Harnessing Energy from Highways

Dr David Williams
Summary

This essay is designed to provide an alternative way of thinking about our road network and looks at a novel way of generating income through harnessing the forces that it is subjected to every day: solar radiation, wind, the movement of water and kinetic energy. This approach is timely because local authorities, the guardians of the road network, are facing the dual pressures of both a reduction in funding from central government and an increase in the number of elderly people requiring social care. Both of these factors are squeezing the money available to maintain our road network. The UK is also at present heavily dependent on imports of energy and fuel and with the uncertainty of the UK’s markets due to Brexit and the pressures on the World Trade Organisation terms there is a need to ensure that the country becomes more self-sufficient when it comes to producing energy.

The solution discussed in this essay provides the UK with the means of generating a new source of funding for highway maintenance, which will help to improve the quality of the network, improve safety by reducing damage to the surfaces. It will make the network more reliable by reducing the impact of hot and cold weather incidents on the road surface, allowing road users to travel as they normally would. The scheme will also help reduce the carbon dioxide emissions associated with energy production and enable the country to become more self-sufficient in energy production.

At present the cost and payback period for developing and installing each of the technologies is prohibitive, due to the relatively low levels of energy produced by each. What this essay proposes is that a Hybrid Renewable Energy System (HRES) is developed that gathers energy from multiple sources in terms of the forces that the highway network are exposed to. This approach would provide a significant level of energy and finance for local authorities to invest in enhancing the road network for the benefit of road users and the wider public.

The challenges to this approach are that at present much of the technology is at a prototype phase, so it is suggested that through government intervention and funding a set of trials can be created to develop the technology and then trial it across the country. Once the market is created for the technology and supported by the government this will improve the level of funding invested by private organisations. The government can retain a percentage of the patent with all of the parties so that the technology can be sold worldwide.

As part of the trial stage the government will need to develop frameworks between local authorities, energy companies, universities and technology companies so that they can come together in consortiums to design and deliver the HRES systems. The roll out of this technology would also require cross-party support and legislation, as the roll out period is likely to take several decades.

The money generated through the sale of electricity on the open market would then be distributed between the consortium members, with a commitment that local authorities invest their profits back into highway maintenance and other key services.

This approach provides a new revenue source for highway maintenance that will improve the flow of traffic by reducing the decay of the road infrastructure. This novel approach could provide significant benefits to the environment and enables the arteries of the economy to stay open for business.
Introduction

The United Kingdom is about to enter the eighth financial year of austerity budgeting. This, along with the uncertainty around the impact on the UK economy of Brexit, means there is a need to maximise the benefits provided by our nation’s existing assets. Paying for the construction and maintenance our road network has become increasingly more difficult in the past seven years as the National Government cut funding to local authorities, who manage most of the highway network, by 30%, or £18bn between 2010 and 2015\textsuperscript{12}. In addition to this, local authorities have to find another £3.5bn of savings by 2020\textsuperscript{3}. This means local authorities face increasing pressure to use their funds in a more effective way.

How does this affect our roads?

Local authorities play many important roles in the UK including: providing social care and housing to the most vulnerable in society, removing and recycling our waste, and managing planning within our towns and cities to ensure that the majority of the highway network continues to function. At present social care accounts for approximately 50 percent of authority funding up from 40 percent of funding in 2010/11\textsuperscript{4}. This is primarily due to the increased requirement for services by the country’s ageing population. With waste taking a further 10 percent of local authorities’ budgets, this has squeezed the funding available for the remaining services to just 40 percent of an increasingly smaller pot of funding. Maintaining the highways is one of the many services fighting for the remaining funds.

This matters, as local authorities are the ‘guardians of the highway network’ and manage approximately 87 percent of the UK’s roads\textsuperscript{5}. This network forms the arteries of the country, allowing the everyday flow of people and creating the heartbeat of the economy. Delays, disruptions and closures caused by poor maintenance have a significant impact on how, when and if people travel and goods are shipped. It is therefore essential to make the roads operate better, safer and to become more reliable in the future if the country is to continue to thrive.

