



UNIVERSITY OF
LIVERPOOL



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The University of Liverpool- Working Towards the Region's Clean Growth Ambitions

Helping Liverpool City Region create
a more sustainable future through the
Centre for Global Eco-Innovation
and **Low Carbon Eco-Innovatory**





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Foreword



Executive Summary

The UK's 2017 Industrial Strategy identified Clean Growth as one of its four Grand Challenges, with the aim to be at the forefront of the development, manufacture and use of low-carbon technologies, systems and services (1). Clean Growth requires CO₂ emissions to be decoupled from economic growth. Globally, low carbon products and processes were valued at \$3.4 trillion in 2014, a figure predicted to increase to over \$8 trillion by 2025 (2). In Liverpool City Region (LCR), the Clean Growth sector employs over 22,000 people, contributing over £2 billion annually to the economy (2).

Two large-scale projects within LCR, the Low Carbon Eco-Innovatory (LCEI) and the Centre for Global Eco-Innovation (CGE), have contributed toward Clean Growth through the creation of new or improved low carbon goods, processes and services. Since 2012 the LCEI and CGE have offered a range of short-term and long-term industry-led collaborative research projects, from 1-month internships to three-year, full-time PhD projects. These projects have provided regional Small and

Medium-sized Enterprises (SMEs) with access to resources, facilities and world-leading expertise from the University of Liverpool, Liverpool John Moores University and Lancaster University. Opportunities for low carbon development are not bound by sector therefore the LCEI and CGE have collaborated with businesses in a wide variety of disciplines such as environmental science, engineering, chemistry, electrical engineering, architecture and management.

The LCEI and CGE collaborations have contributed to LCRs Energy Strategy directly (e.g. development of solar PV and fuel supply for low carbon vehicles) and indirectly through energy efficiency improvements (e.g. waste reduction). To date the CGE and LCEI programme have collaborated with over 500 SMEs, with the CGE programme creating over 300 jobs and adding £45 million gross GVA to the low carbon economy in LCR and the North West (2). These outputs not only benefit local businesses in the North West and LCR but provide exemplars of action that could be implemented by other businesses to develop Clean Growth strategies.

1 Introduction

Since 2012 the Low Carbon Eco-Innovatory (LCEI) and the Centre for Global Eco-Innovation (CGE) have facilitated unique collaborative R&D partnerships between SMEs and the University of Liverpool, Liverpool John Moores University and Lancaster University through work with over 500 local and regional companies. The fundamental driver of all companies engaged with the programmes is the development of new or improved eco-innovative products, processes and services. Both the CGE and LCEI programmes have been part-funded through the European Regional Development Fund.

A drive toward a low carbon economy requires all industries to prioritise the reduction and mitigation of environmental impacts, therefore collaborations are not bound by sector nor subject but by commercial needs. Consequently, assisted projects cover a diverse range of sectors such as manufacturing, chemical engineering, logistics, construction, architecture, waste management, electronics, IT, environmental science and management. Within this interdisciplinary environment, research projects relate to a variety of topics including: sustainable port operations; coastal and marine resource management; geospatial data applications for green infrastructure assessment and community energy projects; apps for sustainable energy, transport and lifestyles; technology for sustainable housing; advanced manufacturing; electrode surfaces for fuel cells; and advanced controllers for wind turbines. The diversity of these projects has resulted in a similarly diverse range of academics engaging with the programmes, with projects across numerous university faculties, schools and departments. This array of projects, sectors and Higher Education Institution (HEI) departments is unique to CGE and LCEI and demonstrates a shift towards all

industries viewing climate change as a challenge that needs to be tackled at every level across government, business and academia.

The programmes offer a cross-cutting framework, providing business support, employment and skills to Liverpool City Region (LCR). The level of support offered by the programmes is dependent on the companies' research and business needs, with opportunities for:

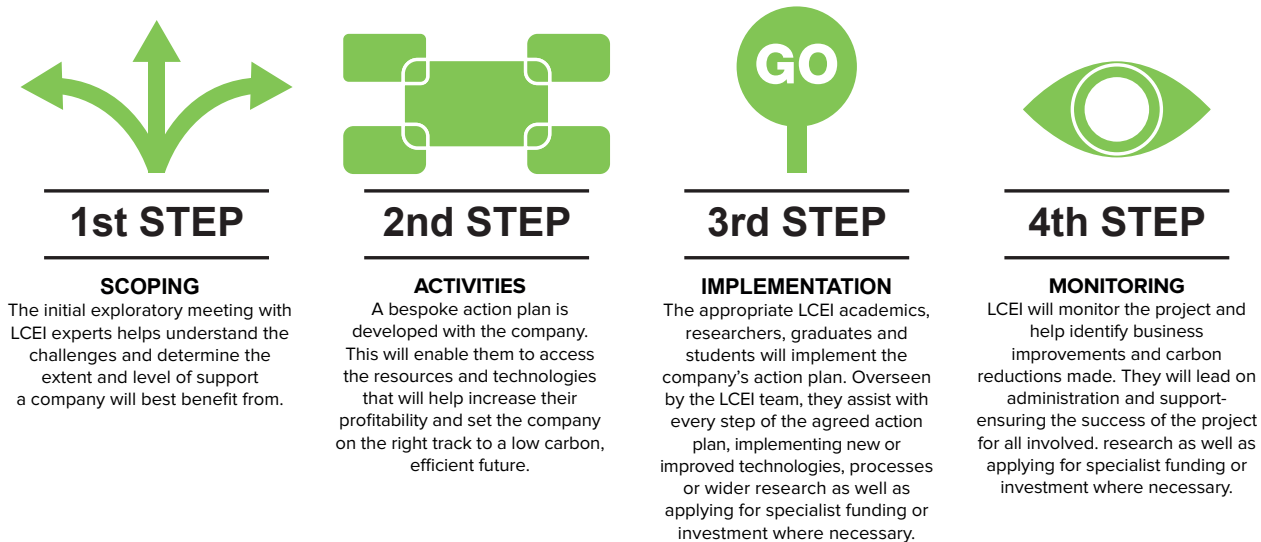
- 1-month internships
- 3-6 month supervised undergraduate projects
- Master's dissertation projects
- Dedicated post-doctoral research support
- Industry-led 1-year masters projects
- Industry-led 3-year PhD level projects

The industry-led 1-year Masters and 3-year PhD level projects are the most research-intensive collaborations offered, with a dedicated full-time graduate researcher working with the SME. To date 45 SMEs have worked with the University of Liverpool through 3-year research intensive PhD projects.

The multi award-winning £10 million CGE, a collaboration between University of Liverpool, Lancaster University and Inventya Ltd., assisted with the creation of over 260 new jobs through work with over 300 SMEs throughout the North West by the end of 2015. LCEI formed in 2015 and focussed on SMEs within LCR, following the creation of local enterprise partnerships (LEP) in England in 2011 by the Department for Business, Innovations and Skills. This continued the

Figure 1.1

How does the Low Carbon Eco-Innovatory work?



work of the CGE through a partnership with the University of Liverpool, Liverpool John Moores University and Lancaster University. On completion, the £4.5 million LCEI programme will have assisted a further 247 SMEs in LCR.

SMEs nationally account for 50% of business energy use, with over 40,000 SMEs situated in LCR (3). It is therefore imperative that reducing energy use is viewed as an important issue for all companies, from micro companies to multi-nationals, to examine what can be achieved through the development of eco-innovative processes and products. In June 2019 the UK government passed laws to be carbon neutral by 2050. Within LCR, the Metro Mayor has outlined his goal for the region to be zero carbon by 2040, with the Liverpool City Council declaring a climate emergency in July 2019. Reflecting this vision, the CGE and LCEI have already been influential, helping LCR move toward its Clean Growth ambitions. It is also important to realise that a move toward a low carbon economy can

be a commercial opportunity, as demonstrated by companies that have previously engaged with the programmes. Through working with CGE and LCEI, SMEs have enhanced profitability, knowledge, competitive advantage and employment, all whilst reducing carbon emissions for themselves or their customers.

Case studies outlined in this report illustrate the low carbon development and eco-innovations that have resulted from direct access to the universities' research expertise and resources, facilitated by CGE and LCEI. This demonstrates the economic and environmental benefits that the programmes have brought to local businesses and the wider community plus their contribution toward the UK's Clean Growth Strategy. Additionally, the CGE and LCEI outputs overlap with key themes identified in the Liverpool City Region Energy Strategy. This forward-looking Energy Strategy outlines the regions energy agenda by sector, detailing factors that will transform future energy use and rapidly decrease reliance on fossil fuel energy sources.

2 Leadership from the HEI sector

Liverpool City Region Energy Strategy highlights the importance of collective action from LCR Combined Authority, the Local Enterprise Partnership, Local Authorities, local businesses and public agencies. The CGE and LCEI model partners SMEs with leading university academics, researchers and students. This collaborative model has allowed the HEI sector to demonstrate proactive leadership in promoting Clean Growth. Additionally, the development of low carbon goods, processes and services may not be possible for many SMEs without HEI expertise and access to their world class facilities, resources and research networks enabled and facilitated through the programmes. The HEI component of the LCEI and CGE, offered by the University of Liverpool, Liverpool John Moores University and Lancaster University, has provided leadership in energy research in LCR by giving the resources and guidance to develop new low carbon technology and promote energy efficiency and circular economy principles.

The leadership and success of CGE was recognised in 2015 with the awarding of the UK Research Council (RCUK) Impact award for Outstanding Knowledge Exchange and Commercialisation Initiative and the Green Gown award for Research & Development. Further, the Green Gown Awards recognise exceptional initiatives being taken by universities and colleges across the UK to become more sustainable. Additionally, the CGE was the winner of the University of Liverpool Outstanding Contribution to Research Impact award in 2015.

