- Consistent policy supporting wider retrofit activities as a pre-requisite for heat pump installation;

- Both of the above points should be delivered in parallel with a **wide-scale public awareness raising** campaign, educating homeowners and tenants about retrofit, its financial and environmental impact and funding opportunities.

At a local level, different parts of local government need to be engaged together to ensure **clarity and consistency across different policy areas** – for example planning, climate emergency response etc.

Another area where local / national government could intervene is in supporting technology use via **land allocation for infrastructure development**. It was suggested that installation of clusters of boreholes connected to distribution pipework would help facilitate wider connection by a range of householder types – similar to district heating arrays but with greater levels of individual control.

In summary, the lack of policy clarity and funding support to enable heat pump solutions to scale up is putting a substantial barrier in the way of this as the future of domestic heating. Relevant professional education providers need to ensure that training is included in their courses, and that updating skills is accessible to all. In parallel, unfamiliarity and nervousness by consumers means demand is still low. Pilots like that of ESO will help to prove the technology and usability but this is a slow way to approach carbon neutrality in domestic heating.

8 ICT for SLE Sub-System: Findings from Data Analysis

ICT infrastructure is the key element that enables the different parts of the system to be optimised and to connect with each other and the wider energy system. We have noted in the different subsystems where there are particular issues to do with ICT – for example in the non-interoperability of chargepoints or consumer resistance to smart domestic heating management. Here, we reflect on the higher level system skills needed to facilitate SLES in the ESO approach.

8.1 Barriers and enablers for the ICT sub-system of ESO

The drivers and obstacles of the ICT sub-system in the ESO SLE project are demonstrated in figure 7 below.

Energy markets are the key enabler for the emerging smart energy system. ICT systems support a range of activity in the energy market, enabling optimised deployment of renewables and flexibility alongside domestic and EV connectivity into the system. The ESO platform is innovating with optimisation of batteries, connections to the transmission grid and EV chargers.

Novel smart energy services are also becoming more important due to the **NetZero targets** set by the UK's local and national governments. Driven by these targets, various funding opportunities have been made available, such as the Green Homes **grant**, which, in turn, has increased the consumers interest in heat pumps, battery storage, and EV solutions, motivating creation of **new services** and development of new business models around such services. The **falling cost of renewable energy-based technology** has also led to improvements in the price and performance **competitiveness** of these projects. This has also been supported by success of the recent **example/demonstrator** smart energy projects.

Unfortunately, the longer-term **energy policy** of national government is less than clear, which makes committing to longer-term research and development projects rather more risky.

Despite the SLE success examples and improved competitiveness of renewable energy technology, the smart energy services-based solutions remain a complex area both technologically (e.g., needing to integrate various data streams, install different batteries, connect to distribution as well as transmission networks, navigate legal and regulatory scenes across local authorities and organisations, etc.) which continues to hamper replication and growth of such solutions.

8.2 Skills for the ICT sub-system in relation to ESO

Below, the current and future skills needs and shortages for the ICT sub-system have been analysed and aggregated into generic skills areas, identifying specific types of skills required in the ESO context. We also note that many topics (such as policy, regulation and soft skills needs) that relate to ICT sub-system, have already been discussed in previous sections, where ICT is integrated into their service delivery. Thus, to reduce repetition, only additional skills, not discussed in the previous sections, are noted.

8.2.1 Energy skills for the ICT sub-system

- **Knowledge of energy trading mechanisms**: the energy system is "incredibly regulated" (E4) and while ICT solutions can be developed to support compliance with the regulations, as well as enable business activities at the energy market, the software design must be informed by what the current legal, policy, regulatory constraints, practices and norms are within the energy sector. Given the complexity of the sector (e.g., energy trading varying from real time to year ahead, keeps to various settlement practices, prices are regulated differently for different customers, etc.), design and delivery of operational solutions can be delayed due to the need to access, gather, implement and validate the energy trading domain requirements.

- **Knowledge of energy management**: to deliver an energy management solution, ICT practitioners need to account for the health and safety and energy quality needs of the system (e.g., what frequency should the system operate at, what kinds of loads can be started/stopped with what time lag and what impact would they cause to the quality and safety parameters, etc.). While detailed understanding of this may be left to the power systems engineers, the ICT engineers do require an understanding of the energy management domain which presently is not integrated into most of the ICT educational programs.