Management of Highway Assets

The way the highway network in the UK is managed has changed in the last 10 years with most local authorities adopting an asset management approach from a ‘worst first’ approach. This transition has been supported by the Department for Transport (DfT), through the incentive of additional funding to local authorities for the introduction of the Highways Maintenance Efficiency Programme (HMEP), which was developed by the DfT to promote efficient and effective working practices at the local authority level\textsuperscript{6}. The asset management approach means that many authorities are prioritising the maintenance of assets to prevent them falling into a state of disrepair, whilst managing, where possible with the remaining budget, to bring the worst surfaces up to a decent standard.
The primary problem with both the reduction and squeeze on local authority funding is that at best most authorities are managing a decline in the quality of their assets, rather than improving them. Without a suitable level of new funding, or a completely new way of thinking about how to best maximise the benefits provided by these assets, this decline will mean that a potentially significant proportion of the highway network will not be fit for purpose in the next 20 to 30 years.

**New ways of thinking about our highway assets**

The Oxford English Dictionary defines asset management as:

> “The active management of assets in order to optimise return on investment”

The problem for local authorities in the case of highway assets is that at present they provide 100 percent of the financial investment but receive none of the returns, with the travellers and businesses receiving all of the benefits of a fully operational transport network. Whilst national taxes ultimately pay for maintenance of the roads, so it is understandable that those who pay should benefit, this does mean that there very few opportunities for local authorities to recoup money from their highway assets to pay for maintenance and other services they provide. With no appetite from any national government in the past 50 years to introduce road user charging nationwide and local authorities being criticised for generating revenue from parking charges, it is currently very difficult for local authorities to make any money from these assets that can be reused to improve the standard of the network. So instead of looking at how we can generate money from charging existing users we should instead look at harnessing energy from our highway network.

**Harnessing the energy**

Highway assets are subjected to different forces every day: solar radiation, water, wind and kinetic energy from vehicles passing over the carriageway surface and structures. Separately each of these actions produces small amounts of energy, however if you combine this energy together across the whole of a network you have the potential to generate a vast amount of electricity that can be used to maintain the surface temperature of the carriageway and provide additional energy to feed back into the grid. Connecting a set of microgeneration systems across the highway network offers an opportunity to harness some of this energy. This approach is known as marginal gains. The theory of marginal gains has been used successfully in sport by British Cycling and Team Sky, winning multiple Olympic medals and the Tour de France on four occasions. Former performance director of British Cycling and the current General Manager of Team Sky David Brailsford describes marginal gains as:

> “The whole principle came from the idea that if you broke down everything you could think of that goes into riding a bike, and then improved it by 1%, you will get a significant increase when you put them all together”

Applying several means of capturing energy into the transport system would provide marginal gains in terms of energy production, if managed appropriately. By diversifying the sources of energy production would also allow for the issues that are used to criticise renewables, as energy would be created in almost all weather conditions as you would be generating small amounts of energy from a number of different sources.
**Solving three problems at once?**

In addition to the issues of maintaining our highways this solution also provides an alternative, sustainable energy source that will help with the country’s energy security. Energy production is a significant challenge for all nations in the 21st century. At present the UK is heavily reliant on energy and fuel from areas of the world that are politically or environmentally unstable, with 45 percent of the energy needed coming from imports in 2015. As a means of improving our energy security the National Government agreed to invest between £18bn and £37bn in the creation of a new nuclear reactor at Hinkley Point in 2016. This scheme is designed to enable the country to become self-sufficient, yet this is essentially ‘putting all the eggs in one basket’ in terms of relying on one energy source. French company EDF, the company chosen to design this reactor, have a poor reputation in terms of delivering on time and to budget and producing the level of energy predicted, as examples of Flamanville in France and in Oikiluoto Finland have shown in the past: at present the Flamanville site current running six years behind schedule. The Hinkley Point scheme comes at a significant cost to the UK tax payer and it is possible that this money could be better invested other more stable means of energy generation and improving the quality of the highway network at the same time.

