Demand Management: Photovoltaics, Electric Vehicles and the Strive for Decarbonisation

Ken Dale Travel Bursary

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Executive Summary

This report documents research funded by the CIBSE Ken Dale Travel Bursary during August and September 2018.

From 2010 to 2016, emissions from the UK's energy sector reduced by 42%. Our electrical grid is decarbonising and the rate of adoption of low and zero carbon technologies such as photovoltaics (PVs) and electric vehicles (EVs) is on the rise. Demand management, the act of predicting and adapting to fluctuations in electrical load, is becoming a focus due to the changing trends in which electricity is generated, stored and used.

I travelled to Zambia, South Africa, California (USA) and Wales (UK) to investigate PVs, EVs and demand management in different development contexts. From Zambia, which could be described as 'developing' and California, which is in some ways 'hyper-developed', I explored the challenges and opportunities brought by these technologies.

In Zambia, I visited rural areas of Monze to see the impact that off-grid PV has had on their development. In South Africa, I visited the Smart Grid Centre at KwaZulu-Natal university to learn about the country's current direction on renewables. In California, I visited Honda Smart Home US to learn about how PVs and EVs can work together with buildings for a low carbon lifestyle. I learnt about the use of demand response in California and while in San Francisco, I attended affiliate events of the Global Climate Action Summit to get an appreciation of policy, collaboration and their role in sustainable development. I also visited San Diego, to find out about past and current initiatives concerning PVs and EVs, and the related challenges and successes. Back in the UK, I visited the Active Classroom and Active Office, Swansea University, to see how it is possible for buildings to connect in a network and generate, store and release their own energy to power both building services and EVs.

The growth of PVs and EVs offersthe potential ofr energy security and affordability without compromising the environment. Decentralised energy itself is a contributor to resilience and social and economic development. Energy storage in the form of batteries or thermal stores, is a convenient way of managing the differences in supply and demand in remote applications. Whereas demand side response, a practice where users adapt their energy use during certain scenarios, can help balance supply and demand in more densely populated areas. It could be particularly successful if users have access to battery storage and can respond by sending back electricity from either their car or home.

However, the opportunities presented are not without their challenges. For example, the benefits of a demand side response approach must not be outweighed by the risk of cyberattacks to energy security. Advancement in building controls are needed and in addition, cross-sector collaboration is imperative to any successful and achievable decarbonisation policy e.g. transport and housing collaboration.

The UK buildings services' industry can use the challenges and opportunities found in this report to further drive sustainable development and manage an increasingly decarbonising grid.

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The Ken Dale Travel Bursary

This report has been facilitated by the CIBSE Ken Dale Travel Bursary. The bursary is targeted at CIBSE members in the development stages of their careers. It allows them to spend up to four weeks travelling the world to research a topic currently relevant to the industry, of benefit to CIBSE, to their employer and their clients. The bursary was established by CIBSE to commemorate Ken Dale's contribution to the institution and the profession.

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Introduction

One of CIBSE's current research priorities is 'systems thinking and integration'. This report hopes to address this by discussing how the growth of two low and zero carbon (LZC) technologies: photovoltaics (PVs) and electric vehicles (EVs) are affecting building services, and how these systems can collaborate to further drive decarbonisation.

The increased adoption of PVs and EVs is changing the nature by which we generate, store and use electricity. This presents a new challenge in the form of demand management i.e. the ability to predict and adapt to fluctuations in electrical load.

This report aims to investigate demand management in different geographic and development contexts and to investigate the challenges and opportunities presented by PVs and EVs and how they might contribute to sustainable development.

These aims were achieved by research trips to Zambia, South Africa, the USA (California) and the UK (Swansea) during summer 2018. The varying development contexts range from Zambia, which could be described as a 'developing' country, to California, which could be described as 'hyper-developed'.

In terms of *sustainable* development, it has been recognised that the most significant challenge is climate change (Kyte & Forum, 2018; World Bank, 2016). The Paris Agreement, which came into force in November 2016, united 184 global parties to reduce the rate at which global temperatures are rising to well below 2^{o}C above pre-industrial levels in order to tackle climate change. This unified approach encompasses the strive for 'clean and affordable energy', which is one of the United Nations' Sustainable Development Goals (SDGs). The building services' industry has a role to play in the delivery of clean and affordable energy and is therefore, amongst in other ways, a key contributor to sustainable development.

In the UK for example, direct emissions from buildings were responsible for 19% of the total carbon emissions in 2016, and indirect carbon emissions from buildings were responsible for 66% of the total electricity consumption (Committee on Climate Change, 2017). The electricity grid is currently decarbonising to contribute to a nationwide target of an 80% reduction in greenhouse gas emissions by 2050, as described in the Climate Change Act (HM Government, 2008).

There are many definitions of the term development and one of the most commonly accepted definitions of *sustainable* development is from the Brundtland report: development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). This report will consider development as largely positive charge in the context of the Brundtland report definition.

The definition of energy sustainability is threefold: energy security, energy equity and environmental sustainability (World Energy Council, 2018). Put more simply: high security, low cost and low carbon. This report will discuss some of the challenges in trying to achieve all three aims.

Case Study 1: Monze, Zambia

Zambia is a landlocked country in Southern Africa. It shares its borders with Malawi, Tanzania, the Democratic Republic of the Congo, Mozambique, Zimbabwe, Botswana, Namibia and Angola. The population of Zambia is nearly 17 million (World Bank, 2016).

In 2016, 43% of the population of Sub-Saharan Africa (SSA) were without access to electricity (@oxfamamerica, 2017; World Bank, 2016) and the International Energy Agency (IEA) estimates that Africa's total demand for electricity will increase at an average of 4% a year until 2040. One of the United Nations (UN) Sustainable Development Goals (SDGs) is "universal access to affordable, reliable and modern energy services by 2030". The UN recognises access to electricity as intrinsic to development, not just at local but at global scale.

Figure 1 Map of Zambia, Africa

The electrical grid in Zambia is managed by ZESCO (Zambia Electricity Supply Corporation Ltd.), a state-owned company. 94% of its energy is generated by hydropower (McPherson, Ismail, Hoornweg, & Metcalfe, 2018), which in the face of ongoing climate change experiences low water levels and lower generation rates (Board, 2015). For example, in April 2016 the Lake Kariba Dam fell to a quarter of its capacity due to low water levels (Onishi, 2016). This is a particular concern as the Dam generates 40% of Zambia's electricity demand (Onishi, 2016).

