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Survey

Skills deployment for a ‘just’ net zero energy transition

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ABSTRACT

A ‘Just Transition’ seeks to protect the rights of the workforce throughout transition away from high carbon industries and towards sustainable economic sectors. This includes reskilling where appropriate and a fair distribution of benefits, alongside recognition and participation of affected communities.

Drawing on a systematic literature review and a case study delineated by the 38 English Local Enterprise Partnerships we analyse the variety of skills required to support a just transition to more decentralised and smart low carbon energy systems (defined as ‘smart local energy systems’) in England.

We found that more attention is required in assessing skills provision, alongside upskilling the workforce, or risk the transition being unjust. Regional disparities in skills availability could be mitigated through a local skills provision system whereby stakeholders can review training opportunities, identify emergent skill-gaps and leverage investment. In addition, greater devolution to local authorities would enable them to support stakeholders more effectively.

1. Introduction

Over the last decade, the global efforts to fight climate change and transition towards low or net-zero carbon energy systems have manifested through different international agreements and strategies striving for a sustainable future (IRENA, 2019; Rogelj et al., 2015; UNFCCC, 2015). The energy supply sector is the largest contributor to global greenhouse gas emissions and the transition to clean energy a major priority for mitigating against the worst effects of climate change (Bruckner et al., 2014). Within this context, many countries are experiencing a *move away from* highly centralised energy infrastructures based on fossil fuel extraction, refinement and combustion industries, and are experiencing a *move towards* increasing levels of decentralised energy infrastructures based on renewable generation sources. This is occurring alongside changes on the demand side (e.g. increased storage, electric vehicles, smart meters, and clean heating (IEA, 2017; IRENA, 2017; UKRI, 2019)) and increasing digital infrastructure to support more effective energy system operation (Judson et al., 2020b). In 2019 Ford et al. termed these decentralised and digitalised energy systems as smart local energy systems (SLES) (Ford et al., 2019).

Underpinning this societal transition is the need for a wide range of skilled people to manufacture, install, operate, maintain,

Abbreviations: AI, artificial intelligence; CHP, combined heat and power; EV, electric vehicle; PV, photovoltaic; R&D, research and development; STEM, science, technology, engineering & mathematics.

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regulate and use the emerging energy system technologies and approaches (Brennan and Limmer, 2015; Geels et al., 2017; Jagger et al., 2013). It is against this background that the green skills required for low-carbon energy systems have been the subject of study for a number of academic papers (Bowen et al., 2018; Consoli et al., 2016; Sooriyaarachchi et al., 2015; Varghese et al., 2018; Vona et al., 2015); as well as grey literature from international organisations (Cedefop; OECD, 2015; Cedefop, 2013; ILO/EU, 2011). While there is no clear definition regarding what a green skill is, work to date has focused on the conceptual lines between the skills needed for green and non-green jobs. Within this context, some authors have outlined that green skills are considered as high-level analytical and technical know-how related to the design, production, management and monitoring of environmental technologies (Vona et al., 2015). Others suggest that the greenness of skills and jobs should be framed as a continuum rather than a binary characteristic, allowing many of the skills present in non-green jobs to be transferred to green jobs (Bowen et al., 2018).

In this paper we argue that a just transition to SLES requires consideration of additional dimensions beyond analytical and technical skills related to cleaner forms of production and supply side technology (whether using a binary or continuum approach). Drawing on a systematic literature review and a case study delineated by the 38 English Local Enterprise Partnerships (LEPs) we explore how the need for new skills and jobs at the local level is underpinned by the need to create a Just Transition for workers and communities. Therefore, the additional dimensions introduced by analysing emergent skills through a Just Transition lens must be accounted for. This includes accounting for the rights of the workforce and ensuring the creation of decent work and quality green jobs in sustainable economic sectors; jobs which are available to people with a range of skills and with clear career progression opportunities (Healy and Barry, 2017; ILO, 2015). It also requires consideration of how benefits and burdens are distributed, how participation is enabled, and how under-represented groups are recognised (Abram et al., 2020; Jenkins et al., 2016, 2021).

In an increasingly localised and technological transition, where distributional effects are likely to occur within and between geographical boundaries and across socio-demographics, it is particularly important to consider issues of inclusivity and distribution of benefits, ensuring that adverse impacts are not unfairly imposed on those who may be structurally, contextually, or systematically disadvantaged. This calls for an increased focus on the geographical elements of green jobs and skills, with Governments and stakeholders taking account of where new green jobs will be located, who will be filling them, and whether there is adequate skills provision training for workers to undertake them, including equal access to education and targeted vocational training for lower skilled workers to ensure that the creation of green jobs benefits workers and regions most in need (Unsworth et al., 2020).

This paper builds on existing Just Transitions literature, but aims to add new insights into the skills required to effectively transition away from highly centralised energy infrastructure and towards smarter and more localised systems of provision. In doing so we reposition the debate away from one that focuses on communities ‘left behind’ or otherwise disadvantaged in energy transitions, to a more anticipatory focus on practically embedding justice. It therefore focuses less on the problems of injustice, but more on creating justice for transitioning communities.

The remainder of the paper is structured as follows:

In Section 2 we review the development of the Just Transition concept and the need to consider just transition dimensions in the move towards smarter and more localised energy systems. In Section 3 we outline our analytical approach and Case Study selection before moving on to the Case Study Findings in Section 4. Section 5 provides a discussion on the Findings in relation to these Just Transition dimensions before concluding with our policy recommendations in Section 6.

2. An increased focus on a ‘Just’ transition

The concept of a Just Transition originated in the 1970s in the USA although it became more explicit in the 1990s through the work of two unions in the USA and Canada (Stevis et al., 2015) with the actual term ‘just transition’ first used in 1995 (Stevis and Felli, 2020). At the start of the 21st Century however the focus changed from one that had originally related to working conditions for those in hazardous industries (e.g. chemicals, asbestos and nuclear energy) to one that increasingly focused on climate change - most notably the displacement of fossil fuel workers in the transition to a low carbon economy (Healy and Barry, 2017; Stevis and Felli, 2020; Stevis et al., 2015).

Healy and Barry (2017) note that historically labour movements have sought to influence the distribution of benefits and harms caused by transition through advocating for and seeking *just distribution, recognition and participation* for workers, but that this has often led to a ‘jobs versus the environment’ narrative that defends fossil fuel workers against a move towards a decarbonised energy system. However, prominent unionists such as Tony Mazzochi promoted a view that “*the only way out of the jobs versus environment dilemma is to make provision for the workers*” which Mazziochi championed through the Superfund for Workers (Mazziochi, 1993). This later led to a change in union focus from one that was defensively ‘labour-centric’, to a much more ambitious position with a broader justice approach (Rosemberg, 2020). This included extending the Just Transition scope beyond the workplace and acting in the interests of society as a whole to pursue a low carbon transition that is also equitable and socially just (Newell and Mulvaney, 2013; Rosemberg, 2020; Snell, 2020).

Through the endeavours of the International Trade Union Confederation (ITUC) and the involvement of organisations such as the International Labour Organisation (ILO) and the UN Environmental Programme (UNEP) the Just Transition concept became globalised (Stevis and Felli, 2020; Stevis et al., 2015). A notable milestone came in December 2010 during the COP16 negotiations in Cancun when the United Nations Framework Convention on Climate Change (UNFCCC) included the directive to “*ensuring a just transition of the workforce that creates decent work and quality jobs*” in their final agreement (UNFCCC, 2011). Other milestones include the ‘2030 Agenda for Sustainable Development’ adopted in 2015 (UN, 2015) which sets out 17 goals aimed at ending poverty, protecting the planet, and ensuring prosperity for all people in line with a just and equitable energy transition. In the same year the ILO (ILO, 2015) also set out ‘Guidelines for a Just Transition’ with clear indicators for international governments surrounding the ‘greening of

economies' in line with decent work, upskilling and reskilling of the workforce, poverty eradication and environmental sustainability. Three years later, during COP24, Just Transition received particular emphasis, with the adoption of the 'Solidarity and Just Transitions Silesia Declaration' (Jenkins, 2019; Jenkins et al., 2020).