8.2.2 Engineering skills for the ICT sub-system

Power Systems Engineering, including:

- **Battery management** software solutions require battery understanding and control support at two levels, both of which will need specific knowledge about the given battery types and software context and domain constraints:

  - as part of the battery interface itself, enabling control of charge/discharge activities as well as monitoring of the battery state; this is the API delivered by the battery manufacturer (e.g., E4: “Each battery has to be managed in different ways, their state of charge has different characteristics….”)
  - as part of the whole SLE system, where a set of batteries are used and their charge / discharge is managed as part of the system optimisation (e.g.: E4: “… understand how a vanadium flow battery works such that we can then figure out how we optimise the two”).

  Familiarity with battery workings and APIs is currently lacking within the general ICT profession, e.g., E7: “if we were to get a control engineer in, there would then be a good chunk of three to six months I would say of bringing that person up to speed with how the systems work and how our control works”.

- **Integrating energy devices** into the data collection and analysis framework is another keenly needed skill, as the wide variety of devices (from PV to smart thermostat) come with a wide variety of hardware and software APIs as well as varied data formats and access rules. (E.g., E15: “‘it’s an unmanned site, … it’s connected to our back office via 4G internet usually… we have a 24/7 call centre…”) Familiarity with the said APIs is an area that needs upskilling within the ICT profession. This is an even more relevant need as the technology development and deployment continues to accelerate even now.

Data Science and Data Management

- **Data management** is very relevant as much of energy data is classified as personal data; the volume of generated and processed data is also very large. As noted by E13: “Habitat Energy is in real time getting data from lots of different sources. Making decisions on that data…Skills around … databases, setting up links between databases, skills around checking for errors, capturing errors [in data], making sure that there’s fault tolerance...” are all critical for energy data handling. Though these skills are not unique for energy systems, they are in high demand across many manufacturing and service industries.

- **Data analytics and machine learning skills** are also critical in ESO, as data analysis will underpin the system optimisation decisions. Both analytics and optimisation algorithm development and use are highly sought-after skills (e.g., E14: ‘the learning and evaluation that will come out … data and the electric vehicles, [will] … help set ongoing fleet strategies’).

- **Technology health diagnostics** is one of the areas where data science can be particularly relevant, e.g., by identifying failing or underperforming aspects within the heat pump installations and proposing solutions, e.g., as per E5: “…gain the data from their installations to make sure that those heat pumps are performing well…”.

- **Optimisation Algorithm Design** skills underline all novel business models, as they are “optimisation services for the energy that we use or produce” (E4). It is worth noting that each SLE aspect of the ESO project would require understanding of domain catechistic to be integrated into the respective optimisation algorithms. For instance, for battery optimisation, the designer would need to understand the issues around battery life optimisation, interactions between different battery types, market opportunities that a battery can utilise, etc. Thus, both basic algorithm design and domain specific knowledge are required here.

- **Security Engineering**, including both communications protocol and network layer concerns, software security issues, and threats and concerns around user-level interactions with the systems.

- Software Engineering skills, including:

  – Requirements Engineering which “provides the user requirements as how you’d define it in product terms for what then the tech team developed” (E4);

  – GUI Design to Empower Users with their energy decisions, “give the customer the ability to understand” (E5) and control their devices better;

  – Back and Front End Development, as ICT solutions must be developed very much for each of the services that ESO is setting up (E4, 13, 16);

  – Software Architecture Design specifically accounting for the integration of the distributed and decentralised IoT devices, networks and cloud infrastructure (E13).

- **Systems and software integration**, as “software can connect with any asset” (E18) and can manage it, but only if the asset and the software are correctly integrated. Moreover, integration of the various parts of ESO software solutions is another challenge, as each is being developed at the same time by different stakeholders.

8.2.3 Managerial skills for the ICT sub-system

- **DevOps skills** to bring software development and managerial processes together “there’s a whole strategy that’s being built … to make sure that IT and operational technology can work together” (E16) as well as to support software developers with processes for concern escalation, communication, etc.

- **Knowledge of both energy and ICT technologies**: from a management perspective, sufficient knowledge of the industry and technologies is needed. For instance, E4 notes that “there is a very steep learning curve not only in the tech industry, but also in the energy sector. So it’s the double whammy of being an incredibly complex industry …. I think there’s a level of depth that you really do need to get to in order to be able to make strategic decisions and have meaningful conversations”.