At the same time as the country's power output being reduced by the results of climate change, economic growth and urbanisation are rising and the demand for electricity is growing (Agency, 2014). Zambia is subject to frequent, countrywide load shedding: ZESCO temporarily disconnecting clients from the grid to manage demand. This is something which I experienced first-hand during my trip.

There is potential for PVs to offer a reliable alternative to grid electricity and, with a suitable infrastructure, to improve grid power quality through export. However, there remains a large challenge in rural electrification rates and in rural Zambia in 2015 only 4.4% of the population had access to grid electricity (Central Statistical Office, Zambia).

I visited two rural schools in Monze district (see Figure 1) during my trip to Zambia in August 2018. The schools were Kampunu Community School and Mwiinga Malimvwa, both built with the help of charity Friends of Monze, Wales. I was interested in the installation of PVs and what opportunities and challenges this brought to the communities.

Kampunu Community School

Figure 2 Kampunu Community School, Monze District, Zambia

Kampunu Community School opened in January 2017. It teaches approximately 160 pupils and comprises three classrooms within one building. The school is in a remote setting with no buildings in close proximity. At the front of the school there is a permaculture garden and several domestic animals roam in the grounds.

The school benefits from a 2 x 320 W PV installation, arranged by Giakonda IT, a Welsh charity working in collaboration with Friends of Monze. 2 x 12 V 220 Ah batteries store power for laptops, a wireless router and lighting.

The installation includes a charge controller, which provides visual feedback to the users of when the system is at risk of overload and prevents the battery going beyond the recommended depth of discharge (limit of discharge beyond which the battery life is compromised), therefore prolonging the life of the battery.

Mwiinga Malimvwa School

Mwiinga Malimvwa school opened in 2018 and serves 358 pupils, excluding adult learners. Similar to Kampunu Community school it was also built with the help of Friends of Monze and is a standard, 1x3 classroom block. Prior to the construction of this building, classes were being taught in an insufficient, small brick structure that was largely open to the elements.

Figure 3 Mwiinga Malimvwa School

Despite their PV system only being recently installed on 21st June 2018, a couple of months before my visit, the school has seen a number of benefits and the staff and members of the community that I spoke to were clearly overjoyed with the new equipment.

The 2 x 320 W PV system generates energy during the day and like Kampunu school stores it in 2 x 12 V batteries. The energy is used to power lighting for studies, to power laptops and a projector.

The lead-acid batteries used for storage are easy to come across in the developing world. They are readily available from those in the vehicle industry, relatively cheap and easy to maintain.

When asked about the benefits the PV installation had brought the school, the headteacher and IT teacher commented that the installation had enabled them to have Wi-Fi, which has gathered the attention of the wider community as much as the school's staff and pupils; due to the school's location in such a rural setting, people come from far and wide to use the Wi-Fi. Phone charging has also been an attractive new benefit of the PV installation and the school has come up with an initiative to charge the community 1 kwacha each to charge their phones, with the profit going into a maintenance fund for the PVs.

The PV installation has facilitated artificial lighting and recently the school has been able to offer evening classes (taught 15:30-17:00) for grade 7s as examination preparation. It has also been able to provide adult learning in the afternoons, after the children have had their lessons.

Computer classes are part of the curriculum in Zambia though not every school has access to them. The PV installation has meant that Mwiinga Malimvwa can provide pupils with the resources they need to participate in the whole curriculum. The learning materials donated by Giakonda IT e.g. 'raspberry pi's have also been beneficial, the IT teacher commented. The fact that the school have an IT teacher is a benefit in itself that the PV installation has brought about, as this is also rare in Monze district.

The introduction of a projector at the school means that they are able to have community cinema nights, bring the local communities together and create a better relationship with the school and the wider community.

When asked about the challenges of the PV system, the staff commented that it is dark in the office without artificial light. This is more a product of the buildings' design than a complication of the PV system. Electrical challenges faced were that the invertor was overheating when the projector was plugged in, and this cuts the power. Fortunately, the fuses in the circuit protected the equipment from being damaged. On further inspection, the converted car charger being used as an invertor was not of the correct specification to be used for the amount of power required by the projector.

For the development context, off-grid PV systems like those at the schools can provide an access to education and important resources and be used to generate income to further economic sustainability.

The UN's SDGs target universal access to electricity by 2030. This is a particular challenge for those in sparsely populated, rural areas where grid electricity isn't available. These stand-alone systems provide power to remote buildings, where there is otherwise no grid connection.

However, while suitable for providing low-emissions lighting and other low power applications to rural applications, PV alone cannot meet the full energy requirements of small and micro-enterprises, which range from 100 to 1,000 times higher than lighting alone (Karekezi & Kithyoma, 2002). For example, agro-processing is one of the most attractive options for generating income in rural communities in SSA and has high power requirements. Off-grid PV therefore provides limited potential for economic development.

With a combined solution of grid, micro-grid and stand-alone solutions it is thought that 100% access to electricity in Zambia by 2030 is achievable (United Nations).

Having witnessed the potential of off-grid PV in rural Zambia to increase access to clean energy and contribute to sustainable development, I travelled to South Africa, where demand management issues exist despite a mature national grid.

Case Study 2: Durban, South Africa

Located a two-hour flight away from Zambia, South Africa is significantly more developed than its neighbouring countries in SSA. Its rural electrification rate, for example, is 77% compared to an average of 17% for SSA (Carbon Trust & CSIR, 2017). Its comparably high energy demand means both challenges and opportunities for the integration of PVs and demand management.

Figure 4 Map of Durban, South Africa

95% of the 45 GW generating capacity in South Africa is generated by Eskom, a state-owned company (Carbon Trust & CSIR, 2017). A country rich in coal, currently only 9% of South Africa's energy mix is renewable energy and 86% comes from coal (IMF, 2011). The country's renewable energy sector has been stagnating due to policy delays failing to bring in investment, and in recent years there have been new coal-fired power plants built. However, the latest Integrated Resource Plan (IRP) draft for 2018 suggests that is set to change as it includes a decommissioning plan for older coal-fired power plants up to 2050.