The highly contested Merseyside Innovation award was won by companies working in partnership with the University of Liverpool team on two consecutive years. Marlan Maritime Technologies Ltd. received the award

in 2017 for its work alongside the University of Liverpool and the National Oceanographic Centre developing unique radar systems for coastal monitoring. Effective monitoring and prediction of coastline erosion can reduce the need for large carbon intensive precast concrete sea defences and replace them with smaller, more appropriate, structures or even use natural interventions, thereby dramatically reducing carbon emissions. In 2018, 5D Health Protection Group won the Merseyside Innovation award for biofilms that have the potential to substantially reduce the drag coefficient of ships' hulls, saving potentially millions of tonnes of CO₂ emissions globally per annum. Marlan Maritime Technologies Ltd. was also awarded the prestigious Mersey Maritime Innovation award in 2018 for the continuing development of collaborative research with CGE and LCEI.

3 Clean Growth within local energy

The UK's 2017 Industrial Strategy identified four Grand Challenges that will transform the future into which substantial R&D funding will be invested:

1. Artificial Intelligence and data
2. Ageing society
3. Clean Growth
4. Future of mobility

The support offered by CGE and LCEI represents a significant contribution in meeting the UK's Grand Challenge of Clean Growth; the programmes outputs being environmentally and economically beneficial for local companies and LCR.

Clean Growth is defined by the Department of Business Energy and Industrial Strategy as the following:

'Growing our national income while cutting greenhouse gas emissions. Achieving Clean Growth, while ensuring an affordable energy supply for businesses and consumers, is at the heart of the UK's Industrial Strategy. It will increase our productivity, create good jobs, boost earning power for people right across the country, and help protect the climate and environment upon which we and future generations depend.'

The objectives identified for local energy in LCR Energy Strategy document are outlined as follows:

- improve productivity by decreasing energy costs to business
- create jobs from increased productivity, low carbon economy growth and inward investment
- create jobs from upskilling the workforce into new sectors of the low carbon economy
- embed efficient, smart and future-proof systems to create resilient cities
- decrease fuel poverty and household energy bills
- create community cohesion through local ownership of energy infrastructure
- reduce carbon emissions and other greenhouse gases
- improve air quality by reducing transport emissions
- measures to mitigate noxious emissions associated with decentralised energy
- improve resource efficiency by reducing use of water and materials and increasing reuse and recycling and local sourcing of materials
- a cleaner and greener environment.

Figure 3.1

Outputs of the CGE & LCEI Programmes to date

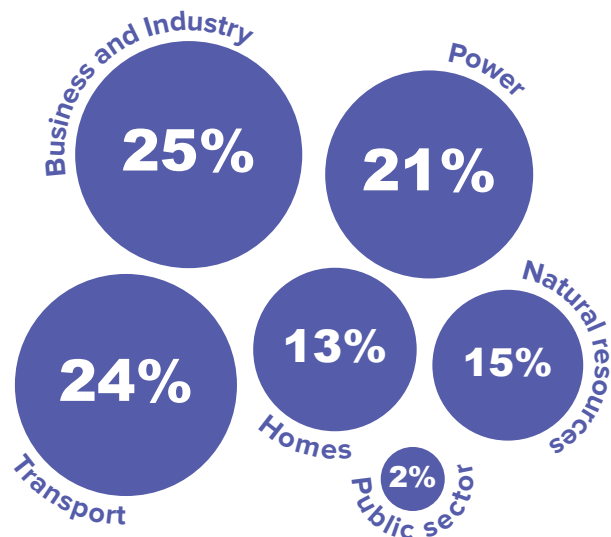


4 National and regional strategies for Clean Growth and sustainable energy

The UK played a key role in securing the 2015 Paris Agreement, a collaboration between 195 countries, equating to 90% of global economic activity. The Paris Agreement came into effect at the end of 2016 with the aim to limit global mean temperature rise to well below 2°C since pre-industrial and pursue a limit of 1.5°C (4). An additional target of the agreement, in order to achieve this aim, is for net global emissions to be zero in the second half of the 21st century. The UK government have legislated to tackle climate change, aiming for UK greenhouse gas emissions to be almost zero by 2050. This revised target is more ambitious than the UK’s previous aim to reduce greenhouse gas emissions by at least 80 % relative to 1990 levels, by 2050 (5). The agreed national targets will require a shift in attitude and a commitment to Clean Growth in policy and economic decisions.

Figure 4.1

2015 UK emissions by sector (5)



The Government's Clean Growth Strategy was published in October 2017 and outlined policies and proposals focussing on the energy sector and climate change with the aim to increase the pace of Clean Growth. The focal policies and proposals of this strategy are divided into the following subsections:

The focal policies and proposals of the UK Governments Clean Growth Strategy are divided into the following subsections:

- Accelerate Clean Growth
- Improve business and industry efficiency.
- Improving homes.
- Accelerating shift to low carbon transport.
- Deliver clean, smart, flexible power.
- Enhancing the benefits and value of natural resources.
- Leading in the public sector.
- Government leadership in driving Clean Growth.

The UK Government have been commended by the Climate Change Committee (CCC) for their commitment to achieving the climate targets outlined in the Clean Growth Strategy (6), in addition to recent legislation for net-zero GHG emissions by 2050. However, the CCC argue that immediate policies, targeting emission reductions across the economy, are required to achieve aspirations.

