1 Overview of the Context

The UK is decarbonising its economy, thus decentralised solutions are becoming an increasingly common part of the energy landscape. This shift can be seen in the energy industry (e.g. through the DNO-DSO transition), policies (e.g. in the Local Energy Teams across local and central governments) and innovations (e.g. UK Government Industrial Strategy challenges and the Prospering from the Energy Revolution (PFER) programme).

Smaller scale renewable and other technologies have become more readily available with the improved energy system, enabling a more localised generation and consumption approach. This is supported with technology-enabled solutions, such as smart meters and smart appliances, increasing electrification of transport, development of heat networks and increasing cross-sector interactions.

Concurrently, there is an increasing awareness of the potential to take action against climate change at a local level amid growing concerns over fuel poverty and societal inequalities.

This is the context in which we see "Smart local energy" (SLE) systems developing. SLE systems aim to manage and balance the supply of local energy, as well as its storage and use across all vectors (e.g. power, heating and transport), bringing efficiencies to energy supply and demand, and social, environmental and economic benefits to the given locality.

While the energy system is undergoing all of these changes at an unprecedented rate, the UK must also train the workforce that would be delivering and operating the new SLE system, as well as educating the citizens and communities who inhabit homes and environments where this system will be integrated. After this, ***what skills and training provisions are needed for the successful transition to smart local energy systems?***

To answer this question, the Skills research team at the EnergyREV [1] project has set out to undertake several case studies at the localities where this transition is underway. This report presents the first of our case studies, i.e. that of the city of Bristol.

1.1 Study Objectives

The key research question addressed in this study is: **What are the skills and training needed for transition to SLE** systems?

This question has been further refined into the following set of sub-questions:

RQ1 What factors contribute to the skill shortages in SLE?

RQ2 How do the locality factors drive and differentiate the skills needs for smart energy (sub-)systems?

RQ3 What skills shortages are the SLE (sub-)systems experiencing?

RQ4 What training is needed to support the availability of the skills that will be needed for SLE within the next few (5 to 10) years?

To explore the answers to these questions, a series of case studies will be developed, focusing on the study of the whole 'ecosystem' of a locality, establishing a clear focus on a place and a specific local system of systems (SoS). The first case study, for the city of Bristol, is detailed below.

We must note that previously well-established practices exist in the labour/job shortages assessment and planning for the *whole economy* (e.g. [2]) or well-defined regions, as well as for sectors of economy (e.g. wind energy sector [3]) with some work considering "green jobs" as a specific sector on its own [4, 5, 6, 7]. However, to our knowledge, there has been no previous work on addressing skills needs and shortages specifically for the domain of "smart local energy (sub-)systems".

1.2 Framing of the SLE Notion

While, in theory, the above description of SLE could cover any of the energy vectors and systems architectures, we also account for the following factors:

1. Zero-carbon economy targets: Given the UK's zero-carbon economy targets for 2050, one can clearly see that any investment other than that in carbon-neutral or carbon-reducing assets will either jeopardise the set targets, or potentially leave these assets stranded during the next 30 years. As a result, this study only considers green and renewables-based initiatives.

2. Decentralisation trend: most renewable energy technologies are dependent on the availability of locally distributed renewable sources. For instance, tidal energy can only be harvested on the shorelines, while sufficient solar generation can be expected from localities with sunny weather, etc. However, should these locally distributed sources be used to generate electricity and supply to the transition grid, the locality aspect of SLE will be disregarded. Thus, this study considers decentralisation as a key characteristic of SLE.

1.2.1 SLE as a System-of-Systems

A **smart local energy system** is itself *a system of systems* (SoS), the simplified overview of which is presented in a rich picture in Figure 1. In this figure, a set of individual sub-systems (such as local/national government, energy supply, building and retrofit provision, transportation and mobility services provision, local citizens and communities, the community energy groups and the ICT infrastructure for digital energy services) are integrated through a digital and physical infrastructure. These individual sub-systems have their own boundaries and behaviours, although they collaborate for the common goal of optimal use of local energy and carbon reduction. To achieve this, they exchange data and exercise control over the energy exchange itself (e.g. drawing on or storing into batteries, switching consumption equipment on/off, etc.).