Like Zambia, South Africa suffers load shedding to manage demand on the grid, though at a less frequent rate. This is attributed to the number of high maintenance, old coal-fired power plant stock (Climatescope, 2017). The latest IRP forecasts less generation from coal-fired power plants and more renewables. Despite this, it includes annual build limits of 1,000 MW for PV and 1,600 MW for wind energy until 2050 in order to manage the change in demand. In addition, 1,000 MW of coal generated power will be added in 2023-24 from projects already commissioned. The Department of Energy hopes this will protect socio-economic growth, and the communities rich in relevant skills, in a climate were coal-fired power plants are otherwise slowly being decommissioned. Along with renewables and coal, 2,500 MW of hydropower was announced to be added in 2030.

South Africa experiences challenges in managing its electricity demand. The national grid in South Africa is congested and Eskom are currently preventing potential generators and consumers from connecting to the grid (Carbon Trust & CSIR, 2017).

Starting this year, the IRP assumes an annual allocation of 200 MW of "generation-for-own-use" i.e. on-site generation between 1-10 MW, may or may not be connected to the grid. This could work to decarbonise the electricity industry and support clean and affordable energy for all.

University of Kwazulu-Natal, Durban

I visited Durban, South Africa during August 2018 with a view of understanding more about the challenges and opportunities with the growth of PV and demand management. I visited KwaZulu-Natal University's Smart Grid Centre, Westville Campus.

The university is home to a high voltage direct current (HVDC) test facility and conducts research in collaboration with Eskom. Though I planned to meet with representatives from Eskom, unfortunately they weren't available at the time I visited so my findings from the trip were different to expected. Electricity generated in Mozambique by hydropower is transmitted into South Africa by HVDC power lines, and both South Africa and Mozambique manage the equipment in their respective countries.

In addition to the test facilities, I spoke to Prinavin Perumal, an MSc student undertaking research to investigate the battery performance of buried batteries in a PV system. Vandalism and/or theft can both affect the growth and effectiveness of renewables, particularly in lesser developed countries.

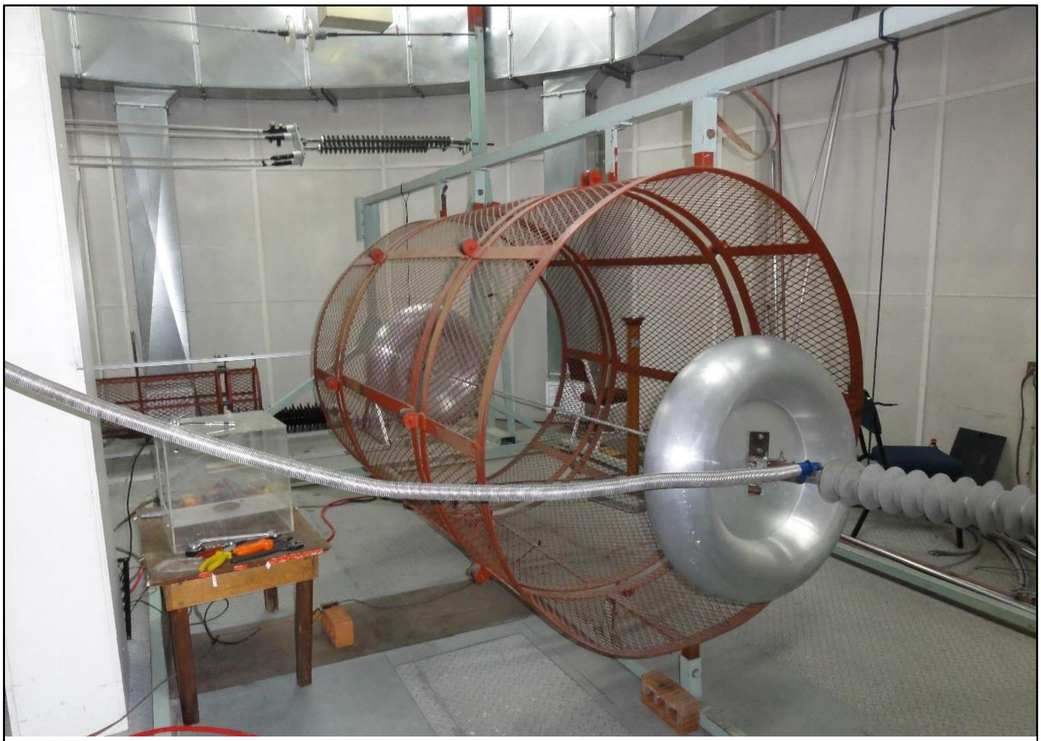

Figure 5 HVDC Test Rig, University of KwaZulu-Natal

This project will investigate these potential benefits as well as any changes in efficiency from protecting the battery from high air temperatures.

I held a discussion with staff at the university regarding South Africa's strategy for managing electricity demand. The staff informed me that rather than a surge in renewables, there is investment in coal-fired power plants. Medupi and Kusile power plants are due to be completed this year, adding an additional 9,564 MW generation capacity. This strategy threatens to compromise the emissions limit South Africa should be targeting since its signing of the Paris Agreement. However, recent changes announced this year show a move away from coal and support for an increase in renewables.

While South Africa had just begun to realise the potential for low and zero carbon technologies in its government policy, the next place I visited, California, was well practiced in policies that put low emissions first.

Case Study 3: California, United States of America

California, on the west coast of the United States, is often perceived as a world leader in sustainability issues and renewable energy. The state has already reduced its carbon emissions to the 1990 level so to challenge itself further, the California Global Warming Solutions Act was amended to target a reduction in greenhouse gas emissions by 40% from the 1990 level by 2030.

In 2017, 29% of California's electricity came from renewables (California Energy Commission, 2018), which included 10% from PVs. EVs in California are common, and sales in the state account for around 50% of those in the whole of the united states (EVAdoption, 2018).

During my visit in September 2018, the state passed a law to generate 100% carbon-free electricity 2045.

University of California, Davis

I travelled to Honda Smart Home US at University of California, Davis, 15 miles west of Sacramento.