LCR is in an advantageous position to utilise Clean Growth as a key driver of its economy due to its coastal location and low carbon and energy business capabilities. As a result,

Clean Growth has been identified in Liverpool City Region Energy Strategy as an opportunity for creating prosperity and high value employment in the region. At present the low carbon sector contributes over £2 billion to LCR economy, employing over 22,000 people in 1,400 companies (2). In addition, LCR has been designated as a Centre for Offshore Renewable Engineering (CORE status) by the Government.

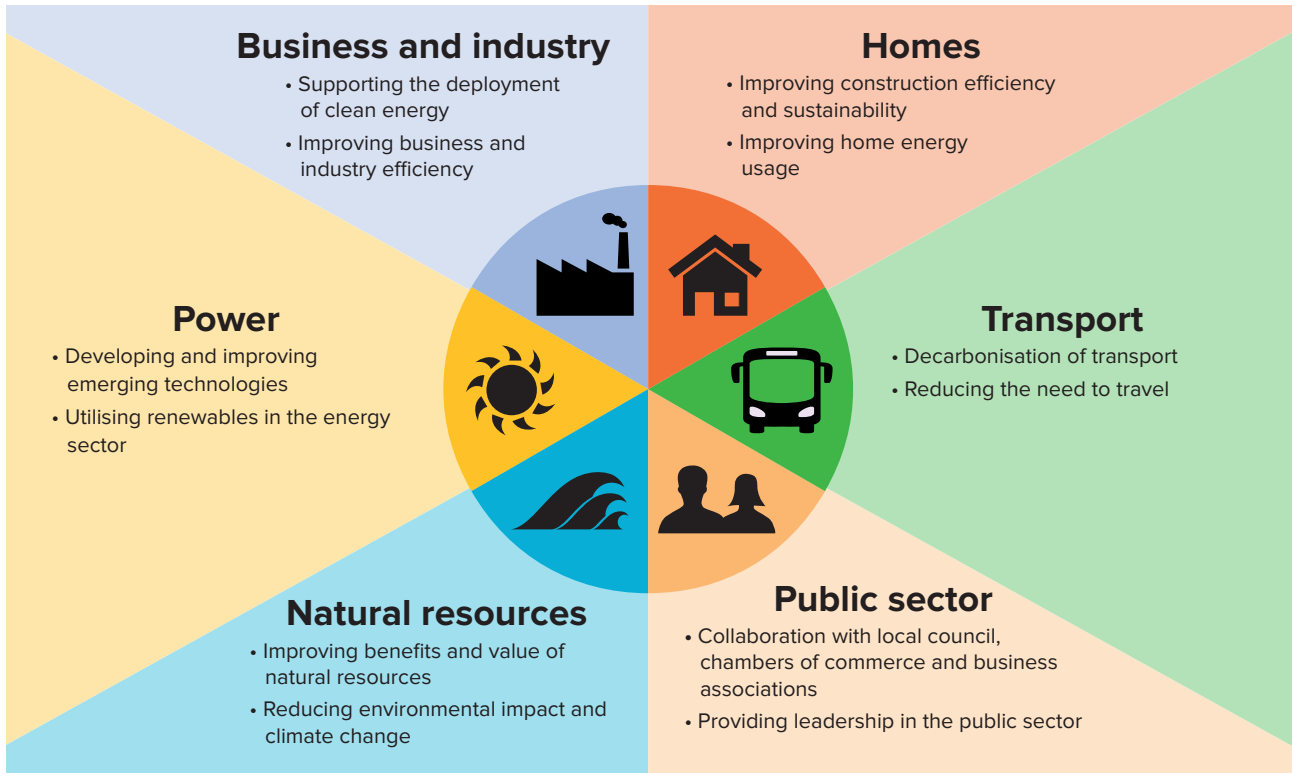
LCR Metro Mayor has stated his ambition for the region to be zero carbon by 2040. Initiatives such as the Sustainable Energy Action Plan (SEAP- 2012) and Low Carbon Action Plan (2011-2015) are helping LCR achieve this ambition to become a resilient low carbon economy with a sustainable and productive energy sector (7,8). The SEAP outlined the following baselines to inform decision making:

- LCR consumed over 37,000 GWh of energy in 2005.
- From this energy consumption a total of 11,500 kt CO₂ equivalent (CO₂e) was emitted.
- In 2009, 23% of households in LCR were in fuel poverty.
- Between 2005 and 2009 energy consumption in LCR decreased by 19 % whilst CO₂e reduced by 16 %.

Achieving economic growth whilst reducing CO₂ emissions is a major challenge as it requires CO₂ to be decoupled from economic growth. The work of the University of Liverpool CGE and LCEI programmes since 2012 has been helping to achieve this across the SME community, promoting Clean Growth through the reduction of CO₂ and energy generation, whilst creating jobs, and increasing GVA and skills.

