabinets	845	119	430,214	137	44	33,723
Transmission Buildings	6	700	36,817	0	0	0
Weather Station	3	37	951	0	0	0
Speed Cameras	0	0	0	300	62	134,119
	4,186		**4,170,697**	**637**		**556,986**
Cabinets - cable heads	376		0	27		0

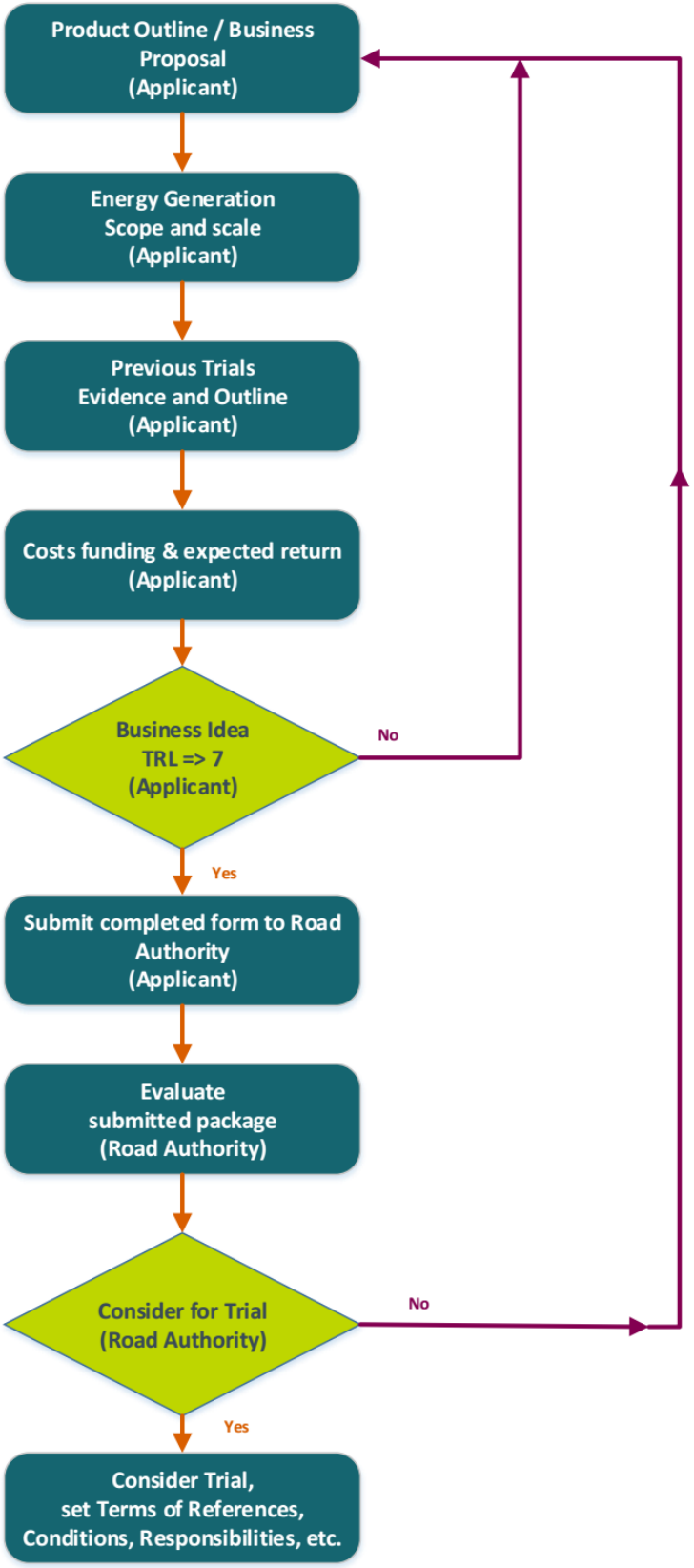
DNO Distribution Network Operator
REAs Roadside Electrical Assets
TRN Trunk Road Network
EAC Estimated Annual Consumption
ITS Intelligent Transport Systems - Motorway Communications