Systems of systems are often defined by the set of traits that they exhibit [8, 9, 10]. The traits of key relevance to SLES are discussed below:

- *Operational Independence* of sub-systems refers to the fact that the sub-systems which comprise the SoS can *usefully* operate independently of SoS. For instance, with or without the rest of the sub-systems, the energy supply sector will deliver energy to its household or business customers.

- *Managerial Independence* of SLE sub-systems refers to the fact that the sub-systems are delivered and operated by *independent commercial companies and organisations* which not only belong to a wide set of different owners, but are also located within quite different industries (e.g. in transport, energy, government, etc.). While, as part of the SoS, the sub-systems *collaborate towards a common goal*[1], each of the *sub-systems must continue delivering its*

[1] which, for SLE SoS is maximum utilisation of locally generated energy and net-zero carbon impact

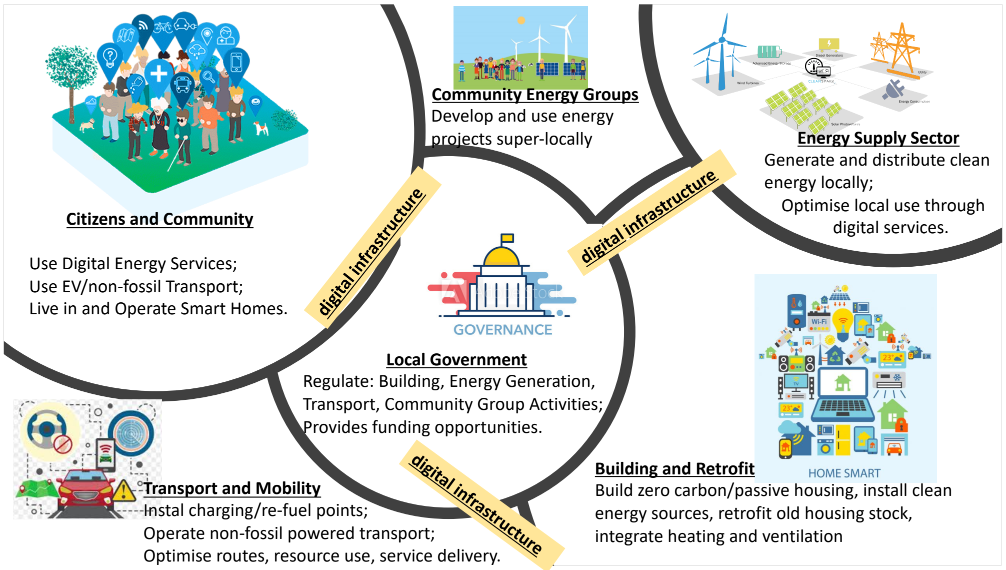

Figure 1: A (simplified) rich picture of a smart local energy system

own goal as well (e.g. a transport and mobility sub-system must ferry people and goods to the required destinations, even if it also stores and re-supplies electricity via EV batteries).

- *Evolutionary Development* of SoS implies that the SoS will be able to deliver useful services even before complete deployment of all its components. Conversely, sub-systems can be removed from the SoS with the SoS still remaining otherwise operational. For instance, a reduced form of SLE SoS can optimise the use of local energy and minimise carbon impact, even if there is no energy supply to citizens and communities from electric vehicles and fleets. This is to be expected because, given that the sub-systems are (at least partially) independent in their development and operation, there can be no guarantee of their continuous availability [8].

- *Emergent Behaviour* of SoS refers to the fact that, by working as the SoS, the sub-systems deliver more that the simple sum of their services - they are able to provide new (levels of) services (e.g. flexibility to grid via EVs from Transport sector and DSR services over citizens' household appliances).

- *Geographical Distribution of sub-systems* leads to looser coupling between the sub-systems (and their components), and may result in longer communication delays.