Figure 4.2

Sectoral outputs of the CGE & LCEI programmes that contribute to Clean Growth in LCR



The following part of this section provides sectoral case studies demonstrating the overlap between the CGE and LCEI outputs and the primary foci of the UK's Clean Growth Strategy 2017. Each example provides a description of the company and details the outputs resulting from the partnership with the CGE or LCEI.

4.1 Business and industry

The UK manufacturing sector accounts for 11% of the national GVA but represents over 50% of business energy expenditure, which is largely associated with industrial processes (9). This significant contribution to business

expenditure from the manufacturing sector highlights the potential energy improvements that could be made by reducing usage. The following examples illustrate how the CGE and LCEI worked with SMEs to specifically address their high energy use through the promotion of energy use reduction and efficiency improvements.

- Weir and Carmichael Ltd.** designed a packaging product, “Britwrap”, to protect products in transit whilst significantly reducing packaging costs, waste, damaged returns and encouraging correct manual handling. A 3-year research intensive CGE PhD led to the development of a tool set to support the design of greener packaging products



and their supply chain. The reusable packaging saves over 7000 tonnes of CO₂ per annum through a reduction in single use cardboard that accounts for almost 1 tonne of CO₂ per tonne of cardboard produced.

- **Renephra Ltd.** has been developing ground-breaking new approaches to dialysis treatment in end-stage renal disease by better mimicking natural kidney function to improve quality of life and long-term prognosis. A 3-year research intensive CGE PhD project developed the technology for a novel device to revolutionise dialysis and reduce the environmental impact of one of the most energy and resource intensive treatments in the healthcare system. Haemodialysis, which is used to treat 95 % of kidney patients, has a heavy environmental impact. Water usage, for example, resulting from worldwide haemodialysis use is estimated at 156 billion litres annually. In contrast, the Renephra technology has minimal environmental impact as it requires no water consumption and is completely power-free as it uses no electricity.
- **NeedleSmart** develop technology that heats hypodermic needles into a molten state, compressing it into a ball. Over 3 million needle stick injuries occur globally each year and this technology has the potential to prevent this. The business aims to become a global supplier of sharp conversion by optimising energy usage and minimising the waste treatment needed to handle used hypodermic needles. Through contact with the LCEI team expertise was identified within the University of Liverpool and Liverpool John Moores University enabling the company to successfully apply for 2 KTPs funded by Innovate UK. The first developed

a simulation model representing the operation of NeedleSmart, refining the melting process to ensure consistent quality and safety. This was compared with experimental data, identifying optimal parameters needed to manufacture the product. Following the initial KTP a 6-month supervised LCEI student dissertation project examined the electrical and thermomechanical theory associated with the product.

- **Mersey Timber** manufactures and processes melamine chipboard, shelving and doors and sought to revise working practices to reduce waste. A 1-month LCEI internship produced detailed recommendations that the business could implement to minimise packaging waste. Recommendations included a cardboard shredder to reduce the frequency of skips, with the shredded material providing fill for packaging voids. Recycling services were suggested for materials such as plastic PET strapping and waste foam.

4.2 Homes

Domestic energy accounts for a third of the UK's national energy consumption, with 80 % of existing homes remaining in use in 2050 (10). Improving the energy efficiency of homes and promoting technologies, such as smart meters, will be beneficial for reducing household energy bills and demand and increasing economic growth. This could be achieved through the promotion of sustainable new buildings coupled with innovative techniques to minimise the price and carbon associated with construction. The following examples illustrate how the collaborative work undertaken by CGE and LCEI has helped SMEs in this sector develop innovative tools to improve energy efficiency, improve the efficiency and sustainability of construction and reduce energy usage.

4.2.1 Improving construction efficiency and sustainability

- **MgMaStudio Ltd** is a chartered architecture and design firm wishing to improve its sustainable design principles. A 1-month CGE internship produced an objective assessment of materials, strategies and technologies used in the design process in order to establish their sustainability credentials, and their usefulness in the design process. Proposals resulting from the internship included improvements to building thermal performance and promotion of sustainable transport by locating flats adjacent to the pavement. This assessment has helped MgMaStudio to promote sustainable design principles to their clients.
- **Dwelle Ltd.** designed and built a prototype sustainable, quick to construct, adaptable micro-building. A 3-year CGE PhD project developed a highly efficient and sustainable building process to upscale construction. Prefabricated elements and systems offer significant advantages in terms of construction time, safety, environmental impact, constructability, and cost. Consideration was given to the design of the buildings, the manufacturing processes used for the building materials and the building itself. This led to a highly modular, adaptable and flexible building design that didn't sacrifice environmental credentials or affordability. Dwelle received the British Homes Award in 2013 for Britain's Future Home, in addition to awards from the Manchester Society of Architects for both design and sustainability in 2014.