The UK has seen significant growth in renewable energy sources in the UK in the past five years, but renewables still only make up 6.3% of the total market in the UK. Therefore, increasing the mix and utilising existing assets through linking them to highway microgeneration schemes would provide a greater use of our existing land and assets without the need to build more solar farms on arable land.

The solution discussed in this essay provides the UK with the means of:

- Providing funding for highway maintenance, improving highway, safety, reliability and potential funding for other local authority services for all;
- Helping to reduce carbon dioxide production associated with energy production; and
- Help towards becoming self-sufficient in energy production.

This would provide a better, more reliable road network that would be beneficial not just to road users, but all of society.

**Structure of this essay**

The remainder of this essay is provides an overview of the potential technologies that could be implemented and the challenges associated with each. The essay includes details of the political and business challenges adopting the technology would require and concludes with a case study how this scheme could be rolled out for a hypothetical average town in the UK.
Energy Production – Solar

There have been numerous schemes to harvest energy from the highway network trialled across the world, but as yet none have gone into mass-production. One of the most widely publicised technologies has been invented by crowd-funded organisation Solar Roadways in the USA. Solar Roadways have designed a road system to harvest energy from the road surface using textured glass solar panels, as shown in the concept picture in Figure 2\textsuperscript{15}. The designers were given a $100,000 grant from the US Department of Transportation in 2009 to build a prototype. This was followed in 2011 by a $750,000 grant to create a car park demonstration system\textsuperscript{16}. The issues with the trial related to the uncertainty of how the materials would perform through constant use and wear and tear. The other challenges for this technology include the cost of construction and difficulty of rolling out across the highway network.

 Whilst the engineers behind Solar Roads continue to trial and improve their technology it is possible that low tech solutions may be more suitable for mass production and roll out in the UK, particularly due to the cost of maintenance and replacement of infrastructure. In 2006 scientists trialled a means of generating energy though the heat of the highway, as shown in Figure 3. The heat transfer between river water, used as a coolant and water in tubes under the road that were heated by the road surface. This produced electric power through the temperature difference between the warm and cool water in a thermoelectric generator\textsuperscript{17}.

Harvesting this energy provided significant benefits to the reliability of the highway, as road surface could be cooled in the summer and warmed in the winter, reducing the impacts of both excessive heat and the freeze-thaw on the highway surface. Installing this simpler technology improved the lifespan of the highway, the reliability for road users and reduced the need for
maintenance to replace pot holes. This would provide significant savings to local authorities, freeing up money to provide other essential services.

In a similar study in 2013 found that in their tests a ‘solar road’ was 3°C-6°C lower than a normal road in the summer months and 14.4% of solar radiation was captured through this approach, which they believed would provide a significant amount of energy for electricity production. On a larger scale in Arnhem in the Netherlands a system of energy harvesting has existed since 1997 that maintains the highway temperature and also provides energy to a local business park.

Another more recent trial in the Netherlands involved a 70m bike path that produced 3,000 kWh, as shown in Figure 4, enough energy for a small household for one year.

The challenge for all these types of technology are that they as yet have rarely made it past the trial phase, possibly due to the cost of implementation and payback period in terms of the energy produced and savings made. The challenge with solar energy is the uncertainty of the level of energy that will be produced due to the prevailing weather conditions. To invest in this technology alone would not make sense from a financial perspective at this point in time; however solar energy could be incorporated into larger approach that adopts other energy generating schemes thereby making the level of energy produced overall greater and the payback period shorter.
Energy Production – Wind

The average wind speed in the UK is 13 miles per hour, although this varies across the country with the highlands of Scotland windier than Cambridgeshire for example. This means that at present harnessing the power the wind exerts on the road network has yet to be exploited at the present time. To maximise the benefits of wind power we would need to install windmills across the country. Tying this in to existing infrastructure would lessen the impact on the environment, both visual and land use, providing the means to generate energy within our urban areas. This would help to mitigate the criticism of this technology that currently exists.