- *Heterogeneity* of sub-systems refers to the fact that the components would have very different compositions (e.g. each sub-system will own hardware components - from wind turbines to EV charge points, washing machines and software systems to monitor and control them); pursue different goals; serve different stakeholders; operate different economic models, etc.). As a result of this heterogeneity, as well as independent ownership and development of the sub-systems, the only way of ***architecting a SoS is through interfaces between the sub-systems***. For SLE SoS, the main set of interfaces between sub-systems is presently delivered through the ICT infrastructure and electricity distribution network[2].

Given the above properties of the SLE sub-systems, it is clear that we cannot expect to see a homogeneous set of skills, work practices, or educational environments across them. Consequently, we ***suggest that each sub-system must be studied in its own right, as well as part of the integrated SoS, with the relevant interfaces considered each time.***

1.2.2 Local in SLE SoS

The **"local"** aspect refers to a defined geographical area where local energy initiatives take place. This also covers a range of organisations, including partnerships between public, private and non-profit sectors.

Public authorities may take a coordinating role to leverage private sector investment in local energy provision [11]. The local energy landscape includes a range of energy-related activities including generating energy; reducing energy use through energy efficiency and behaviour change; managing energy by balancing supply and demand and purchasing energy. Local authorities can provide support for community-driven energy projects which deliver social benefits.

1.2.3 Smart in SLE SoS

The **"smart"** aspect of an energy system often implies *digitally supported coordination of decision-making for (sub-)systems* to optimise their resource use and waste reduction (both generation and consumption), fault tolerance and recovery from failures, support for human decision-making for efficiency and comfort. On the other hand, the smart energy system will not fulfil its potential without *smart users*, thus the household and business users also need to acquire skills in the functioning and use of digital energy systems [12, 13, 14, 15].

It should be noted that a number of relevant sub-systems, such as manufacturing and finance, are omitted from the rich picture in Figure 1 for simplicity. These sectors, while very important to the SLE SoS operation, do not require any dramatically new skills, as per our current case study analysis. However, where each of the discussed sub-systems requires finance, policy, regulatory, or other skill updates for successful operation within the SLE SoS, such skill categories will also be discussed.

1.3 Structure of the Report

The rest of this report is structured into 10 further chapters. Chapter 2 presents the methodology used in this study. Chapter 3 describes Bristol's energy ecosystem, based on the documentary analysis undertaken. The next seven chapters (from 4 to 10 inclusive) each address one of the seven above listed sub-systems of the SLE SoS (as per Figure 1). Finally, chapter 11 considers the cross-subsystem challenges and skills needs for the system of systems level.

Each of the seven subsystem-specific chapters (i.e. chapters 4-10) is structured into 4 sub-sections that address the above listed questions:

[2] Other interlaces, e.g. heat captured from ICT infrastructure to heat citizens' homes, can also be envisioned, although it is outside of the time-frame scope of this study.

1. Sub-section one addresses RQ1 and RQ2 and details the set of factors and their impact on the given SLE sub-system, and uses a causal link diagram to illustrate these factors and their positive or negative interrelationships. We underline that the set of factors discussed are those elicited for Bristol's case study, and are from the set of data collected for this report. The models are also available for execution through URLs listed along with each diagram. We note that each diagram uses colour differentiation for Bristol-specific (purple colour) and general UK-wide (red colour) factors.

2. Sub-section two addresses RQ3 and details the skills that are in short availability within each sub-system. For each sub-system, we compile sets of such skills for their relevant knowledge areas: Engineering, Energy, Finance, Legal, Managerial, Policy, Trades (e.g. construction, electrical, etc.) and Soft Skills.

3. Sub-section three addresses RQ4 and details the training needs and modes, as noted by the study participants.

4. Finally, sub-section four presents a set of insights and recommendations for each sub-system.

We note that a number of quotes from the study participants have been used to demonstrate the perspectives on specific skills needs and other issues. To maintain a readable format, we use a single relevant quote at a time, and we do not list all interviewees who expressed the same or similar view. (In other words, the fact that only one quote is used per skill type or point does not mean that only a single source has expressed this opinion.)