- An ongoing LCEI PhD project working alongside **Urban Splash** is focussing on the development of a model for zero carbon prefabricated housing respectively. Urban Splash plans to become a carbon neutral business in a cost-effective manner, creating buildings that have no net environmental impact. The project has been designed to assess the impact of their hoUSe development in order to inform future decision making on all new developments. The PhD project is assessing the full environmental impact of this development, producing a useable model, process and approach.
- Furlong Innovations is an engineering company specialising in a valve system designed for domestic combi-boilers. Its product allows for quicker and more efficient use of the heated water, whilst reducing the waste of colder water. A 1-month CGE internship undertook market research to identify international markets, suppliers and customers for the business.
- **Inclusive Designs Ltd.** is a company aiming to reduce the environmental impact of current cooling systems through a form of heat trapping that reduces the energy used in the cooling process. A 1-month LCEI internship provided proof of concept for a new solid-state cooling device, allowing the business to refine their design process.

4.2.2 Improving home energy performance

- **Radwraps Ltd** specialises in the production of environmentally friendly radiator covers. A 1-month LCEI internship completed laboratory-based testing to quantify the energy efficiency of Radwrap products in order to help the business expand into new markets. The laboratory-based testing concluded that Radwrap products, compared with wooden radiator coverings, save between 1.85 and 3 kWh daily. As a result, Radwraps products have saved between 660 and 1000 tonnes CO₂e since 2016. The carbon emissions tests completed as part of the LCEI internship has led to the development of a new product, with the first prototype made. The LCEI programme has provided Radwraps with access to top class facilities and professionals, giving them a great advantage and platform from which to work to realise their Low Carbon potentials. As a result of the LCEI programme, Radwraps now have more opportunity to create world leading products and technology which will strive to cut carbon emissions.
- **Inteb Sustainability Ltd.** provides integrated energy and sustainability services and solutions, such as energy and carbon management, to a wide range of real estate clients in both public and private sectors. A CGE PhD project developed an easy-to-use, low cost app-based solution for remotely monitoring and controlling on-site usage of energy and water in domestic and commercial buildings, including multi-tenanted properties.

4.3 Transport

The transport sector is one of the largest sector consumers of energy, accounting for 40 % of the total UK energy consumption in 2017 (11). In 2005, this sector represented 23 % of total energy consumed and 24 % of carbon emitted in LCR (7). Cars are the primary mode of transport in urban areas throughout the UK, accounting for over 60 % of commuting travel in Merseyside in 2011 (12). The UK Government aim to end the sale of conventional petrol and diesel vehicles by 2040, with zero emission

vehicles being used almost exclusively by 2050 (13). The following examples illustrate how the research assistance provided by the CGE/LCEI helped SMEs develop new technologies to decarbonise transportation and promote changes in travel behaviours.

4.3.1 Decarbonisation of transport

- **ACAL Energy Ltd** was a clean power company aiming to create a new generation of cheaper, longer-lasting hydrogen fuel cells. Fuel cells promise a clean and efficient way to produce electricity for industrial, domestic and transport applications. However, their uptake was limited by issues of cost and durability. ACAL Energy's FlowCath[®] system eliminated 80% of the platinum from conventional Proton Exchange Membrane (PEM) fuel cells and sidesteps the significant degradation processes, but further development
- **Ionotec Ltd.** manufactures ion-conductive ceramics in addition to developing rechargeable sodium batteries for energy storage based on beta alumina solid electrolytes. Motive power without fossil fuel consumption depends critically on the availability of batteries that meet modern needs regarding vehicle range, power, life and cost. All present battery chemistries fall short in most of these characteristics. The sodium metal-chloride battery is a promising candidate; however, the energy available is limited by various design features and by the characteristics

was needed to meet the efficiency and size requirements of a car. A CGE PhD project provided a detailed study of the core of the FlowCath[®] system (the chemical and electrochemical interactions between catholyte and cathode) leading to an improved understanding and development of new materials.



of the cathode. A CGE PhD project used high-temperature electrochemical measurements to understand the electro-kinetics of the cathode, with prototype cells constructed to demonstrate if an improved understanding of the core chemistry can be translated into enhanced cell performance.

- **Franklin Energy** is an automotive company specialising in electric vehicle charging for domestic and business environments. A 1-month LCEI internship produced a social media campaign to determine the market for electric vehicles. The report recommended data capture at events to gain subscribers to the mailing list, investing in promoted tweets on Twitter to reach a greater audience and partnering with other companies in the industry to create a deeper market presence.
- An ongoing LCEI PhD project is investigating the optimum pathways from waste to fuel cells for **Mersey Fair Air**. The company is working in the transport sector, developing low carbon fuels and retrofitting existing vehicles with the Cygnus Atratus multi-fuel Alkaline Fuel Cell, which is currently capable of running on hydrogen, ethanol or ammonia. This PhD project aims to develop a conversion process enabling existing vehicles to run on alkaline fuel cell technology supplied by their partner: Cygnus Atratus Enterprises Limited (CAE). CAE lay claim that they have created a micro waste to energy system which will generate the required fuel for their fuel cells from waste. This project will critically analyse the system, compare against the competitors and ensure that the optimum systems can be selected for installation in Liverpool to ensure the success of Mersey Fair Air. It will investigate the



existing technologies used to produce green hydrogen and other fuels identified by the fuel cell supplier such as ethanol, methanol and ammonia. The project is also investigating technologies and equipment that can be used to generate fuels from waste, in particular agricultural, industrial and food waste streams such as anaerobic digestion, gasification and fermentation, at the point of source.