Just Transition as identified by the UNFCCC focuses on protecting the rights of the workforce by guaranteeing decent, well-paid jobs which are available to people with a range of skills in sustainable economic sectors; or early retirement for workers displaced by environmental regulations (Abraham, 2017; Jenkins et al., 2020). It also sets out that the burden of climate action should not be borne unequally by one set of workers or communities or any one country, encapsulating a geographical perspective on who is affected and where (Jenkins, 2019; Jenkins et al., 2020).

Delivering a Just Transition is an intrinsically political debate "since it is characterized by issues of power, distribution of and access to resources, political economy, and so on, it can be described as a deeply political struggle" (Healy and Barry, 2017). Governments globally have a key decision-making role in mediating between competing energy futures (and the global elites who advocate them), in determining difficult political trade-offs and in managing levels of support for affected communities (Newell and Mulvaney, 2013).

In this paper we focus on the trivalent egalitarian dimensions of just transition as identified in academic literature - the fair distribution of benefits and harms, recognition for those affected (including effects on frontline communities) and participation (Healy and Barry, 2017; Stevis and Felli, 2020; Stevis et al., 2015). We then apply these dimensions to an analysis of the skills required by workers and communities for the emerging global trend toward smarter and more localised energy systems.

2.1. Toward smarter and more localised energy systems

The shift toward SLES is associated with a range of new energy system functions, including the implementation of new smart technologies for flexibility and grid balancing services, the use of automation and self-regulation through AI or machine learning and more local forms of energy system management, operation, governance, ownership and engagement (Ford et al., 2021; Judson et al., 2020b). This is also driving a change in how different stakeholders engage with the energy system and the new skills required for this. In this paper we review how these changes are impacting on energy system planning, operation and delivery in England through the use of a case study drawing on the experiences of the English LEPs.

In England more local forms of grid management and operation are seeing distribution network operators (DNOs), who have traditionally taken a passive role in network management, transitioning towards becoming more active 'distribution system operators' (DSOs) (Bray et al., 2018). This entails potentially replicating the system balancing functions which National Grid ESO currently undertakes at the transmission level (Nolan, 2015) in order to forecast and actively manage energy flows across distribution networks, matching supply and demand locally and facilitating local trading arrangements (Bray et al., 2017; ENA, 2017; WPD, 2017). This requires new skills and ways of working for these actors.

In addition, local authorities (LAs) are increasingly expected to integrate energy systems planning within their remit and capabilities due to the uptake of decentralised generation technologies and associated planning decisions (BEIS, 2020; UK100, 2021). However, challenges exist due to regional and distributional differences in both capacity and resource to deliver the changes necessary following a decade of budget cuts, and with climate and energy remaining non-statutory responsibilities. Therefore LAs are limited in how well they are able to deliver climate action, creating the risk that those LAs with fewer resources are left behind in the net-zero transition (PCAN, 2021).

The new skills associated with the shift toward smarter and more local energy system planning, delivery and operation require a broadening of the definitions of green skills beyond those normally associated with the manufacture, installation and maintenance of new technologies (Bowen et al., 2018). It encompasses changes to existing established systems and practices and changes in established organisations. Each organisation along the supply and demand chain will face different resource and financing challenges, in embedding new skills and working practices as well as differences in capacity to affect change.

Beyond these new management and working practices introduced by SLES, the uptake in decentralised and digital technologies (many of which can be incorporated into households e.g. solar PV, home batteries, EVs etc.), also brings the energy system much closer to people and the communities in which they live. For some, this will enable them to enjoy benefits associated with owning these systems, such as the ability to engage in demand-side response activities, charging their EVs at a time that takes advantage of preferential time of use tariffs etc. However, for those who cannot afford to purchase these technologies, there could also be unintended consequences linked to the 'death spiral' effect, whereby those who can't take advantage of preferential tariffs and demand shifting are left with increasingly negative tariffs (Castaneda et al., 2017).

Bringing the energy system closer to people and the communities in which they live also requires skilled consumers to operate these systems within their businesses and households. Integration of new technologies could be significantly hindered if energy consumers lack the skills and awareness of the potential benefits of the smart energy revolution (D2N2 LEP, 2019; de Boer et al., 2019; McCabe et al., 2018). Therefore, the smart skills required by consumers to engage with new technologies and processes also need to be identified and addressed.

Thus, in the context of an energy system transition away from highly centralised infrastructure and towards smarter and more localised systems of provision, an increased focus on justice means considering the new skill sets required for workers and communities to meaningfully engage with emerging technologies, markets, industries, and operational paradigms surrounding this transition. In the political context, this means ensuring that benefits and burdens are equally distributed, that under-represented groups are recognised and involved in decision-making and that participation of affected communities is enabled. This focus on the additional justice dimensions relevant to the analysis of emergent skills for SLES forms the basis for the analytical framework introduced in Section 4.

3. Methods and case study selection

A full account of the Methods employed in this study can be found in [Appendix 1](#).

This study employed a systematic meta-narrative review to assess the literature which engaged with skills and the smart and local elements of SLES. A Meta-narrative review is one of an emerging menu of new approaches to qualitative and mixed-method systematic review, which seeks to highlight the contrasting and complementary ways in which researchers have studied a similar topic (Wong et al., 2013). This approach, developed by Greenhalgh et al. (2005), is well suited as a method to distil, summarise and broadly understand the way in which different strings of literature engage with a heterogeneous and interdisciplinary topic such as the role of skills within SLES and enabled the authors to examine skills requirements, provision, and gaps from differing perspectives across a range of disciplines and dimensions. Following procedures and guidelines suggested by Wong et al. (2013) and Snyder (2019), three methods were used to locate relevant studies: a keyword search in reference databases, a backward search of key documents, and an official website search.

First, keyword searches were conducted in Science Direct, JSTOR, academia.edu and Google Scholar looking specifically for publications on skills related to digitalised / smart and / or decentralised / local and energy systems. This approach was intended to identify any previous work that examined the different streams of information around skills and emerging energy systems, providing more holistic insights and a more coherent set of references than a scattered search. Fifteen articles were selected through title and abstract screening. Next, backward searches were performed on these 15 initially selected documents by reviewing the reference sections for additional potential studies. From this backward search 193 new documents were identified, making a total of 208 relevant academic documents.

In addition to the academic literature, we were keen to examine outputs published by international governments, utilities, and