Of the four methods of energy production from highway assets the street-lighting market is the most mature with several products already available. German company Scotia have created zero emission street lamps that convert sunlight to streetlight via photovoltaic cells. This energy can be stored in batteries or fed back into the grid. To maximise energy generation another company, Energy Environmental Technical Services (E.E.T.S), has included a wind turbine in addition to a photovoltaic cell that can help to ensure the unit generates power at night and during the winter. Various researchers in recent years have both explored the benefits of hybrid energy production and found that this approach is optimal, particularly in countries with weak grid systems. Whilst the UK system is not weak in terms of energy availability, any means of reducing demand and possibly increasing supply would provide a benefit to the country’s energy supply. Due to the availability of products these would be as easy to install as conventional street lamps, albeit at a greater initial cost.

Such technology offers significant potential benefits to local authorities as most residential streets in the UK have some form of street lighting. Keeping these lights on at night is a considerable cost to local authorities, estimating the cost to be around £300m per significant source of carbon emissions, which are a contributory factor in global climate change. It is estimated that if the 7 million streetlights in the UK were converted to this technology could produce 4 terrawatt hours of energy a year, half the output of Sizewell B nuclear power station. At present the major barrier to investing in this technology is the cost of the units and an agreement between the local authorities and the energy companies to produce energy in this way. Again if delivered as part of a package and through a major roll out across the country, this cost could be reduced significantly through government subsidies and bulk purchasing.
year in 2016. In addition to the cost street lighting is as a

**Energy Production - Rainwater**

Of all the forces that the highway network is exposed to water is the most prevalent. Between 1981 and 2010 it rained on average 133 times per year in England, with higher levels of rain recorded in Scotland and Wales. At present the management of this water and the impact it has on the road surface is a significant problem in highway maintenance terms, as water gets into gaps within the surface slowly breaking it down to form pot holes. Add to this the issues of the water within the road surface freezing and thawing, this leads to significant issues in terms of maintenance. The movement of water though the drainage systems does however provide an opportunity to create energy.

To generate this energy any new carriageway surface would need to include a Sustainable Urban Drainage System (SUDS) or include a pervious highway surface. A 2013 study found that the introduction of a SUDS system helped to filter the water of waste and impurities so that it could be used to produce energy through Ground Source Heat Pumps (GSHP). GSHPs create energy in a similar way to the heating and cooling, system, except they used the ground’s energy. However, it is possible that the water from the drainage system could be used in conjunction with the pipes in the solar roads instead of installing a GSHP.

With the existing cabling for energy to properties and street lighting running under highway surfaces, this energy could be fed back into the grid as part of this process. At present this approach is at a hypothetical stage, but with appropriate funding and trialling it is possible that an appropriate technology could be brought to market.
A second approach for generating energy was adopted in Le Châble, Switzerland in 1992. This involved the installation of hydro turbines within the existing sewage system. The scheme overcame issues of solid elements in the water and corrosion resistance through the use of stainless steel and ceramic coating of the turbine. Designing this technology to sit within existing drainage systems would be incredibly challenging, but not insurmountable, although the turbines would have to be relatively small and less complex in comparison to the system in Le Châble.