- **CAL International** is an engineering design consultancy working in a number of sectors including the holistic transport sector to develop new low and zero carbon fuelling solutions. A 3-year research intensive LCEI PhD project working alongside CAL International is aiming to develop in situ low or zero-carbon fuel delivery, in the exact amount required by the user, by means of small-scale modular devices. Internal combustion engines already have a level of ability to operate using low or zero-carbon fluid fuels, however, very few of these types of machines have advanced beyond working concepts due to complexities relating to on-board fuel storage which are yet to be overcome for the mass consumer. The outcome of this LCEI PhD project may potentially revolutionise the way we supply fuels to any form of combustion engine. The project began with a focus on creating a marketable device but as the research has developed it has become apparent that this is not just a device but part of an end to end solution with the potential to remove carbon emissions from all forms of transport and combustion in line or close to the governments long-term strategic targets. This has enabled CAL International to begin to integrate with the government associated bodies such as the Department for Transport, UKRI and the Catapults, that are setting these long-term strategies and the frameworks to deliver them.

4.3.2 Reducing the need to travel

- **Mamaer Digital Ltd** are aiming to develop an app-based system that would allow consumers to combine their journeys with others to increase efficiency, reduce vehicle use and mileage. A 1-month LCEI internship determined the carbon impact of the business and produced marketing materials that could be used by the company to seek investment and support.

4.4 Power

The following examples illustrate how the collaborative work undertaken by CGE and LCEI has assisted with the development of new low carbon technologies for the energy sector. Further examples of the research support the programmes provided for emerging technologies in the transport decarbonisation sector are listed in section 4.3.1.

- Eco Environments Ltd., now known as Extreme Low Energy (ELe), have manufactured and implemented a 100 % off-grid photovoltaic (PV) 'cabin' that is powered using a battery that connects the power sources on the exterior of the cabin to electrical components without the need for energy transformation to AC. A 3-month supervised LCEI project investigated the feasibility of using the Eco Environments cabin to provide off-grid energy supply to communities in Africa. ELe won the 2017 Energy Institute Innovation Award for its Low Energy Computing project, whereby low-energy PCs were installed at two Liverpool schools to reduce energy consumption. ELe's DC micro-grid systems run on approximately 70% less energy than existing technologies, equating to significant energy savings for the schools.



4.5 Natural resources

In 2015, the Office for National Statistics valued the UK's natural environment at £761 billion (10). Renewable energy is generated from natural sources and contributed 9 times as much energy in 2015 to the UK than that produced in 1997 (10). LCR specialises in offshore wind and has been awarded national status as a Centre for Offshore Renewable Engineering (CORE). The offshore wind turbines situated in Liverpool Bay (Burbo Bank and Burbo Bank Extension) are some of the largest in the world, producing enough electricity to power over 300,000 UK homes annually. The following examples illustrate how the CGE/LCEI worked alongside SMEs to utilise natural resources and mitigate climate change.

4.5.1 Utilising natural resources

- **Genco Ltd** is a plasma process and control specialist. Its process control system, Speedflo, is an integral component in the manufacture of a variety of technology applications worldwide. The company realised that wind turbines require a reliable and efficient pitch angle controller to regulate power output and to damp structure flexing due to the use

of lighter construction materials, and its existing technology could be developed as an effective control system in this situation. Genco Ltd. initiated and led a CGE PhD project to design a novel pitch angle controller for wind turbines based on the company's Speedflo plasma controller, maximising energy conversion efficiency while minimising the mechanical load of the drive train. A more economic and efficient wind turbine generation system, including monitoring and control equipment, was installed and tested. Experiment results found advantages and advancement in generating efficiency for the developed controller compared with the turbine's original control system.

- **The Centre for Marine and Coastal Studies Ltd.** provides ecological and environmental services such as surveys and Environmental Impact Assessments. A CGE PhD project aimed to aid the development of approaches that holistically assess the sustainability of small-scale fisheries. Extensive analysis of literature and assessment frameworks led to the development of approaches that robustly assess the sustainability of the ecological, social and economic dimensions of small-scale fisheries.



Utilisation of the tools developed as part of this PhD will promote improvements in fisheries sustainability.

- In 2012 **Landlife** was a pioneer of creation conservation, with Landlife's Soil Inversion technology providing a novel forestry and landscape-scale habitat creation technique that inverted a metre of soil to expose the subsoil, bury weeds and retain moisture at depth. Initial research demonstrated faster tree growth, greater survival rates, better adaptation to climate change impacts, and reduced herbicide usage. A 3-year CGE PhD project with this business fully explored important elements of soil fertility and carbon capture to evaluate the implications of landscape work using Landlife's soil inversion technique. Landlife stated that the outputs were highly significant for biodiversity gains and delivering more resilient landscapes in the face of climate change impacts and would have been unobtainable without the expertise and resources available through the CGE.
- **Merseyside Environmental Trust** help to protect and conserve the environment and promote wider sustainability issues in Merseyside. A 6-month supervised LCEI project completed alongside Merseyside Environmental Trust identified the environmental and societal benefits of street trees, such as improved air quality and increased sequestration of carbon dioxide.