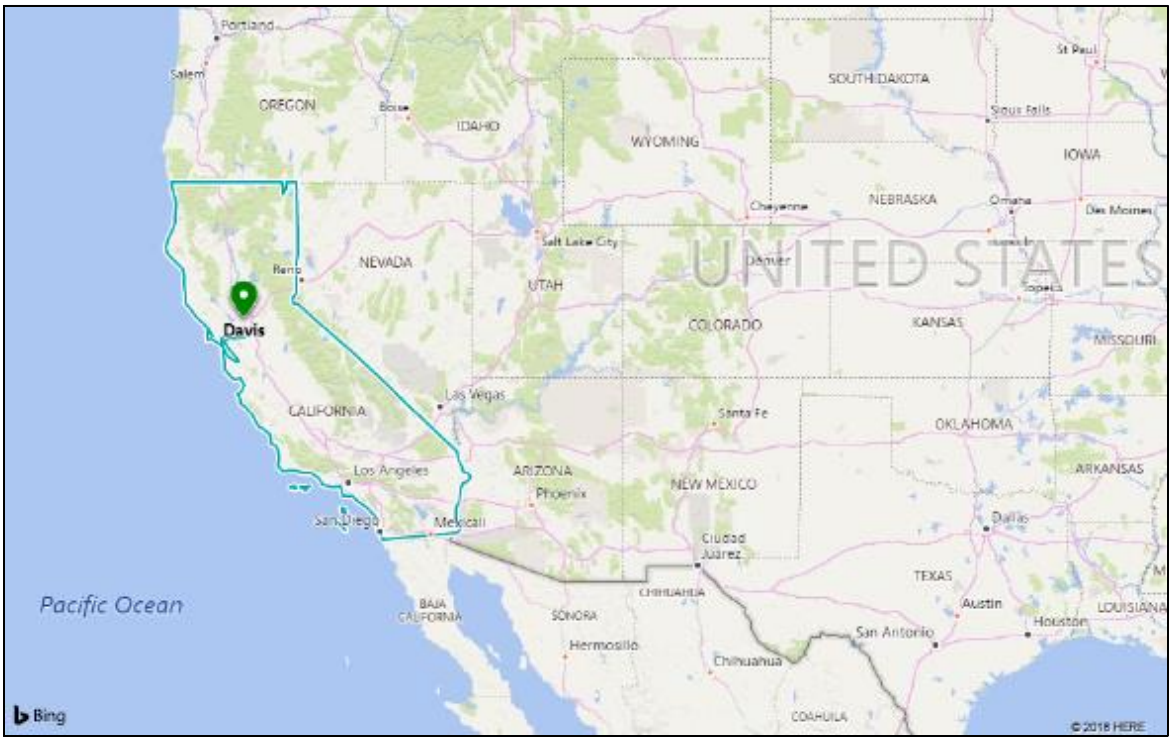

Figure 6 Map of Davis, California

The Honda Smart Home is a sustainably designed house that can produce more electricity than it uses. The home charges an electric Honda Fit (Honda Jazz, as it is known in the UK) by PVs, battery storage or grid electricity as chosen by the Home Energy Management System (HEMS), a hardware system programmed to make the lowest carbon choice. The home incorporates various low and zero carbon technologies including a ground source heat pump (GSHP) for heating and cooling, which provides underfloor space cooling and uses the rejected heat for domestic hot water.

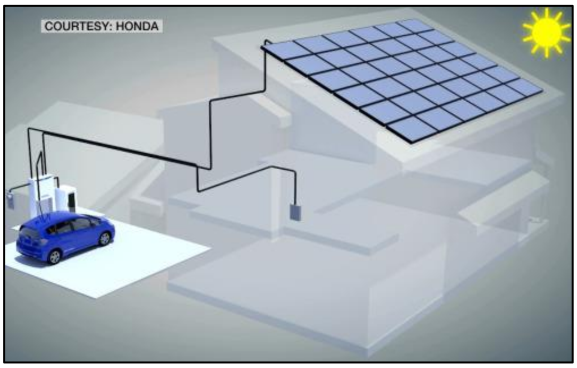

Figure 7 Honda Smart Home US

Figure 8 Car Charging Configuration, Honda Smart Home

The home was completed, commissioned and had its first residents move in in 2014, and has been recording data since March 2015. This energy consumption and efficiency data is published on their website[1].

The HEMS controls the home's microgrid, which includes a 10 kWh lithium-ion (Li-ion) battery (the same type as in the Honda Fit) used to the store electricity generated by PVs. If unable to charge directly from the PVs, the car can charge by battery when it arrives 'home' at the end of the work day: a peak time of demand on the grid. If the battery is insufficiently charged from the PVs, the HEMS predicts the times when the grid will likely be at lowest carbon intensity and will automatically charge it during those times.

The Honda Fit is capable of bidirectional charging, vehicle-to-grid (V2G), and can be used as storage for times of demand fluctuation. The HEMS contributes to balancing the grid's supply and demand by responding to demand side response (DSR) events, or demand response (DR) events, as they are called in the US, via OhmConnect.

A DSR event is when a message is sent from the grid to users, telling them to limit their electricity consumption or increase it. Users are often given financial incentives to change their demand accordingly. In California, demand response events are often issued on a hot summer's day when cooling demand is at its peak. In the unique case of the Honda Smart Home, it has been configured to send electricity from on-site storage back to the grid at times of peak demand.

DSR is a way of managing the grid that relies on behavioural changes rather than grid reinforcement. It lowers the cost of an expanding grid and is therefore a preferred method of managing demand.

[1] http://www.hondasmarthome.com/

Figure 9 HEMS system in the garage with Honda Fit EV

As mentioned previously, the HEMS predicts the carbon intensity of the grid and therefore selects the best time for the vehicle to charge, if it is charging from mains power. The stationary battery is charged during the day from the PVs. Once the car is plugged in it is considered 'home', and it will be charged according to a user-defined schedule to ensure that the battery is full before it is next needed (e.g. 7:00am for driving to work). This energy will first come from the renewably-charged stationary battery, and if additional energy is needed then the HEMS will charge the car using grid power at the time of lowest carbon intensity that meets the user's schedule needs.

The HEMS demonstrates how building services can make undoubtably positive impact in terms of avoiding increased emissions and increased cost to reinforce the grid when new homes are built. However, it also emphasises the importance of efficient controls in buildings.

When I asked about the challenges facing V2G charging at the moment, Michael Koenig, project leader of the Honda Smart Home US emphasised the need for understanding between all sectors and coherence of standard setting across sectors.

For example, the California Public Utilities Commission require projects interconnecting to the grid to use invertors capable of autonomous grid support functions; they must be UL 1741 tested and certified. However, the auto industry is generally governed by other standards, so future interconnection regulations will need to consider the needs of both industries.