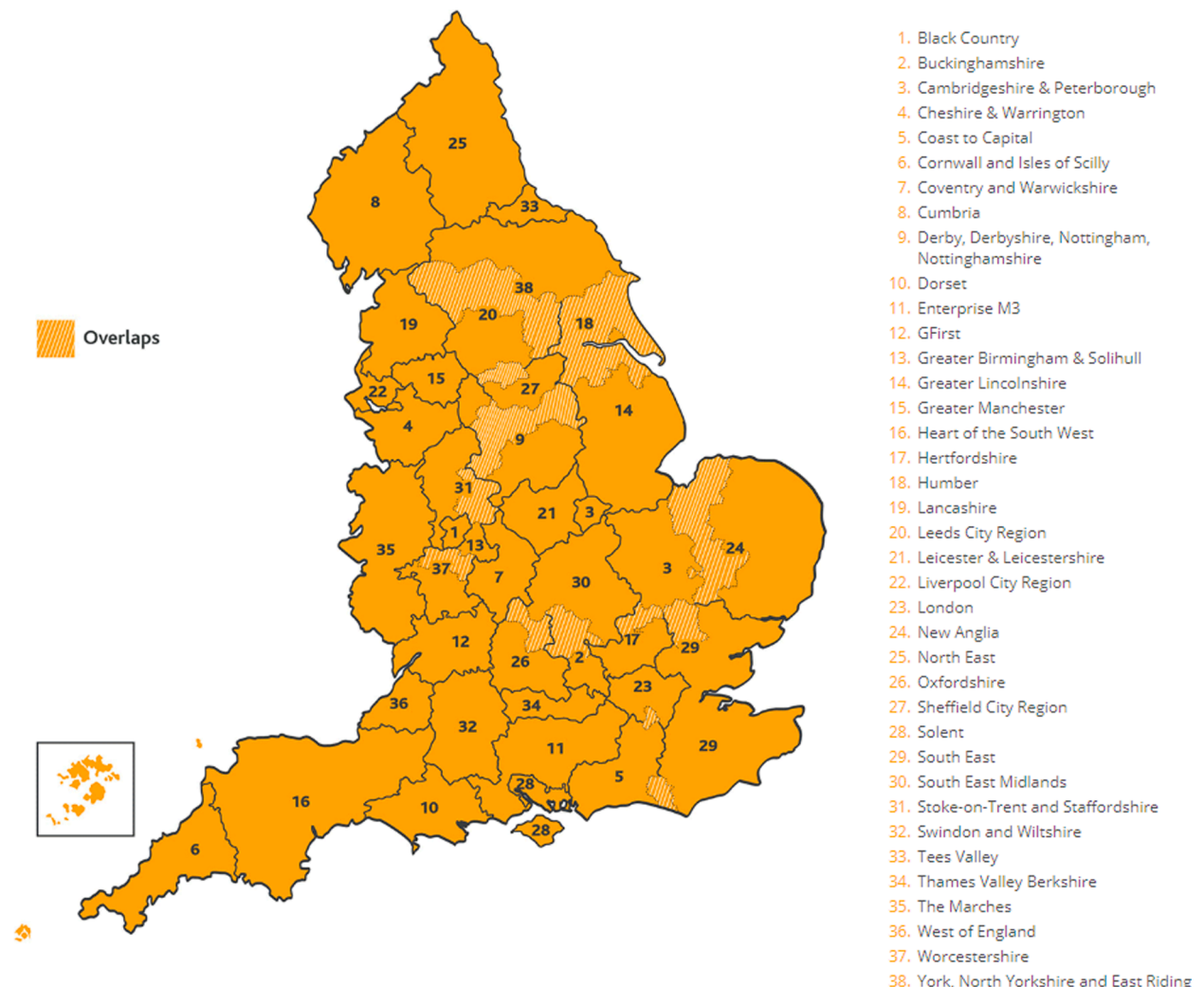


Fig. 1. The 38 LEPs across England (REF <https://www.lepnetwork.net/about-leps/location-map/>).

private firms with an interest in digitalised / smart and / or decentralised / local energy systems. However, the enormity and the scattered nature of this grey literature represented a major challenge for in-depth exploration, and it was subsequently decided to narrow the scope of the grey literature search by focusing on the 38 English Local Enterprise Partnerships (LEPs) as a distinct and comparable case study for analysis.

The English LEPs (Fig. 1) are business-led partnerships between LAs and local private sector businesses (The LEP Network, 2019). They play a central role in determining economic priorities and undertaking activities to drive economic growth and job creation, improving infrastructure and raising workforce skills within their local area. LEPs were therefore considered an ideal focal point for examining local considerations regarding workforce skills and perceived skills gaps, educational opportunities and the policy interventions required for implementing SLES within a geographical context.

This transformed the search for grey literature into a feasible and efficient process and also grounded the research to an empirical realm delimited by the case study of the English LEPs, to illustrate how skill provision and skill gaps vary regionally, how they are being addressed, and where intervention may be necessary within a well-defined geographical context. Through contrasting the academic and grey literature this enabled us to combine theoretical and conceptual understandings of skills within the uptake of SLES, with the empirical richness captured in the grey literature which described and portrayed the actual experiences of the English LEPs. This combination of academic and grey literature enabled the paper to build upon previous academic conceptualizations and framings of skills within energy transitions, as lenses to analyse and discuss the data provided by grey literature, grounding and contextualising the paper to the English LEPs case study.

The search of the LEPs official websites for grey literature which specifically related to digitalised / smart or decentralised / local energy systems and skills resulted in a further 564 documents. Therefore, the research initially compiled and reviewed 772 documents: 208 academic documents (15 original documents plus 193 references from backward search) and 564 documents from the LEPs.

Following the application of inclusion and exclusion criteria (see Appendix 1) 61 relevant sources of information were included for analysis (22 academic papers and 39 grey literature documents).

Included studies were inductively coded to capture concepts relating to skills needs, provision, or gaps within SLES. As new codes were added, the reviewers re-read the previously coded studies to see if the new code should be applied elsewhere (Fereday and Muir-Cochrane, 2006). Finally, when saturation was reached and no new themes were added, the descriptive coding system was considered complete.

Following this the reviewers moved to a more interpretive stage, looking for constructs and meanings within the codes to identify patterns. The thematic structure was derived empirically from the data, grounded in the concepts of both SLES and justice focusing on the emergent skills required by workers and communities, the distribution of skills provision and participation and recognition for those affected. Themes were checked and refined by two reviewers until agreement was reached.

4. Findings

The resulting thematic structure is presented in Fig. 2. Three nodes represent the smart, local and energy systems elements through a focus on skills. The Skills Provision node portrays skills as a complex system integrated by different life-cycle stages bonded to specific local stakeholders. Finally, the Deployment of Skills node explores how these skill-sets can be utilised by the workforce and SLES communities. The following subsections provide description, including examples, to help understand and navigate the concept of skills within SLES.

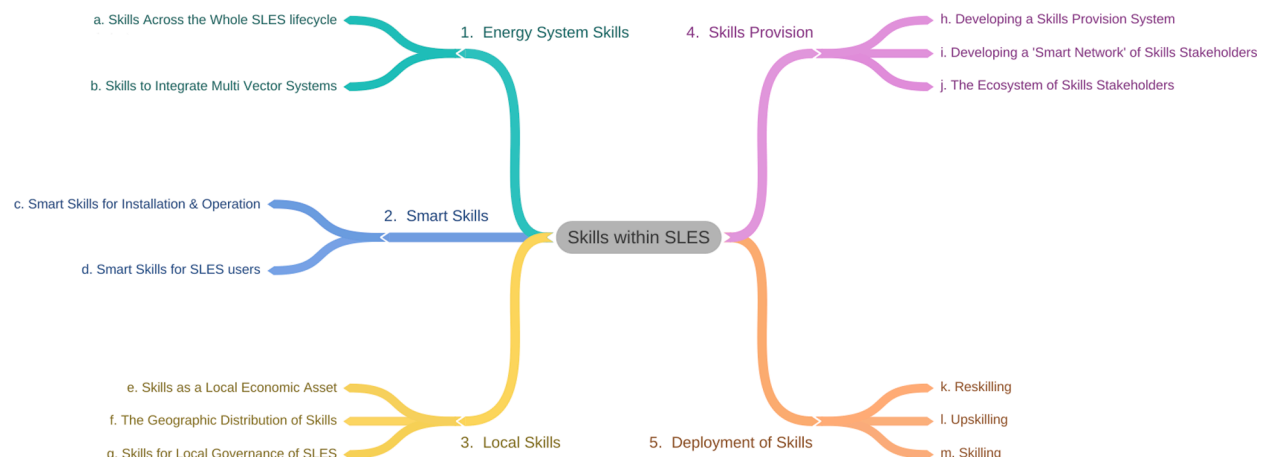


Fig. 2. Analytical themes emerging from coding.