Energy Production – Kinetic Energy

The final potential energy source is harnessing energy from the movement of cars, as shown in Figure 8. Trial schemes for this technology have been implemented in the UK, with the installation of ‘sleeping policemen’ in the carriageway that generate free kinetic energy. The panels are almost flush with the existing road surface and are pushed down as the car passes over it. This system sets a cog in motion to turn a motor that creates mechanical energy, as shown in Figure 9. The units cost between £20,000 and £55,000 depending on the size of the unit and 10 units can generate a similar level of energy as one wind turbine. This technology was installed at the Sainsbury’s car park in Gloucester in 2009, as shown in Figure 10, and produced enough power to run the store’s tills. This approach was criticised as it only generates approximately “one four-thousandth of the energy used by the trip to the supermarket”, assuming the driver travels three miles to and from the store. Although it is worth considering this argument it is unlikely that people will stop using cars in the near future. It therefore makes sense to install this technology in areas where there are a large number of vehicle movements to generate energy.

Alternative methods of energy generation using the movement of vehicles have also been trialled across the world. A piezoelectric energy
system has recently been trialled in South Korea that generates energy as vehicles move along the road. This is gathered through cantilever beams that do not raise the road surface, so can be integrated into an existing highway network, with the designers believing that this system has the potential to become a macro energy producer if the trials continue to be successful\textsuperscript{33}. One of the issues is the difficulty in maintaining and replacing the parts if the system is too complex, as the cost of purchasing and maintaining the network would be too prohibitive.

Another trial has been undertaken by Mexican entrepreneur Macías Hernández, who has invented a far simpler system that uses small ramps in the road that are pushed down that forces compressed air into a storage tank. This is fed into a turbine to generate electricity and is similar in style to the scheme in Gloucester\textsuperscript{34}. This is a more low-tech approach, which if mass produced would cheaper to construct and easier to maintain than the piezoelectric system. Again this scheme has only been trialled rather than mass produced with the early results suggesting the technology would generate energy. To maximise the benefits of this technology the components need to be cheap to purchase, use, maintain and eventually replace, especially if rolled out on a large-scale.

Energy Production – Kinetic Energy

![Energy Ramp Diagram](Image)

Figure 9 – Energy Ramp\textsuperscript{29}
Hybrid Renewable Energy Systems

One of the main reasons why none of the four technologies discussed have been adopted by local authorities at the present time is due to the cost in relation to the energy produced\textsuperscript{12}. Separately each of the four microgeneration schemes produce relatively low levels of energy, however, merging these systems into what is called a Hybrid Renewable Energy System (HRES) is a possible solution\textsuperscript{35}. The HRES would form a number of stations alongside the carriageway with batteries and mains connections to pass the energy either into a local network or the national grid, as shown in Figure 11 with the concept of a dual wind and photovoltaic HRES system\textsuperscript{36}. The problem with the national electricity grid is that it cannot store energy\textsuperscript{21}, so it is possible that energy would need to be stored in batteries locally, so that it could be utilised at times of peak use. The HRES approach provides a better solution, as you are not relying on just one means of energy production but four for producing this energy. Generating energy through vehicle movements would be beneficial, as this energy would be generated during the peak periods of travel and could be utilised through the surges of people turning on ICT equipment in their offices or when returning home at the end of the working day.

The HRES approach is not without its challenges, although many of these can be overcome through forward thinking, energy management, the breaking down of institutional silos and funding into innovative techniques in harnessing these energy sources as will be discussed in the next section.

\textit{Figure 11 – Wind-pv hybrid streetlight control system}\textsuperscript{36}
Dr David Williams

Challenges of Delivery
The development of a HRES that could be incorporated into the UK highway infrastructure but there are many challenges of trying to deliver this type of scheme on this type of scale. These include technical challenges, political challenges, organisational challenges and ultimately the cost of installation and management of the whole process.

Technical Issues
As discussed above each of the four methods of energy generation would produce relatively small amounts of energy on their own. Added to this two of the four methods of energy production are still at the prototype stage, rather than being available for mass roll out. This means that here needs to be a reason that companies and universities are going to spend time investing in these types of technology through creation of a potential market place.