It should also be considered that inclusivity is imperative for successful sustainable development initiatives. For those who do not own their own house or car or cannot afford PVs etc. the benefits of an energy-positive home do not materialise. In addition, the financial incentives from DSR events may only benefit those who are already rich unless something is done to avoid further marginalisation of those with currently less awareness of the opportunities available to them and less financial mobility. Policy can help to combat these issues and on the next stop of my journey I had the chance to learn from policy-makers in this area.

Global Climate Action Summit, San Francisco

I travelled to San Francisco to attend affiliate events as part of the Global Climate Action Summit. The events I attended had a particular focus on policy.

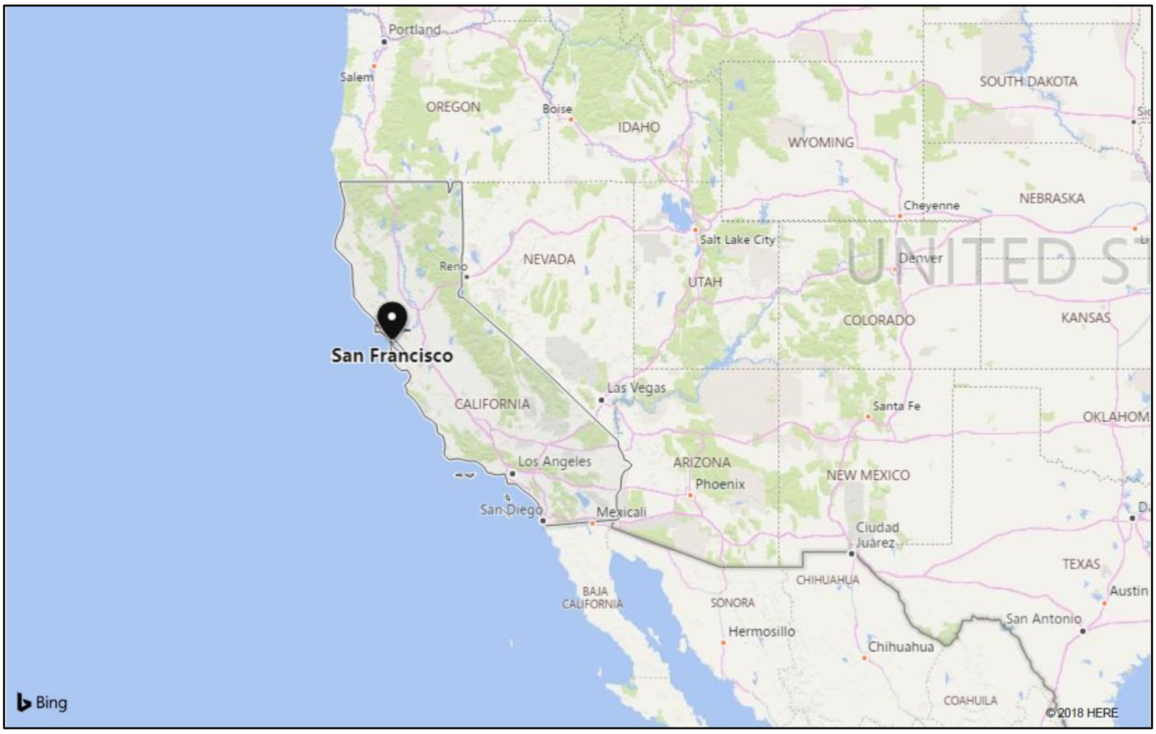

Figure 10 Map of San Francisco, California

Regional Transport Policy Collaboration

At the 'Regional Transport Policy Collaboration' event, the Mayor of Oakland, Libby Schaaf highlighted the need for collaboration across industries at planning level. The mayor noted that cities are becoming expensive to live in and low-income workers are being pushed out into the suburbs and faced with a commute. Where houses positioned near the residents' jobs, they are far less likely to own a car, and this can reduce predicted future emissions.

The mayor said that bad decisions are made when housing and transport policy are considered separately. In order to reach emission reduction goals, a holistic way of thinking needs to be adopted.

The event discussed public transport, including electric buses. Some of the challenges for these remain:

- inadequate electric infrastructure;
- inequitable utility rates;
- lack of collaboration between industries/departments to achieve the set emissions targets.

'Decarbonising road transport', organised by the European Commission and the ICCT (International Council on Clean Transportation)

At the 'Decarbonising Road Transport' event, representatives from Europe, Canada, California and China discussed the path to reduced emissions in their respective geographies. Though they discussed both light and heavy-duty vehicles, the challenges and opportunities in decarbonising light-duty vehicles were most relevant considering EVs potential integration with buildings in means such as in the Honda Smart Home.

In the EU, the following challenges to the decarbonisation of low duty vehicles were identified:

- it's difficult to reinforce infrastructure at the same rate as the growth of EVs
- assumptions used in modelling vehicle emissions can be unrealistic, preventing change from the status quo

In Canada, lessons learned from their attempts to decarbonise the transport sector included:

- consultations and collaborations are key to reducing emissions from transport. Particularly at policy level, collaboration is essential in establishing an achievable road map to success.
- Electric charging infrastructure, and therefore the purchase of EVs, is most accessible for home-owners and then home renters. For those who live or rent flats without parking or charging infrastructure, the switch to EVs is not as accessible.

In China, the world's largest vehicle market, the new energy vehicles (NEVs) currently being supported consist of battery electric vehicles (BEVs), PHEVs and fuel cell vehicles, with the latter being the most preferred by policy partially due to concerns over energy security.

By 2030, 40% of new vehicles in China are required to be NEVs, and there is ambition to build over 80 million charging points. These initiatives are driven by local and national policy including purchasing incentives and tax deduction.

However, the following challenges were identified:

- energy security must be maintained
- the market is reliant on central subsidisation
- current charging infrastructure needs to be optimised

'Grid Resilience: How do We Strengthen it?', organised by China-U.S. Energy Innovation Alliance

This event included representatives from Pacific Gas and Electric Company (PG&E), research, government and California Independent System Operator (CAISO) among others.