4.1. Energy system skills

4.1.1. Skills across the whole SLES life-cycle

As with any energy system, SLES will follow a set of well-defined stages in order to deliver energy services. The full sequence of stages which begins with the research and development (R&D) of new technologies, leading to production and consumption of energy and finalizing with the decommissioning of an energy system is known as the technology life-cycle (Sooriyaarachchi et al., 2015). The successful completion of the different tasks involved within each stage of the SLES life-cycle will rely on many different skill-sets as shown Table 1. Range of skills required. In short, there is a need to ensure that education providers resource and provide the appropriate type of skills to be able to specify, install, champion and manage SLES.

4.1.2. Skills to integrate multi-vector systems

SLES are multi-vector energy systems, utilising a wide range of technologies, based on different energy sources (predominantly low carbon and renewable sources), to provide energy services such as electricity, heating and mobility. These systems can incorporate generation technologies such as solar PV, wind turbines and CHP; storage technologies; retrofit technologies such as energy efficiency measures, smart meters and thermostats and mobility technologies such as EVs.

One of the primary advantages of SLES is that they enable the integration of all these various energy services, sources, or technologies. This integration across energy vectors enables SLES to utilise the most appropriate energy supply mechanism (e.g. solar or storage) depending on local generation and consumer demand levels at any given time and place. Underpinning this ability to optimise across energy vectors is the recent dramatic increase in energy digitalisation (Judson et al., 2020b). Judson reports how energy digitalisation has been influenced by changes in software and data processing, new energy technologies and connectivity; with the application of optimisation algorithms and machine learning expected to develop further as energy digitalisation grows. Therefore, new skill-sets in digitalisation will increasingly play an important role in the development of SLES and the ability to optimise across energy vectors in terms of price, carbon reduction and efficiency by responding to dynamic signals surrounding demand and supply activity (Ford et al., 2021).

In addition, while some of the skills required for SLES can be found in existing business practices, such as plumbing, installation, management, manufacturing, IT and logistics; SLES require an overarching understanding of the complete system and how all of these technologies, practices and vectors work together, in order to install a coherent SLES system. Therefore, the extant industry silos need to be broken down to enable innovative, cross-disciplinary learning and skill-sets (Zekaria and Chitchyan, 2019).

4.2. Smart skills

4.2.1. Smart skills for SLES installation & operation

One of the main prospective advantages of SLES is their ability to process information in an intelligent and responsive manner to maximize the benefits of energy systems. Smart skills are therefore likely to become increasingly necessary to provide consumers with services related to the installation, assessment, maintenance and operation of the innovative technologies necessary for SLES (Liverpool City Region LEP, 2012). However, the Industrial Strategy Council forecast that by 2030 five million workers in the UK could become acutely under-skilled in even basic digital skills without intervention measures applied (HM Treasury, 2021).

A key theme linked to the smartness of SLES is its ability to help balance electricity network usage through optimising supply and demand of generation in an intelligent manner to help overcome peaks and troughs, thus easing pressure on the networks (Burrows and

Table 1

Range of skills required across the whole SLES lifecycle.

Type of skill	Skill example
R&D	Innovation skills for advancing new energy technologies (DEG, 2013; Rhodes, 2018) and the innovation of new products and services related to smart grids and internet of things (IoT) (Barlow et al., 2018).
Business	To enable SLES innovators to understand market needs and become confident users of methodologies that allow them to strengthen their business cases like carbon accounting (Carbon Trust, 2018).
Leadership and analysis	To enable local authorities, planners and policy makers to look beyond minimum standards and aim higher; seeing benefits from SLES early adoption (D2N2 LEP, 2019).
Manufacturing Technical	Electrical and mechanical engineer skills applied to advanced manufacturing (Burrows and Cripps, 2018; Carbon Trust, 2018). Such as plumbing and electricity for microgeneration, to enable the workforce to deliver quality products and processes related to SLES (DEG, 2013).
Building and retrofit Operation and maintenance	Sustainable construction and building technology skills (Burrows and Cripps, 2018; Paterson, 2018). Skills in sub-metering, monitoring, data management etc. (Carbon Trust, 2018).
Distribution	Skills to manage connections to the network, develop smarter control methods, constraint management etc. (Cheshire and Warrington LEP, 2018).
Supply	Skills to read smart meters and other smart appliances, as well as skills in engaging with consumers to raise awareness and promote behaviour change (D2N2 LEP, 2019; Gyron LLP, 2016).
Operability	End users (consumers, prosumers, householders) skills to best utilise and optimise appliances, as well as enable them to access services to increase energy efficiency and reduce costs, such as the choosing of different SLES technologies or behavioural change (Carbon Trust, 2018).
Decommissioning	Electrical and mechanical engineering skills; waste and recycling skills.

Cripps, 2018). Distribution network operators need smart skills to identify these balancing requirements, identify network constraints in time and place, and provide the necessary dynamic signals to SLES operators to adjust usage accordingly.

This agility of SLES to adapt to external signals requires mechanisms such as home sensors, or energy supply controls to provide the necessary response; along with the ability of the SLES data handler or operator to monitor and accurately record the response taken in order to reconcile settlement and billing. These systems therefore not only need the skills to design, install and operate SLES, but also to compile and interpret complex data sets.

Some LEPs have recognised that the energy transition will be enabled by smart skills to manage and assess new technologies such as data capture, handling and analysis; smart networks and digital technologies (Greater Lincolnshire LEP, 2019; Seguro, 2018; West of England Joint Committee, 2019). Therefore, in order to release potential, LEPs are looking for test areas where these innovative technologies can be further researched and developed, in order to be later exploited within their regions (West Yorkshire Combined Authority, 2019). The Warmer Worcestershire programme, for instance, seeks to increase local skills around smart thermostats (Corliss, 2018). This smartness of SLES also needs to be thoroughly understood by LAs in charge of developing local energy strategies, policies and programmes, allowing them to recognise and harness the potential economic, environmental and social benefits arising for their local communities (Gyron LLP, 2016).

4.2.2. Smart skills for SLES users

Skills provision needs to extend beyond the workforce to also include affected communities if energy transition is to be socially just. Therefore, the smart skills required by consumers to engage with new technologies and processes need to be properly identified and assessed and these skills should be fostered through local initiatives such as the ‘one stop shop’ advice centres advocated by Cumbria (Carbon Trust, 2018) or skills workshops as advocated by Derbyshire and Nottinghamshire (D2N2 LEP, 2019).

These skills can range from those which are relatively simple, such as reading a smart meter; to the more complex, such as understanding the nuances to choose between different energy providers, tariffs and technologies (Coast to Capital LEP et al., 2018). As more consumers become prosumers using behind-the-metre technologies and generation assets installed at users’ premises, prosumers also need to learn additional skills (including behavioural change) in order to best optimise these assets.

4.3. Local skills

4.3.1. Skills as a local economic asset

Analysis by Shakoor et al. (2017) shows that a smarter, more flexible energy system could result in financial benefits of between £17bn and £40bn to the UK by 2050, with many of these benefits realised at the local distribution level (BEIS and Ofgem, 2019). These benefits would accumulate from avoided generation costs and utilization of demand side response, storage and low carbon technologies on the distribution networks.

Additionally, there will be a range of economic benefits to be made by individual localities. For instance, the transition to a decarbonised energy future provides a key opportunity to both grow regional gross value added (GVA) through the creation of SLES related jobs, business ventures and trading models thus increasing local earning potential (Carbon Trust, 2019a); and also reduce the amount of GVA that leaks out of the local economy through energy spend (Humber LEP, 2019).

The development of the appropriate skill-sets within the local workforce should therefore be considered a priority for local communities to harness these economic benefits (Cheshire and Warrington LEP, 2018; West of England Joint Committee, 2019). However, local earning potential also depends on areas’ abilities to both attract and retain skilled workers to fulfil these roles (Carbon Trust, 2019b) as shown below.