Appendix B. Self-Assessment Form

Tab	Topic	Checklist
1	About The Product	
2	Energy Generation	
3	Previous Trials	
4	Costs	

Flowchart – Application for Renewables Trial on the Road Network

ATKINS



ABOUT THE PRODUCT

	Criteria		Assessment Guidance	Detail	Supporting Evidence	Assessment
1	Developer	1a	What is the name of the Applicant			
		1b	Companies House Reference / DUNS / VAT Reference			
		1c	Number of years trading?			
2	Proposal	2a	Text and illustrations of the proposal sufficient to understand the principle of operation.			
		2b	Technology Readiness Level (TRL) stated and justified.			
		2c	Details of how the product will be used on the road network			
		2d	Product benchmarked against already commercialised products intended for similar applications			
		2e	Provide evidence of support from equipment or component manufacturers / suppliers for the proposal			
		2f	Provide evidence that product complies with DNO connection requirements.			
		2g	MCS Accreditation registration reference (if accredited)			
3	Operational Summary	3a	Detailed Results of any Previous Trials			
		3b	Explanation of how the product survives in adverse weather (such as wind, snow, ice or rain)			
		3c	Explanation of why the trial needs to undertaken on the public road network at this stage in the product development cycle.			
		3d	Explanation of why the installation will not provide a hazard to road users.			
		3e	What is the anticipated interval between maintenance visits?			

Overall assessment		

ENERGY GENERATION

	Criteria		Assessment guidance	Detail	Supporting Evidence	Assessment
1	Energy Generation	1a	What is the estimated annual energy generation?			
		1b	Provide a set of calculations to support your application			
		1c	Clearly explain and justify the assumptions made in this calculation.			
		1d				
2	Site Conditions	2a	What site conditions are required to maximise performance?			
		2b	Where on the road network is the device to be located?			
		2c	Is traffic management required to install the device, if so please describe			
3	Road Asset Operation	3a	Which road assets is the product designed to supply power to?			
		3b	How many hours will the product supply to the road asset?			
		3c	Is storage required?			

Overall assessment	

PREVIOUS TRIALS

	Criteria		Assessment guidance	Detail	Supporting Evidence	Assessment
1	Experience	1a	Demonstrate where previous trials have been undertaken			
		1b	Provide the results from those trials			
2	Trial Purpose	2a	What are the expected outcomes from the trial?			
		2b	How is this to be measured?			
3	Performance	3a	System Performance - the system efficiency, power output, annual energy yield – this should include all the key assumptions used			
4	Site feasibility work	4a	What experience does the developer have of working on the road network?			
5	Access survey	5a	Has an access survey been carried out for construction and delivery of plant?			
		5b	What are the traffic management requirements for installation, maintenance and decommissioning stages?			
6	Site Visits	6a	What is the purpose of the site visits?			
		6b	What is the frequency of site vists anticipated during the trial period?			
7	Site telecoms	7a	What are the plans for site telecoms links to obtain data from the trial?			

Overall Assessment	

COSTS

	Criteria		Assessment guidance	Detail	Supporting Evidence	Assessment
1	Development costs	1a	Provide evidence of the detailed costing for all items required			
		1b	Provide evidence that the appropriate levels of insurance are in place for the duration of the trial.			
2	Installation Costs	2a	Installation cost for product, including metering, isolation means, cable connection costs.			
		2b	Traffic management costs for installation			
		2c	Connection charges			
3	Recurring Costs	3a	Insurance Costs			
		3b	Servicing / Maintenance Costs			
		3c	Traffic management costs for servicing visits			
4	Decommissioning	4a	Insurance Costs			
		4b	Servicing / maintenance Costs			
		4c	Traffic management costs			
5	Power generation	5a	Rated Output			
		5b	Average daily operating hours			
		5c	Average load factor during generating time			
6	Levelised Cost of Energy	6a	Total Lifetime Cost of Ownership (£)			
		6b	Total lifetime electricity generated (kWh)			
		6c	Levelised Cost of Energy (£/kWh)			
7	Funding	7a	Confirmation that funding is available for the full cycle of the trial.			

Overall assessment	

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