Regarding demand management, CAISO cited the following opportunities for when demand peaks:

- collaborate with other states to use their hydropower instead of gas-fired power plants
- change utilities market rules to better integrate renewables

The following environmental events are threats to California: wild fires, flooding, earthquakes, typhoon and heatwave. Considering these risks and the consequent growing concern over energy security, small scale generation can bolster the grid and provide resilience in the event of these events. In the same way, buildings that can operate off-grid have the potential to provide resilience.

One example of resilience mentioned was Sendai, Japan, where a multi power quality supply DC microgrid consisting of gas engines, a fuel cell and PVs with battery storage, survived the 2011 tsunami and earthquake and was able to provide power when the national grid took three days to recover.

Managing demand in the grid is imperative to California's resilience as a state. DSR was stated as the priority above other management strategies in California. Incentivising behaviour change is cheaper and longer lasting than upgrading the grid to take further generation technologies. However, despite DSR's benefits in balancing demand, using the internet of things (IoT) enabled devices for automated DSR events can pose risks to energy security e.g. espionage and terrorism though cyberattacks.

City of San Diego

I travelled south down the pacific coast and met Jacques Chirazi, Program Manager of the Cleantech initiative, City of San Diego.

San Diego is targeted to generate 100% of its electricity via renewables by 2035. Jacques explained to me some of the initiatives in San Diego and any of the unexpected benefits and challenges so far.

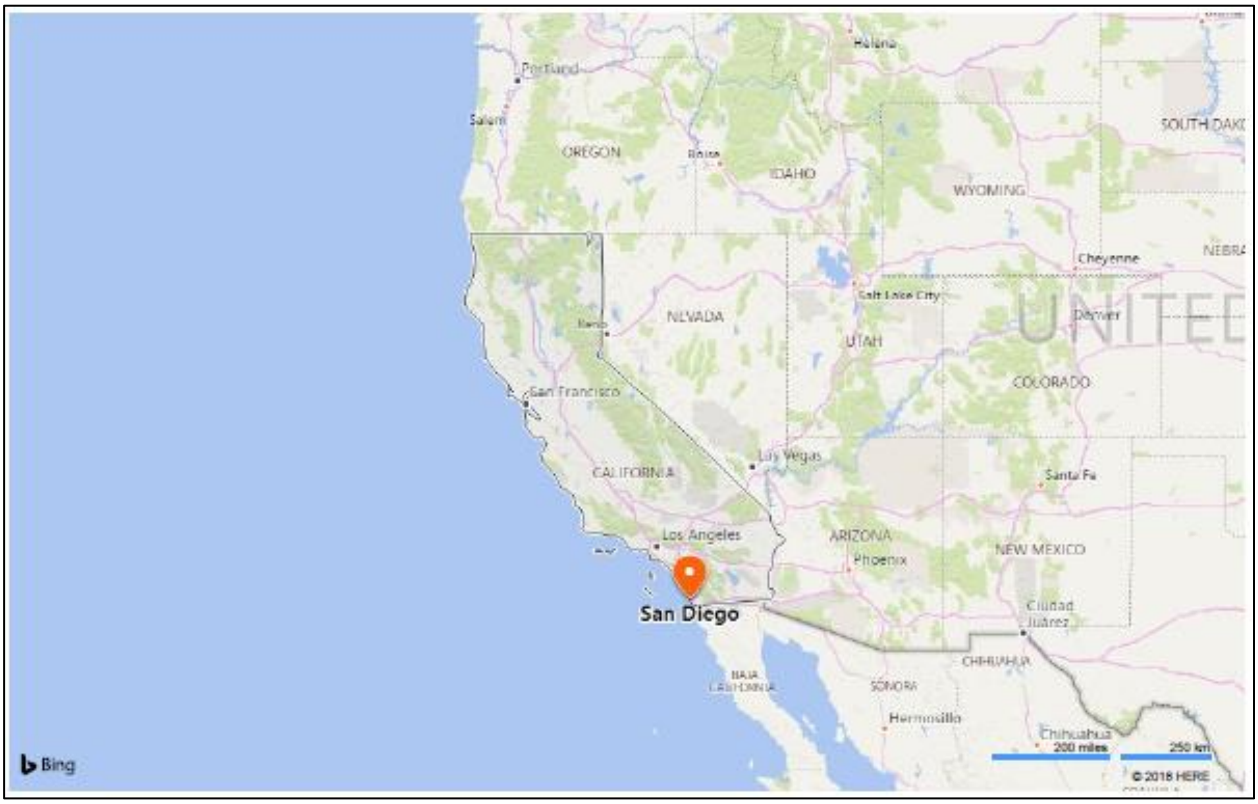

Figure 11 Map of San Diego, California

Solar-to-EV

The Solar-to-EV project, launched in 2012, compromises solar canopies in San Diego Zoo's car park. There are 10 solar canopies, which produce 90 kW of electricity, as well as five EV charging stations. Using new battery technology, a 100 kW energy storage system will be charged by the solar canopies and used to offset power demands on the grid to charge the vehicles. When the battery is full, the excess solar energy that is generated will be put onto the electric grid to improve reliability and benefit the surrounding community. The solar canopies also provide shade to approximately 50 cars in the Zoo's southeast parking area.

Figure 12 Solar-to-EV Project at San Diego Zoo

The project has been successful and greenhouse gas savings achieved were equivalent to removing 21 cars off the road per year.

However, the project was not without its challenges, including intentional and unintentional vandalism. For example, EV users were unintentionally driving over the charge cables and damaging them.

Car2Go

Car2Go was the largest all-electric car share program in the United States. The services ran from 2012 to 2016. The fleet comprised 350 Smart Fourtwo vehicles. To manage the demand on the scheme, the 50% of vehicles that weren't in use had to be plugged in and charging. This was a challenge to achieve. In addition, during the conception of the scheme, it was a challenge to identify locations for the charge points where people were likely to spend relatively long amount of time and where it was possible to install them e.g. on public land.

Charge points were retrofitted to several publicly owned buildings and where a charge point was added to the existing distribution board, sometimes problems arose with differences in ownership and the metering and billing of the electricity. Due to a number of operational and market demand challenges, the company ceased its operations in San Diego at the end of 2016.

EVgo Charger Upgrades

EVgo is the charging network which is currently trialling DC fast chargers in San Diego. EVs have three modes of charging: level 1, level 2 and Level 3. Level 1 and 2 are AC charge modes access to most types of EV. Level 3 is what EVgo uses to provide DC fast charging at higher ampages via CHAdeMO and CCS combo connectors. Most Level 3 charges provide 80% charge in 30 minutes and are backwards compatible.