4.3.2. The geographical distribution of skills

Skills and the ability to develop skills are likely to be unevenly distributed across different counties, regions and countries in terms of the quantity (i.e. the number of skilled workers) and quality (i.e. the specialisation) of the workforce (Sooriyaarachchi et al., 2015).

Regarding *quantity*, there is a general trend for skilled workers to migrate to urban areas where there are more work opportunities, leaving rural areas with a shortage of skilled workers to develop, manufacture and install innovative systems and technologies (Carbon Trust, 2018). Rural areas can therefore be locked in a ‘brain drain’ whereby it is difficult to attract skilled workers into the area, or retain existing skilled workers due to a lack of opportunities; resulting in their migration to more innovative urban areas (Carbon Trust, 2018). To help address this programmes such as the Rural Community Energy Fund aim to support rural energy projects to ensure that local skills can be properly used, fostered and retained (D2N2 LEP, 2019).

Regarding *quality*, specialist skills for developing specific tasks in the SLES life-cycle can also be unevenly distributed across different localities or regions. For example, areas with a long history of leadership in the engineering, industry and manufacturing sectors could consider that their existing skills base are well placed to transition their focus to developing the energy technologies within SLES (Gyron LLP, 2016; Humber LEP, 2019; Rhodes, 2018); while other areas could build upon their existing skills in research or digital innovation to become pioneers in energy systems innovation (CATAPULT, 2016; D2N2 LEP, 2019).

Therefore, some regions may decide to specialise in developing and strengthening skills which focus on specific stages of the SLES life-cycle, such as R&D or manufacturing, which other regions might struggle to provide in the short term. Indeed, one LEP identified the potential to “steal a march on other regions” in the development of new SLES business models (Rhodes, 2018). However, some regions have already taken a pragmatic approach in determining what aspects of the SLES life-cycle they can provide. For example the Isles of Scilly plan to import skilled workers from the mainland to install SLES; while developing SLES maintenance skills within the island community (Hitachi Europe Ltd, 2016). Additionally, North Yorkshire aim to rely on local skills for the installation and

maintenance of electric vehicle charging points and heat pumps, leaving activities like manufacturing to other regions (York North Yorkshire and East Riding's LEP, 2018). Such geographical sharing of skills and resources in the short term would necessitate collaboration amongst different areas looking to balance complementary skills and capabilities, which to some extent already occurs between neighbouring LEPs who have developed joint Energy Strategies (Paterson et al., 2018; Rhodes, 2018; West Midlands Combined Authority, 2018).

4.3.3. Skills for local governance of sles

The development of SLES is closely related to the devolution towards local governance of energy systems and the empowerment of local stakeholders into an increasingly decentralised energy system (D2N2 LEP, 2019; Geels, 2004; Greater Lincolnshire LEP, 2019); with traditional stakeholders such as policy makers or government adopting roles of facilitation (Frank et al., 2018).

It is therefore crucial to provide policy makers and LAs with the appropriate skills to understand how systems of innovation develop as this will be key for SLES to be able to transition from the R&D stage through to deliverable business models (CATAPULT, 2016). These skills include regulatory insight, inclusive leadership, finance, legal, IT, data collection, community engagement and business model development skills to be in place so that local communities can develop their own projects (West of England Joint Committee, 2019).

However, recent studies have shown that this isn't an easy task for LAs due to the lack of core funding for LA energy teams and their limited statutory powers or duties; meaning that LAs have a limited capacity for engaging in strategic energy management (Kuzemko and Britton, 2020; Webb et al., 2017). Despite this 310 District, County, Unitary and Metropolitan Councils across the UK have declared a state of climate emergency as of December 2021 (climateemergency.uk, 2020) having recognised that local energy solutions are key to local regeneration and prosperity. To this end LAs are developing their own creative energy propositions with the resources available to them (Webb et al., 2017) and research has shown that those LAs who have worked with knowledgeable third parties, such as universities, have been able to boost their knowledge capacity and political authority, often at no financial cost to the LA (Kuzemko and Britton, 2020).

Community energy projects supported by LAs have been identified as one of the main strategies to ensure that local skills can be used in the implementation of innovative technologies (Carbon Trust, 2018) while generating new income streams and building local confidence (CATAPULT, 2016). LAs can also play a role in engaging communities to develop interest, as well as the necessary business and finance skills for the trial of community SLES at different scales, such as smart meters in neighbourhoods, or large scale PV and energy efficiency in buildings (Liverpool City Region LEP, 2017; Owen, 2019). These business and finance skills would also enable community projects to seek out local investment for continuous development (GFirst LEP, 2019). If such skills are in place in communities, it would also be possible to build a stronger public, private, academic and community partnership for SLES (Barlow et al., 2018).

4.4. Skills provision

4.4.1. Developing a skills provision system

In economic theory, a skills gap is regarded as the mismatch between the skills held within the workforce and the skills required from them by employers. This mismatch can be caused by changes in demand, leading from the decline of certain industries and the emergence of new ones (Zekaria and Chitchyan, 2019) as is the case with the transition from fossil-fuel based energy technologies to smart energy technologies and digitisation. Skill gaps mainly occur when the new demand activity takes off quickly or changes rapidly; causing difficulties for training providers to react fast enough to address the new skill provision (Sooriyaarachchi et al., 2015).

Therefore, to anticipate the future workforce needs, the skills provision system could be approached in a systemic way, as a pipeline integrated by different stages, from the identification of skills gaps through to the effective deployment of the workforce. Developing a skills pipeline should enable both current and future workers to access the training and education programmes required to ensure they have skills and qualifications to carry out new and evolving roles (York North Yorkshire and East Riding's LEP, 2018).

Stages within the skills pipeline could include, but are not limited to:

- Identification of skills gaps needed for a SLES transition and the courses already on offer locally (DEG, 2013).
- Developing policy to effectively and efficiently shape the demand for, and development of, energy skills in the economy (Vona et al., 2015). In the case of SLES these policies could be targeted to support apprenticeships or community training to overcome future skill gaps (West Yorkshire Combined Authority, 2019), or support the development of education programmes based on STEM subjects.
- Developing or strengthening skill sets through embedding green education in the curricula of both lower and higher education establishments (Carbon Trust, 2018) or training providers, like energy training hubs (Rhodes, 2018), or by attracting and retaining skilled workforce from other regions (Carbon Trust, 2018).
- Distributing the skilled workforce where needed by providing a direct link between institutions linked with the skill provision system (i.e. universities or training centres) and the energy systems (i.e. R&D, manufacturing, energy generation or operation). Alternatively, through providing policy intervention (e.g. through subsidies) to incentivise the workforce to the areas of most need.

4.4.2. Developing a responsive network of skills stakeholders

To help address skills gaps an ideal skills provision system should develop a responsive network of key stakeholders to ensure skills provision meets industry and consumer requirements in quantity, quality and specificity (DEG, 2013; York North Yorkshire and East

Riding's LEP, 2018). Such a system would rely on close collaboration of sector skills groups and other partners to assess the existent training provision, as well as gaps in provision, so that a proactive skills pipeline that matches the emerging commercial opportunities from energy industry, can be developed (Barlow et al., 2018; D2N2 LEP, 2019).

LEPs are a natural starting point for creating a responsive skills pipeline, as they have a privileged position in facilitating, orchestrating and brokering relationships between the different stakeholders within their region that should play a key role in skilling, upskilling and reskilling individuals and organisations towards SLES (Carbon Trust, 2019a). In order to enhance cooperation some LEPs have introduced Skills Advisory Panels (SAPs) to “bring together employers, skills providers and key local stakeholders to better understand and resolve skills mismatches at a local level” (Oxfordshire LEP, 2021). For instance, the Oxfordshire SAP meets on a quarterly basis to produce evidence-based skills and labour market analysis in order to identify local skills and employment challenges, along with key areas of future needs relating to projected local employment growth. However, this level of commitment requires funding, resource capacity and the political foresight to prioritise skills assessment; which may not be currently achievable in all regions.