4.5.2 Reducing environmental impact and mitigating climate change

- **Marlan Maritime Technologies** provides solutions for vessel traffic monitoring and management in ports & harbours and along coasts, to help ports and vessel operators reduce CO2 emissions by increasing operational efficiency. A CGE

PhD project completed with the company developed and applied novel algorithms using radar techniques for hydrographic monitoring. Changing coastal morphology arising from climate change, storms, sedimentation and hydrodynamics affect port operations and the ability to manage coastal resources in a sustainable way. The product produced as part of this PhD has allowed the business to provide the services to ensure that vessel traffic and maintenance operations are safe and resource efficient. Marlan was awarded the Merseyside Innovation Award in 2017 and Mersey Maritime Innovation Award in 2018 as a result of the CGE PhD project completed with them.

- Following the success of the CGE PhD project, an ongoing 3-year research intensive LCEI PhD project at **Marlan Maritime Technologies Ltd.** is developing a new mapping tool for beach morphology based on digital elevation models from still camera image analysis. The key research challenge here is to complement Marlan's radar-based products for monitoring coastal change in the intertidal zone and below the water line. The research will examine the use of still photographs and light reflectance to produce digital elevation models of beaches and maps of their evolving grain size. The technique is based on current 'structure-from-motion' methodologies that are being developed for monitoring environmental processes and geomorphology from new data platforms. A key problem for the sustainable management of coastal resources and the protection of coastal infrastructure from erosion and flooding is appropriate time intervention that reduces the emergency use of concrete and steel interventions.
- An ongoing 3-year research intensive

LCEI PhD project collaborating with **MM Sensors** is aiming to develop a sensor for monitoring tidal levels in order to improve the accuracy of radar-based mapping of intertidal environments therefore providing a strategic coastal management service. The acquisition of tidal level data for ground-truthing coastal surveys will ensure coastal resilience and safe port navigation. The key research challenge will be to effectively complement radar-based technologies for monitoring coastal change in the intertidal zone and below the water line. The acquisition of radar-based coastal survey data requires local data on tidal levels to ensure high accuracy monitoring of coastal morphology and coastal morphological change over timescales from days to years. Through this data coupling, beaches and tidal flats can be characterised in terms of their instantaneous and long-term behaviours.

- A LCEI PhD project currently being completed alongside **Coastal Engineering** is aiming to develop and optimise storm survey technologies to better understand coastal response to extreme events. This will contribute to the company's aim to develop and implement sediment-based solutions to coastal erosion and flood risk. This project is investigating and developing an effective method for sensor deployment, including cross-shore arrays of buried pressure transducers and remote measurements to characterise shallow water wave modification, breaking, run-up and overwashing/ overtopping during storms, in order to quantify consequential changes in beach morphology. The objective is to develop and optimise storm survey technologies to better understand coastal response to extreme events, enabling a move away from CO₂-intensive sea defences.

4.6 Public sector

The CGE and LCEI have demonstrated proactive leadership in the low carbon sector through the promotion of Clean Growth in a variety of sectors. Close collaboration with LCR Local Enterprise Partnership and the respective councils, chambers of commerce and business associations has helped to achieve this. For example, Liverpool City Council used CGE PhD case studies as exemplars for xxx commission in 2014.

"I am committed to making Liverpool a cleaner, greener city. Bringing together our world class academic institutions alongside businesses in the city, projects like the Low Carbon Eco-Innovatory really help place Liverpool at the forefront of moving towards that vision of a low carbon economy. "

Mayor Anderson OBE, Mayor of Liverpool

Conclusion

This report illustrates the low carbon development that has resulted from the collaboration between the University of Liverpool and Liverpool John Moores University CGE/LCEI teams and local SMEs in LCR. Case studies highlight the new and improved low carbon products and services that have resulted from direct access to University research expertise and facilities and the resulting economic and environmental benefits for local businesses and the wider community. In addition, the report demonstrates the contribution of the programmes' outputs to achieving the UK's 2017 Clean Growth Strategy. The programmes are focussed on determining solutions to challenges, resulting in collaboration with, in addition to economic and environmental benefits for, SMEs from a wide range of sectors.

The CGE programme has created over 300 jobs and increasing gross GVA by £45 million in LCR and the North West, with similar benefits expected for LCR from the ongoing LCEI programme. The collaborate approach adopted by the CGE and LCEI has been influential in successfully promoting clean and sustainable energy in LCR. Partnering HEIs with SMEs has provided local businesses with access to the expertise, skills and facilities need to aid development of low carbon technologies, products and services. The CGE won multiple awards for its successful commercial initiative, knowledge exchange and research impact whilst the Merseyside Innovation award has been won by Marlan Maritime Technologies Ltd. and 5D Health Protection Group, SMEs working in partnership with the University of Liverpool LCEI team.

End notes

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