There is also a challenge in relation to how and where the energy would go to. Would it be stored in batteries locally, delivered to a local grid, fed into the national grid or a combination of each of these options? It is therefore likely that a network of electricity stations would need to be set up close to the highway network, within urban areas. This is likely to be difficult to administer due to land ownership issues and the uncertainty over the size and scale of what would be delivered. Again these challenges would need to be addressed through the creation of a market place rather than at the concept stage.

Government Intervention
Commitment from the National Government level is therefore essential for any new technology to become accepted and for this technology to become a viable means of funding highway improvements and generating energy. Ensuring that the senior minister for transport’s supports this scheme, as well as his political party’s support was essential for funding to be made available for the trial and implementation of any new approaches or technology. For example the funding to deliver the Local Sustainable Transport Fund, between 2011 and 2015, would not have been made available without the influence of Norman Baker MP, the senior Under-Secretary for Transport’s understanding of sustainable transport and his party’s commitment to delivering schemes that enabled people to switch to more sustainable modes of travel\textsuperscript{36}. Securing the support of the senior ministers at the DfT, Department for Energy, and DCLG is therefore essential to the success of this scheme going forward.

Government Funding
Most major infrastructure schemes require a level of National Government funding before the private sector are prepared to invest in it. To see energy generation from the highway network there needs to be some funding from the Government made available to kick-start this new market. The best approach would be to identify a trial scheme to test the technologies and demonstrate the proof of concept. This could be undertaken through a competition to design the relevant technology and demonstrate that it works. This is a low cost/low risk approach to creating the market as the project can be stopped if the trials are not successful. If they are successful then the benefits for the winning organisations would be include the patenting and licencing of any new technology for implementation.
A secondary competition should be open to housing developers, energy companies, community groups and local authorities to identify where this technology could be implemented. This would be a trial of 3-5 years that would look at all aspects of the scheme, from design, construction, use, maintenance and replacement of each type of technology. This would look at what has worked, what can be improved, where savings can be made and the challenges of implementing the technology. This would also lead to understanding the level of energy that would need to be produced to make sure the delivery of HRES schemes would be affordable in terms of capital funding and payback.

The implementation of the trials is likely to win approval from the local authorities, as most councillors and officers at this level are pragmatic in terms of delivering initiatives where funding has been made available. The local councillors who see the developments being successfully delivered in their wards will be very happy with the outcomes due to the likely positive feedback from their residents. Similarly, councillors who were not in receipt of new developments are likely to pressure officers to identify schemes that could be delivered in their wards. If these schemes prove successful and the benefits are noticed by residents in relation to energy costs, or improved highway performance, in terms of reduced disruptions due to maintenance and weather related incidents, this is likely to increase the demand at the local level for greater roll out of the technology.

Following the trials and assuming there is a system or a number of systems that were successful it would then be necessary for parliament to create legislation to ensure roll out of the technology began. This would require cross-party support to ensure that the scheme was not shelved when there was a change of government. This continuity is important as the roll out of this technology is likely to take several decades. This would also mean developers would have to comply with the legislation in the construction of new highways that generated energy through their use. They would also be more willing to commit financially if they know that their investment is supported by Government legislation. Both are unlikely to happen if the legislation is not in place as the technology is likely to cost more than existing approach to constructing and maintaining infrastructure.

By the National Government underwriting this project at the start it would be possible to create a market where the benefits of installation of these schemes would be trialled and delivered. The Government investment and control of patents would ensure that the country received a payback on their funding through the delivery of the new infrastructure in the UK and licencing of the technology to other nations who want to use the innovative designs created by UK companies. This would be a win-win for the government in creating a legacy of reliable/sustainable roads and ensuring the nation’s energy security moving forward.