4.4.3. The ecosystem of skills stakeholders

The successful development of innovative solutions like SLES rely on the inclusion of a diverse, proactive, and cooperative ecosystem of local stakeholders within the SLES life-cycle (Lupova-Henry and Dotti, 2019).

The local ecosystem of stakeholders comprise two different, but closely related, systems:

- The first ecosystem of stakeholders is related to the skills provision system - in charge of assessing the gaps of skills and its development. Stakeholders included in this system could be training facilities, growth hubs, local councils, universities, civil organisations, businesses and so on (Carbon Trust, 2018; GFirst LEP, 2019; Greater Lincolnshire LEP, 2019).
- The second ecosystem is related to the SLES life-cycle and its supply chain, from the initial R&D through to final decommission of SLES. This ecosystem would include stakeholders such as manufacturers, installers and builders, energy producers, and network or systems operators (Burrows and Cripps, 2018; DEG, 2013); as well as stakeholders identified in the first ecosystem such as universities, local councils and businesses.

These stakeholders will be responsible for the correct development and deployment of skills for SLES.

4.5. Deployment of skills for SLES

4.5.1. Reskilling & skills transferability

LEPs historically strong in industries such as manufacturing and construction, believe that their existing workforce skills are highly transferable to the energy sector, which will prove to be a valuable asset (Foster et al., 2018; Rhodes, 2018); potentially enabling these industries to reap the rewards of SLES as early adopters, or take the lead as innovators (CATAPULT, 2016; West of England Joint Committee, 2019). To this effect, the University of Salford, developed the Energy House, serving as a construction innovation hub, where companies can shape research and develop construction skills (Owen, 2019); while the Intelligent Energy Systems Demonstrator at Thornton Science Park provides companies with installations to test smart grids, electric vehicles and other innovative technologies (Cheshire and Warrington LEP, 2018). In addition, the Electra project in Oxfordshire is developing smart charging points (Oxfordshire LEP, 2019) and projects like the Cumbria Low Carbon Energy Accelerator provide workshops and forums to guide local businesses on the transitions towards energy efficient opportunities and practices (Carbon Trust, 2018).

Adopting an approach based on the transferability of workforce skills, would safeguard the existing workforce as far as possible (Marin and Vona, 2019), thus providing stable employment futures and maintaining or increasing GVA in the local economy which is an important feature of many of the LEP strategies (Humber LEP, 2019). Safeguarding the workforce is also a key theme in the ILO's 'Guidelines for a Just Transition' (ILO, 2015).

4.5.2. Upskilling

It is expected that 41% of the energy sector vacancies in 2021 will require an education attainment of National Vocational Qualification Level 4 (NVQ4) or above in an appropriate discipline (Carbon Trust, 2018). This has been identified as a significant limitation for the energy industry in some rural and coastal regions, with for instance only 17% of Great Yarmouth residents reaching this level of educational achievement, which equates to less than half of the national average (Local Energy East Network, 2018). Such lack of native high-level skills across the English LEPs could become an even more acute problem for realising the potential of SLES which will require high quality and cutting-edge skills linked to innovation, digitisation and data in order to fulfil roles relating to technology development, maintenance and operation (West of England Joint Committee, 2019).

The provision of training through apprenticeships has been identified as a promising strategy to up-skill the working population and increase the number of NVQ4+ local people (Carbon Trust, 2018). Within this context, programmes like HETAS (Heating Equipment Testing and Approval Scheme), provided by the training centre in Sudbury, make a good example on how people NVQ Level 2/3 can be up-skilled in the energy sector (Local Energy East Network, 2018); likewise the Dalton Cumbria Facility which has developed close bonds through a skills group established between industry and the University of Manchester (Carbon Trust, 2018). In addition, some LEPs are planning the development of new multi campus universities within their regions to both provide higher education and address identified local skills gap (Ricardo Energy and Environment, 2018).

4.5.3. Skilling

Some LEPs are incorporating energy education into school and college curricula. Promotion of energy awareness at a young age could encourage more apprenticeship applications or involvement in further and higher education, thus opening up opportunities for ecosystem innovation (Carbon Trust, 2018). As the full SLES supply chain does not rely exclusively on high level skills linked to higher education, such a holistic approach to the skilling of wider local populations will be advantageous in recruiting for SLES across all skills levels. For instance the SLES supply chain also requires medium level skills related to supervisory, technical or crafting roles, as well as skills considered as lower level such as operation and transportation (Sooriyaarachchi et al., 2015).

To this effect, a group of UK students launched the Teach the Future campaign in 2020 (Brindle, 2020) with an aim to introduce climate change education into primary and secondary education as a ‘golden thread’ across all subject areas; and for vocational courses to be overhauled to reskill the workforce with the skills required to deliver a low carbon energy transition.

Many of the English LEPs reported the lack of STEM skills which are required for the development and deployment of new technologies (Carbon Trust, 2019b, 2018; West Yorkshire Combined Authority, 2019). Approaches to deal with this skills gap include the delivery of STEM focused programmes at different levels in local school or colleges (Carbon Trust, 2018; Hitachi Europe Ltd, 2016) as well as higher education programmes on mechatronics, automation and digital, electronic and mechanical engineering (Humber LEP, 2019; Liverpool City Region LEP, 2017).

The Humber LEP also identified that women are currently under-represented in both STEM training programmes and STEM career roles, citing that only 11% of the UK’s engineering workforce is female, the lowest percentage in Europe (Humber LEP, 2019). Additionally in the technology industry women make up only 12.6% of board members and 16.6% of senior executives (Inclusive Boards, 2018). To address gender equality the Humber LEP launched the pilot project ‘Women into Manufacturing and Engineering’ (WIME) in 2016 to attract women to careers in these sectors. WIME now has a network of over 30 companies in the Humber region promoting the industry to girls and women, from encouraging them to consider STEM subjects at school and helping them to access apprenticeships and employment in the manufacturing and engineering industries. Similarly, Greater Manchester has launched the Building on Equality programme for women (Greer, 2018).

Additionally, it is necessary that education and training providers cooperate with business, through the skills pipeline, so programmes align with the labour market demand. This will increase the employability of people when leaving universities or training centres by providing them with attractive skills and talents for an innovative and rapidly changing energy sector (West Yorkshire Combined Authority, 2019).

5. Discussion

This section draws on the key themes outlined in the Findings section and explores the relationship between these and the concept of a Just Transition. This involves the provision of decent, well-paid jobs which are available to people with a range of skills and with clear career progression opportunities in sustainable economic sectors - while also seeking ‘just’ distribution of burdens and benefits, recognition and participation for workers and affected communities.

We acknowledge that a Just Transition to decentralised and digitalised energy systems is a global concern, and not just an English one. Therefore, we recognise that by undertaking an English case study that we have limited the potential impact of this study. However, by contrasting the international academic literature with the grey literature that forms the English case study we show how theoretical and conceptual understandings of skills within energy transitions can give context to the experiences of affected communities. We believe that many of the issues raised through this study will be transferable to other contexts and can provide insights to other communities on the identification and deployment of skills provision to enable take-up of SLES.

5.1. Timely skills deployment

Whilst the transition to a low carbon economy will cause an increasing demand for the new skills required by the workforce (ILO/EU, 2011; Jagger et al., 2013) without direct and timely intervention the transition also has the capacity to both create skills gaps in emergent industries and cause adverse impacts for workers in declining industries.