Updating EV chargers at the same rate as advancements in technology is a necessary step, and faster charging times can encourage those, who haven't already, to use EVs. However, these upgrades are not without cost and disruption. While the EV market is relatively young, it's likely that further upgrades will be needed.

Accessible Parking

Accessible parking spaces are required as per the Americans with Disabilities Act, and accessible EV charging spaces are no exception. However, this mandate, which supports inclusivity, is not without its challenges. Where standard EV charging spaces can be located conveniently near to the distribution board of a building, accessible parking spaces are usually required next to the entrance where there isn't always an existing power connection. Where overlooked at project conception, the design and installation of accessible EV charging spaces have delayed projects and added extra cost. The cost and logistics of installing accessible EV charging spaces should be accounted for at project conception.

My visit to California had given me an insight into a lifestyle where EVs and PV are commonplace, and I had seen the benefits and challenges of their integration with a decarbonising grid. At Honda Smart Home in particular, I'd seen how the buildings' industry can collaborate with the transport and energy industries to contribute to zero-carbon living. I travelled back the UK, to Swansea University to investigate the 'active buildings', which are model energy-positive buildings with integrated EV charge points.

Case Study 4: Swansea University, UK

The UK's Climate Change Act 2008 (HM Government, 2008) specifies a reduction in the nation's carbon emissions by 80% from 1990 levels by 2050. In a positive step towards this, the electrical grid is decarbonising and emissions from the energy sector reduced by 42% from 2010 to 2016. Interdisciplinary collaboration, between transport and buildings, has been identified as a strategy for decarbonisation and is noted in the Road to Zero strategy (HM Government, 2018), in which the UK government makes a specific push for charge points to be installed in newly built homes, and for charge points to be installed in existing homes as part of its £1.5 billion investment in ultra-low emission vehicles by 2020.

Figure 13 Map of Swansea University Bay Campus, Wales

As a post-graduate student at Swansea University this year, I visited their two Active Buildings, which are energy positive, generating enough energy to power both the buildings and a fleet of EVs.

The UK Government recently announced investment of £36 million for research into Active Buildings led by Swansea University. Active Buildings are those which generate electricity and heat from solar energy and are controlled by intelligent systems for energy management and occupant comfort.

Active Classroom and Active Office

Swansea University's Bay Campus is home to both the Active Office and Active Classroom - two energy positive buildings that were designed by SPECIFIC, an Innovation and Knowledge Centre led by Swansea University. SPECIFIC lead research in Active Buildings (formerly 'Buildings as Power Stations'). In addition to generating sufficient power to supply electricity and heat to the building, the electricity generated can be used to supply the university's fleet of EVs (Nissan Leafs and ENV200s), as there are charge points integrated into the buildings.

Figure 14 Solar Collectors on the Active Classroom (south facing)

Figure 15 Active Office (left) and Active Classroom (right)

The Active Classroom was opened in 2016 and was the first demonstrator for eight new building technologies. It has a gross external area of 206 m^2. The classroom generates electricity using PVs integrated into the steel roof panels (BIPVCo integrated solar panels) which is stored in 2 salt-water batteries (providing 40 kWh, enough to power the classroom for 2 days).

The space heating and hot water is provided by an air-source heat pump (ASHP), assisted by solar air collectors on the south side of the building (see **Error! Reference source not found.**). The solar air collectors are coated, perforated steel panels from Tata Steel (Colorcoat Renew SC®). Air enters the panels through the perforations and is pre-warmed before entering the ASHP to heat the building. The panels can capture up to 50% of the radiant energy falling on them and so contribute to a more efficient ASHP. They are equivalent to 500 W_p/m^2.

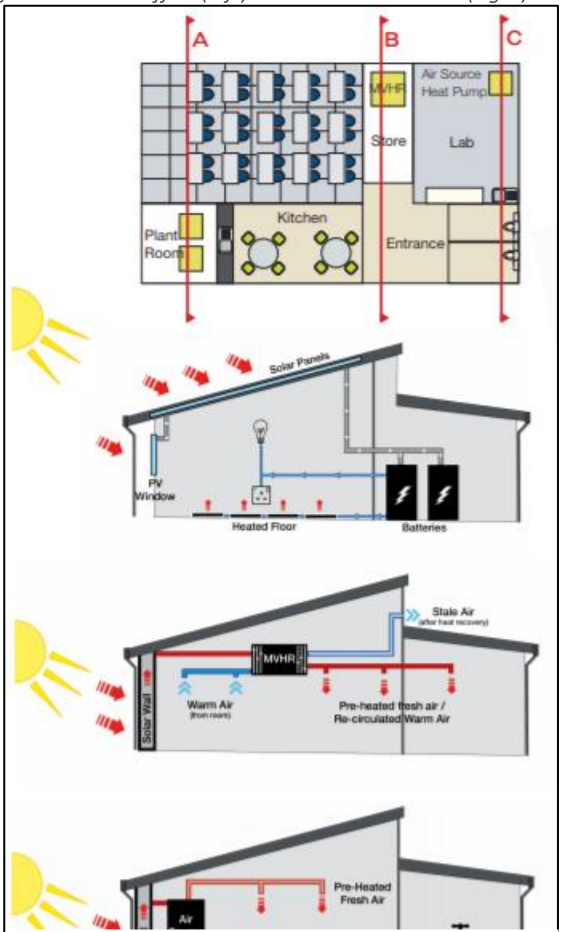

Figure 16 Active Classroom Services Layout

The space heating in the classroom is provided by novel underfloor heating: printed resistive electric panels developed and manufactured by SPECIFIC. This resistive heating system is quicker to react than wet systems and is suited to fast installation.

The classroom also features NSGs first solar window (Pilkington Sunplus™ BIPV) generating 77 W_p. In 2017, the building generated 1.6 times the energy it used, making it the UK's first energy positive classroom.

Following the completion of the Active Classroom, in 2018 the UK's first energy positive office was constructed - the Active Office. Both buildings are connected to the University's network and are able to share energy.