**Energy Providers**

One of the biggest challengers to the delivery of this approach to maintaining the roads and producing energy will be the existing energy providers. They have invested significantly in technology and infrastructure to provide the UK with access to energy from a variety of sources. It would therefore be essential for the national government to engage with all energy providers at the earliest point to identify the best means of utilising and distributing the energy produced by the highway network. This should involve identifying the role they can play in the design and trialling of the technology.
At the same time, it is also worth identifying whether alternative models of management would be better suited to small-scale energy production. Setting up local community groups to manage energy production in local areas could be considered, allowing for local buy-in and management of any trial schemes. The Centre for Sustainable Energy (CSE) undertook a feasibility study of creating a community based Energy Service Company between 2001 and 2004. The study found little feasibility in creating a community based company at this time; however, changes to energy requirements and the pressure to ensure the function of the highways may lead to different results now, particularly if the energy is coming from multiple sources located across the highway network.

**Building Frameworks**

At present local authorities in the UK do not have the resources, skills and expertise to deliver schemes on the scale that is being proposed to roll out this technology. The National Government would need to facilitate the means of local authorities, energy companies, universities and the technology companies to come together to form consortiums to trial and deliver the schemes. The National Government’s role is likely to be relative hands-off after this trial is set up, although the initial introductions would be an essential starting point.

The consortiums would allow each party to financially commit or provide the assets for the trials of the technology. Each member of the consortium would benefit from any new patents generated through this process so that the financial benefits would be available to both the public and private sectors. The consortium members would also benefit from the value of any energy generated as it is sold on the open market.

**New Funding and Investment**

At this point there would need to be a commitment by the National Government that local authorities would be responsible for managing the financial benefits of the electricity regeneration. The agreement to set up the consortia would therefore need a clause that stated that local authorities would be required to spend a certain proportion of any profits gained on improving the safety and reliability of the remaining highway network to ensure that the road becomes easier and quicker to use, due to the reduction weather related delays. In addition this funding would also allow local authorities to manage and speed up the maintenance of an higher proportion of the highway network than is currently maintained through the existing system, again benefitting road users by reducing the number of pot holes, for example, that can cause damage to their vehicles.

**Areas where the Technology is Not Suitable**

It is clear that there will be some locations where installing this technology is not practical from both a technological and a financial perspective. The installation of this technology should not therefore replace other methods of highway construction and maintenance, but complement them. If local authorities are able to generate additional funding from the parts of the network that are suitable for energy generation, this can be used to ensure the other sections of the network and various structures are maintained to a high standard improving the reliability of the network to the benefit of all road users.
Pathway to Delivery
The introduction of micro-generation Hybrid Renewable Energy schemes is an extremely long-term approach to the improvement of the highway network that would require the following steps to be taken.

- Commitment by the National Government to fund a competition to develop each method of energy production and their integration into a HRES system – 1 Year.
- Trialling of delivery of the competition winning technology. This would take place in a number of different locations nationally in different settings including: new developments, retrofitting technology to existing highways and scheme delivery in cities, towns, villages and rural areas to identify the best models for each area. – 3-5 years.
- Negotiations to gain cross-party support for the delivery of the technology. 1-2 years
- Creation of an act of parliament to ensure delivery of the appropriate technology – 1 year.
- National roll-out of approved technology – 30 years.
- Changes, refinements and technological leaps in technology – on-going.
Future Scenario – Summerstown

Background
Summerstown is a medium sized town with a population of 75,000. The town is situated on the coast and as such is a popular destination in the summer where the population of the town can double. This puts pressure on the road network during peak periods with a large number of vehicle movements in and out of the area. The town is also a dormitory town for a large city 20 miles away. This involves a large movement of vehicles into and out of the town during the rush hour on Monday to Friday. The flows of traffic follow regular patterns within the area.

As a coastal town Summerstown has over 100 days with winds over 6 metres per second (13 mph). In addition the town experiences rainfall or other precipitation between 180-200 days of the year, with over 100 days of sunshine that attracts the visitors to the resort.