Given the importance of the low carbon transition in combatting the effects of climate change, and the international commitments to a Just Transition, more attention therefore needs to be given to assessing the skills needed for SLES, alongside enabling the workforce with the new skill-sets required or risk the transition being made slower, more costlier and more unjust (Jagger et al., 2013). However, there is a fear that technological change will outpace the capacity of the training system to respond (Jagger et al., 2013) due to the inevitable time lag between developing courses, recruiting students and eventual graduation.

Our findings show that due to the multi-vector approach of SLES it is no longer possible to view energy skills within traditional industry silos of plumbing, heating, manufacturing, mobility, etc. A coherently functioning SLES has to encompass all of these skills within one system, using both novel combinations of existing skill-sets and new skill-sets (Jagger et al., 2013). Therefore, traditional training programmes need to increasingly reflect this integrated multi-vector approach, enabling cross-disciplinary learning and the combination of skill-sets needed for the interoperability of SLES. In addition, reskilling of workers already operating within traditional sectors should be encouraged, to ensure that workers existing skill-sets can be adapted, rather than become obsolete. This could include ‘on the job’ training and CPD opportunities to keep abreast of the emerging energy landscape (such as already advocated for plumbing and heating engineers) (CIPHE, 2020) or the new Lifetime Skills Guarantee to be launched in 2021 (HM Treasury, 2021).

It is essential then that the skills required for SLES are identified and anticipated early, potentially through local enablers such as the Skills Advisory Panels highlighted in 4.4.2. This should be in conjunction with the implementation of policies and strategies that

enable a managed decline of carbon intensive industries, alongside support for the growth of new industries. This will assist in both easing impacts on the workforce (Gambhir et al., 2018) and ensuring that the new skills acquired by the workforce are relevant for the emergent labour market (ILO/EU, 2011).

5.2. A 'Just' distribution of skills

It has been estimated that changes in energy production and use toward net-zero could lead to the loss of 6 million jobs globally by 2030, whilst creating 24 million new jobs, compared to a 'business as usual' pathway (Gambhir et al., 2018). However, these jobs will not be distributed evenly, for instance the siting of fossil-based energy infrastructures was determined by the presence of coalfields, oil wells and gas drilling rigs, which saw large-scale industries in manufacturing, engineering and technology maintenance converged around these regions. The shift away from such extractive industries could lead to increasing levels of poverty and unemployment in these regions, along with the loss of embedded local identity (Harrhill and Douglas, 2019). Additionally, job losses in areas dependant on fossil based industries can lead to further job losses in other sectors such as retail and construction due to the general decline in local and regional economic vitality (Graff et al., 2018). Therefore without policy intervention combined with public investments, these regions could suffer disproportionately (Nicolle et al., 2020).

A Just Transition ensures that the burden of climate action is not borne unequally by one set of workers or communities or any one country (Jenkins, 2019). However, in many countries the low carbon energy transition is happening against a backdrop of increasingly uneven distributional impacts caused by past transitions and in the case of England, a worsening of social inequality and regional disparities (Lacey-Barnacle, 2020). Problematically, there is a marked misdistribution of skills across the English LEPs which constitutes a barrier for some regions to be able to actively engage in, and reap the benefits of, a low carbon SLES transition. While some LEPs recognise their strength as emanating from a world class education and skills provision system; other LEPs report a shortage of home-grown highly skilled workers, combined with an inability to attract skilled workers to the region and an undiversified supply chain (Carbon Trust, 2018).

Rural areas in particular are associated with skills shortages on specialist skills like engineering combined with a perceived inability to deploy SLES infrastructure (York North Yorkshire and East Riding's LEP, 2018). The lack of skills in these areas could therefore require cooperation from across different regions in order to access the necessary technical skills and the numbers of people required for developing SLES (Hitachi Europe Ltd, 2016). To help alleviate regional disparities, governments could direct investment to those geographical areas which are most adversely affected by skills gaps; whilst also providing subsidies to support the migration of jobs into those areas (Zekaria and Chitchyan, 2019). This would enable 'levelling-up' between regions by creating opportunities for all regions to participate in the energy transition.

While energy systems themselves are becoming more localised, energy governance remains primarily at the national level (Britton, 2019a; Willis et al., 2019); stifling LAs opportunities to provide a coordinated response to system change due to the lack of statutory duties. It has therefore been argued that decentralisation of energy resources and other interrelated issues (i.e. energy democratisation, growing levels of digitisation and meeting decarbonisation targets) leads to a greater need for local level energy governance, with a formal co-ordinating role devolved to local authorities (IGov, 2019). However, as successive governments in recent decades have reduced grant funding to LAs (PCAN, 2021) further activity is currently stifled through lack of funding as well as lack of powers, so this would need to be rectified accordingly.

A devolved role for LAs would however support the further development and implementation of SLES due to closer involvement with SLES communities, local businesses, training providers and other stakeholders (e.g. DNOs) through local decision-making. Local decision-making is important from several aspects. It can increase participants' levels of trust and involvement in the system; it can ensure that local challenges, constraints and desired outcomes are fully considered in SLES planning and development; which in turn can lead to better SLES engagement and outcomes through participation and sharing of ideas. Cumulatively, local decision-making, local energy planning, local carbon budgets etc. then begin to form a virtuous circle that increases participation through communication, network and partnership building and developing common goals.

5.3. Recognition and participation

Even with appropriate training provision, there will be certain sectors within the existing workforce who struggle or who are unable to transition from one form of working to another, for example either through age, health, capacity to learn new skills, caring responsibilities or relocation impacts. In these instances, social protection systems will be required to either provide additional support for retraining, or to provide redeployment or pension provisions for disaffected workers (Just Transition Centre, 2017).

Further analysis also needs to be taken to avoid discrimination of certain sectors of society when retraining and repositioning the workforce. For instance, the IEA reported that women's participation in the energy sector is below that of the broader economy, although there is notable variation across energy sub-sectors (IEA, 2020). For instance, despite making up 48% of the global labour force, women only accounted for 22% of the labour force in the oil and gas sector and 32% in renewables. They also reported a lack in female representation in higher paid roles, with women only holding 14% of STEM managerial roles.

The grey literature was silent on racial inequalities in the energy workforce, however research shows that in the technology industry 74.5% of board members are from white ethnic backgrounds, as are 71% of senior executive roles (Inclusive Boards, 2018). Therefore if SLES are to create a more inclusive workforce all inequalities need to be examined within both existing workforces and within training courses offered to ensure that everyone has the opportunity to a career path and progression within that pathway. The Just Transition Commission in Scotland recognised this, stating their intention to decrease gender disparities in relation to digital and

STEM skills training; along with the intention to increase employment of women, ethnic minority and disabled people to build a more inclusive workforce (Just Transition Commission, 2021).

While SLES immediately points to the higher-level skills of R&D, IT and manufacturing, SLES also require a broad range of skills across the whole SLES life-cycle and supply chain. While focus has been drawn on a lack of STEM skills, the broader inclusion of STEAM skills (including the Arts) would help to ensure a broader diversity of skilled workers, including skills in marketing and communications, as well as equipping those who will need to educate and persuade others of the advantages of decarbonisation and the necessary changes to lifestyle for mitigating against climate change (Vona et al., 2015; Zekaria and Chitchyan, 2019).

In addition, skills for SLES do not solely sit within the remit of employment. SLES also require skilled end-users able to optimise their equipment, read smart meters and adapt their energy behaviour in line with achieving net-zero. As more consumers become prosumers, or are able to participate in financially beneficial activities such as demand side response and time of use activities there could become a widening of the gap between those who are able to engage with SLES and those who can't. This could be through lack of the appropriate smart skills to be able to choose between different tariffs, technologies and the ability to best optimise these resources; or the lack of IT skills to engage with online energy trading platforms. In particular, older people are likely to lack the digital skills necessary to understand, customise and control technology (Judson et al., 2020a). However, evidence suggests that across England there is limited awareness of the meaning for, or the advantages of, smart technologies (West Midlands Combined Authority, 2018) which will need to be addressed in order for governments to garner the support needed for developing new practices, behaviours and standards aligned with decarbonisation objectives.