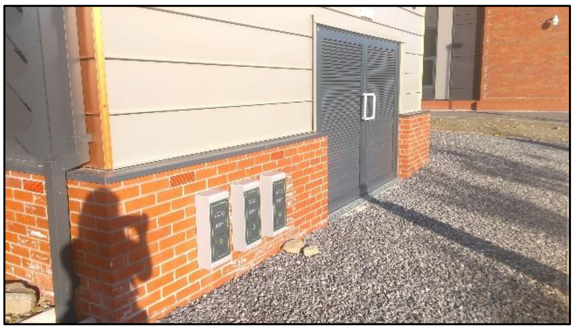

Figure 17 Charging points at the Active Office

The Active Office has three integrated car charging points connected to the building's solar generation and storage system. These will be connected to a Cisco 'smart network' that allows staff to locate vehicles, see their state-of-charge and check the availability of charging points.

Both buildings were constructed using off-site construction techniques – a panelised system for the Active Classroom and a modular system for the Active Office. A different battery technology was used in the office - lithium-ion phosphate instead of saltwater batteries. The batteries provide 110 kWh energy and the building is connected to the grid so excess energy can be exported. The electricity for the building is provided either directly from the PV system, from the batteries or from the grid at any one time.

The roof of the Active Office is also a BIPVCo solar roof: a film of solar cells integrated into a steel roof. Unlike conventional types, these PVs have been curved to follow the profile of the roof and provide a 22 kWp output.

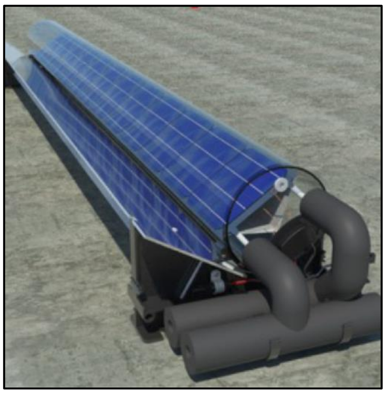

Figure 18 PV-T tubes for the south facing wall of the Active Office

The Active Office also includes a PV-T system on the south elevation; photovoltaic thermal hybrid tubes that provide electrical and thermal energy (2.4 kWp of electricity and 9.6 kWh of heat): the first demonstration of this product.

The system is used to charge a 2000 L thermal store to manage the space heating and hot water demand in the building. This has enough capacity for a day's space heating and can also supply a separate 90L hot water tank. The thermal store can be charged by the PV-T system, or the ASHP (either driven by rooftop PVs or the grid at times of lowest carbon intensity).

On a warm, overcast summer day, when no space heating is required, instead of charging the 2000 L storage tank, the batteries can be used to heat the hot water via an immersion heater.

On cooler, bright days, the PV-T system can be supplemented with the ASHP to provide space heating and hot water.

Overnight or on cold, cloudy days, the ASHP alone can be used to heat the thermal store and hot water tank.

Although currently in their infancy, the classroom and office working together as a network are demonstrators for buildings as power stations. Their ability to be powered off-grid as well as being connected to the grid for feedback is resilient and offers protection against power outages, as well as energy security.

Conclusion

The growth of PVs and EVs has the potential to contribute to sustainable development both in developed and developing countries, by offering energy security and affordability without compromising the environment. The technologies contribute to lowering emissions and offer environmental, social and economic benefits but require different demand management practices.

In remote areas of developing countries, car batteries act as a readily available, affordable way of managing demand by storing electricity from PVs to be used in the evening. In more densely populated areas, smart networks of LZC technologies, with integrated storage, can help balance supply and demand.

For developed countries with grid infrastructure, DSR provides a way of balancing supply and demand whilst keeping the cost of grid reinforcement to a minimum. DSR has the potential to reduce the excess capacity, and associated emissions and cost, of current power station generation. It could also encourage storage by way of li-ion batteries, connected or disconnected from the grid to balance supply and demand. Energy-positive buildings, with the capacity to operate off-grid, have the added benefit of resilience.

However, the growth of PVs and EVs and their impact on the building services industry is not without its challenges. Even in California, where policy is established to drive the growth of PVs and EVs and the reduction of carbon emissions, it is redundant without true collaboration between sectors (i.e. transport and housing) at planning stage and beyond. Controls need to be upgraded to smart controls to suit DSR events and despite the benefits, automated programs leave systems vulnerable to cyber-attacks and adequate protection needs to be in place to assure energy security. In addition, a comprehensive metering and billing strategy needs established before EV charge points are added to current buildings' infrastructure, particularly in retrofit scenarios. Accessible EV charging parking spaces also need to be budgeted for in project conception.

Although there is potential for PVs, EVs and demand management practices to contribute to sustainable development, inclusivity needs to be addressed to ensure this. There is a risk that financial incentives for DSR events will only benefit those who are already fortunate enough to own their own home and storage systems and that those without will be marginalised. In the same way, tenants whose landlords are unwilling to install charging infrastructure for EVs could be left vulnerable to fuel shortages and rising fuel prices.

The different geographical and development contexts I visited each have specific challenges concerning demand. In Zambia, where demand is currently low, the availability and affordability of electricity is paramount. In South Africa, as demand continues to grow, increasing capacity whilst ensuring reliability is a particular challenge. In California, collaboration between sectors in policy planning is imperative for ensuring that emission reduction targets are met. Finally, at Swansea University, the ability of buildings to generate their own power could respond to the challenges of resilience, emission reduction and energy equity.

If the UK is to meet its obligations under the Climate Change Act and the Paris Agreement, the buildings services industry should consider some of the benefits and challenges documented in this report concerning the growth of PVs and EVs, and how to collaboratively manage the change in demand.

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A little thank you

The Ken Dale Bursary has been a wonderful experience which I am grateful to CIBSE for. It's not every day you get funded to travel the world and research a topic of your choice at this developmental stage of your career. The experience has been a positive one and I have learnt many things beyond the scope of this report. I have been challenged and as a result grown in knowledge and confidence in my practice. I have enjoyed meeting interesting people across the world who contributed to my research and their support has been very encouraging.

If as you're reading this, you are in the developmental stages of your career and have a bright idea to research for CIBSE, I encourage you to apply for this bursary.

About the Author

Lucy Pemble is joint-chair of the CIBSE Young Energy Performance Group (YEPG). Previously a Sustainability & Energy Consultant, she has spent the past year completing a scholarship at Swansea University. The MSc Sustainable Engineering Management for International Development was developed with the Prince's Foundation and involved a live, student-led project in Zambia.