Trial for Technology
The local authority for Summerstown was successful in being granted funding to create a three-year trial scheme for delivering a HRES system within the existing highway network. This provided the council to trial the technologies on four different road types:

- Quiet urban roads;
- Quiet rural lanes;
- Busy urban B roads; and
- Busy urban A road.

The trial was conducted on both new development roads and retrofitting to the existing carriageway with promising results. Each road included tubes under the carriageway to generate solar energy and maintain carriageway temperature, ramps to generate kinetic energy, a series of turbines in the drainage system to generate energy through the movement of water and the replacement of all lighting columns with dual energy lighting columns.

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Length (metres)</th>
<th>Cost for (Re)construction</th>
<th>Cost of HRES system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiet Urban (new)</td>
<td>200</td>
<td>£100,000</td>
<td>£150,000</td>
</tr>
<tr>
<td>7m width</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quiet Urban (retrofit)</td>
<td>200</td>
<td>£56,000</td>
<td>£150,000</td>
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<tr>
<td>7m width</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quiet country lane</td>
<td>200</td>
<td>£56,000</td>
<td>£150,000</td>
</tr>
<tr>
<td>7m width</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Busy urban B road</td>
<td>1000</td>
<td>£1,000,000</td>
<td>£2,000,000</td>
</tr>
<tr>
<td>10m width</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Busy urban A road</td>
<td>1000</td>
<td>£1,000,000</td>
<td>£2,000,000</td>
</tr>
<tr>
<td>10m width</td>
<td></td>
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</tbody>
</table>

The average cost of replacing standard lighting columns is £2,500[^2], with the new columns costing £5,000[^2]. These costs have been included in the calculations. From this it was possible to see that delivering a HRES system cost three times as much to install on quieter roads with the cost doubled.
for busier roads. This meant that to be affordable compared to existing methods of highway maintenance the sites needed to generate enough energy to pay for this additional cost.

**Benefits**

The trial found that over the course of the three years of the study the energy produced was significant, with the trial in the new housing estate generating enough energy for the street lighting and use by the houses either side of the road for the duration of the trial. The retrofitting to the quiet urban roads was less successful, as the carriageway was blocked by parked cars, which reduced the solar energy reaching the surface. The technology was particularly successful in generating energy on the busy roads due to the movements of vehicles throughout the peak periods in the week and the summer holidays, although the level of energy produced reduced in the off season. This was mitigated by the increased precipitation and energy produced by the turbines under the road surface.

The payback period for the technology at all sites was slightly longer than the three year study, but the consortium members were happy that this would be achieved by year seven. The consortium concluded that the roll out of the technology would require government funding at the start of the process, but this would be paid back once the scheme was delivered across a wider area.

Other benefits included the reduced cost of gritting the highways in the winter, the reduced impacts of freeze-thaw and heat events on the surface with the council’s engineers concluding that the surfaces would need replacing up to five years later than surfaces using existing techniques. This provided significant benefits for road users who were able to guarantee that they were able to travel during the winter months, as the road surfaced did not require treatment with salt or grit.

**Into the Future**

Following the success of this and other trials it is agreed that the technology will be rolled out nationwide, putting local authorities and their consortium partners at the forefront of road safety, road maintenance and the generation of energy.

By 2035 Summerstown has converted 50% of the carriageways to HRES systems, with another 10% due to be completed in the next five years. The Council hope to have up to 90% of the network, particularly the drainage systems included in this set up by 2050. All new developments post 2025 had a legal requirement to implement HRES technology, with the decision to upgrade existing carriageways up to the local authorities. In some locations within the town the local authority deemed that it was not financially viable to install this technology, due to the limited daylight, or traffic levels for example.

The Council have seen significant benefits through the installation of the technology in terms of a reduction in weather related incidents affecting the network, a reduction in the cost of maintenance of carriageways and financial receipts due to the energy generated. This has been used to maintain and enhance the existing infrastructure as well as pay for other services provided by the Council.
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References