In addition, some households may not be able to participate in SLES either due to cost of technologies (such as solar PV, batteries, EVs, heat pumps and smart appliances) or housing tenure (e.g. the inability or unfeasibility of adapting rented properties). Unless these socioeconomic issues are fully explored within the context of a net-zero energy transition this risks creating an energy system that is more unjust, as well as making it more likely that national decarbonisation targets will not be achieved (Britton, 2019b).

6. Conclusion

Energy transitions don't happen overnight; they can take decades or generations, even for relatively wealthy, small, and committed countries (Gambhir et al., 2018; Sovacool, 2017). However, given the need to deliver net-zero by 2050 at the latest, and the current disruption already emerging in the energy system, this means action on skills development is required now, or risk slowing down the energy transition and making it more costly and more unjust (Jagger et al., 2013).

Throughout this paper we have shown the inadequacy of analysing skills for the net-zero transition along the conceptual lines of green and non-green jobs only. Instead, we argue that a 'just' net zero energy transition necessitates consideration of additional dimensions such as those of distribution, recognition and participation. This study was therefore challenging in that it necessitated bringing together contrasting areas of academic study into a practical examination of what justice entails for communities in transition, as well as a range of policy tools to enable these Just Transition considerations. We therefore suggest that future research could build on this framework to develop the findings and apply them to different regions.

Upskilling, reskilling and the retention of skilled workers are crucial components for regions to create sustainable jobs and maintain and attract investment in their areas (Paterson, 2018). However, we have shown that the net-zero transition has the potential to widen existing regional disparities further if workforce skills are not addressed within a coordinated approach. We noted that at the local level, the creation of a skills provision system would enable stakeholders to review current skills provision, identify skill gaps and seek to influence greater availability of skills in alignment with the requirements of industry.

We also noted that a range of skills are required by end users. While some LEPs are incorporating energy education into school and college curricula to promote awareness from a young age, there also needs to be wider community promotion of the benefits arising from the energy transition, along with the requisite skills needed to engage with new technologies and processes to lever those benefits.

While we recognise the potential role for LAs in identifying local priorities and shaping local decision-making, we also recognise that not all LAs will have the same capacity to act due to funding priorities, political will, access to local training provision as well as skill-sets held within LAs themselves. We have shown how for some regions there are aspirations to become 'national pioneers', building on a history of industrial expertise; whilst for others there are concerns of being 'left behind' unless they can either attract permanent skilled workers or import them temporarily to fulfil certain aspects of the SLES life-cycle. Without direct intervention and investment in those areas therefore, SLES development could further exacerbate the urban-rural economic divide.

A national framework approach which supports devolution to the local level alongside long-term policy objectives for net zero carbon localities, investing in LA net-zero teams and capital expenditure planning could be beneficial (Tingey and Webb, 2020). This could ensure that people and businesses in all regions have the opportunity to experience the same benefits, whilst also maximizing the chances of meeting national net-zero targets through allocating local carbon budgets (Webb et al., 2017).

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CRedit authorship contribution statement

Rachel Bray: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **Adolfo Mejía Montero:** Investigation, Methodology, Data curation, Writing – original draft. **Rebecca Ford:** Conceptualization, Validation, Writing –

review & editing, Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. Methods

This appendix details the methodology employed in the case study, which underpins the Findings presented in the paper.

Approach

The relative infancy and scattered nature of literature related to the different dimensions of SLES stood as a challenge for effectively underpinning and analysing the skill gaps related to the delivery of SLES and its overcoming strategies. In response to this challenge, the authors deemed it appropriate to use a systematic literature review as an appropriate research strategy to pull together the various strands of academic and grey literature which engaged with skills and SLES. It was by following the procedures and guidelines suggested by Wong et al., (Wong et al., 2013) and Snyder (Snyder, 2019) that the following three methods were used to locate relevant studies: a keyword search in reference databases, a backward search of key documents, and an official website search.

This approach intended to identify any previous work already pulling together the different streams of information around skills and SLES, potentially providing more holistic insights and a more synthetic set of references than a scattered search on more general documents. From this initial search 15 academic documents were selected through title and abstract screening.

Review Search strategy

The literature review was conducted through an online search in Science Direct, JSTOR, academia.edu and Google Scholar Scopus looking specifically for the words

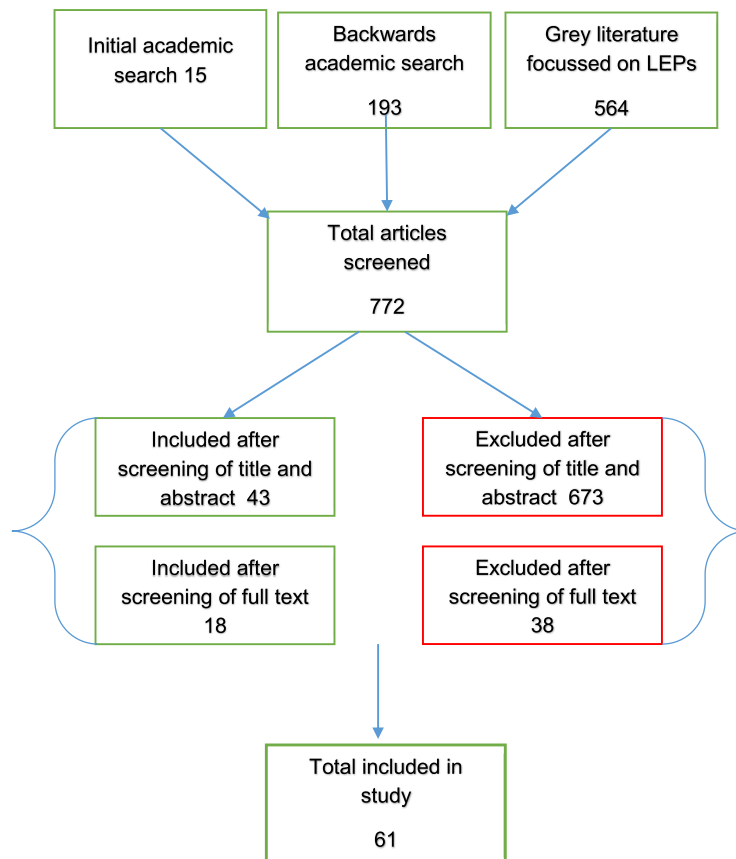


Fig. 3. Studies remaining after search, screening, and inclusion/exclusion processes.

- Systematic review AND
- Skills AND
- Smart OR digitalised OR
- Local OR decentralised AND
- Energy systems

Screening process: applying inclusion and exclusion criteria

All articles found through the online search were screened for relevance to the study by two researchers until high levels of agreement were reached. Inclusion and exclusion criteria were first applied to titles and abstracts where available. Where the title and abstract provided insufficient information to be certain, the full paper was assessed and the inclusion and exclusion criteria reapplied. Those that did not meet these criteria were excluded from the study, although have been counted as excluded under the initial search term for completeness. All included studies were added to Mendeley and any duplicate articles discounted from the final total.

Inclusion Criteria

All documents were assessed for inclusion based on the following criteria:

- Inclusion of substantive consideration and discussion of skills in the context of energy systems
- Appropriate focus on aspects of smartness/digitalisation and localness/decentralisation in the context of energy systems and sustainable economic development
- Published in English

Exclusion Criteria

Since the scope of this review was concerned with the delivery of skills in a smart and / or local net-zero energy system, we excluded documents which met at least one of the following exclusion criteria:

- The paper had a focus on jobs rather than skills
- The paper did not have a focus on energy systems
- The paper did not have a focus on skills

Following application of the inclusion / exclusion criteria, a total of 61 studies were included for analysis (see Fig. 3).

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