- **Building collaborative relationships across disciplines and hierarchies** is importation as noted by E4: ‘from a project management point of view … with each topic we pull in people, commercial, legal, tech as needed….”. This is because the ICT delivers not only as a technical solution, but also a business model that will be enabled and must legally operate on basis of that solution. As previously noted, such cross-disciplinary and collaborative relationships building is a generic, but highly valued and sought after skill.

8.2.4 Finance and Business skills for the ICT sub-system

- **Development of new business models** is a key part of the ICT solution delivery, as noted by E4 "it's hard to kind of disassociate our technical function from our commercial function because they're so intertwined in the initial development of the tool". Thus, given that all SLE solutions are "smart and digital", the business model developers need to have a clear understanding of how this model will be supported and/or enabled through the ICT solution.

- **Operating energy trading platforms** requires good grasp of financial and commodity market operation, as well as strong grounding in the energy trading domain, as these professionals will monitor both the software and the market behaviour and make trading decisions accordingly. E.g., E4 notes 'we have a commercial team that oversees the actual management of the assets from a physical point of view to make sure is our algorithm behaving correctly. But then also what decisions do we make from a trading point of view in the short-term energy markets…"

- **Commercialisation of Research** is another overlooked aspect of Financial and Business skills, e.g., E5: "This area has been researched and researched for many years. In terms of commercialisation, I haven't seen that many projects that have done it…".

8.2.5 Legal skills for the ICT sub-system

- **Integrating GDPR constraints into software solutions** is necessary, as all SLE services are built around "… the sharing of data, [yet] different organisations have different acceptability in terms of liability and also what they're prepared to accept in terms of different terms and conditions… when it comes to sharing of data and good old GDPR and also liabilities, you start talking about putting in 5, 10, 15 million pound liability clauses, it's certainly not going to fly with some of the smaller more tactical organisations that we need to work with." Thus, software professionals need to have sensitivity to, and build in checks for such data related concerns into the solutions they produce.

8.2.6 Soft skills for the ICT sub-system

- **Willingness to Participate/Dynamism** is a necessary skill for those working in a fast-changing environment, as noted by E4: "… you pick up jobs as you go through, my job description has changed three times over the course of a year."

- **Customer engagement**, which requires thinking about "how to best make sure that these customers are happy..." (E5), including:

  1. **Customer Education**, e.g., "there has to be a lot of education. [to]… the people that are using those tariffs and going into these projects. But also a more wider education into how the system is going to work…" (E5)
  2. **Ability to Listen to Customer needs and address them**, e.g. "identify …issues and then basically tell them that if you change some of these settings it might work better." (E5).

8.3 Training for the ICT sub-system

8.3.1 Training needs

Building on the skills areas identified above, we identify the following key training areas:

- **Data Science, Analysis and Management**: as noted above, all SLE solutions are rooted in use of data for designing optimised ways of resource (e.g., EV, battery, heat pump) use.
- **Software Engineering** training to deliver applications and platforms which fit the user needs (for homeowners who would be controlling heat pumps at home, to energy traders who would be using buying and selling energy supplied and demanded by their customers).
- **Cross-Domain training**, whereby the ICT solution developers (e.g., algorithm designers, security professionals, platform developers, etc.) are well informed about the:
    1. **energy and power systems properties** (e.g., from criteria affecting battery degradation rate, to factors impacting heat pump operation), energy market mechanisms (e.g., what services – such as firm frequency response or demand side management - and markets (e.g., real time or day ahead) can a particular device participate in, and what returns can be expected from such participation), and user behaviours and perceptions which impact how they engage with devices and software solutions.

8.3.2 Modes of Training

- **University (Degree Level) Education** and events where "there was a lot of stuff that …[one]… picked up on during the … engineering degree". But also by getting "…involved in projects outside of his university degree" (E5) (e.g., as part of an electronics club or computer science club, attending hackathons) where the skills and knowledge from the degree level program can be applied and expanded upon.
- **Take courses while working** "… people that needed additional training, which courses they would like to take and the company would pay for it, we just need to agree on the timescales…" (E5). This relates to the very specific technical courses, e.g., React Native for GUI development, etc.
- **Learning on the job**: "There really is only one place to get those skills from and that's spending time working on our systems. So there's no course you can go on, there's no external training you can get for this. You just need to spend time with our control engineers that we already have and learning off them how it works. But also getting your hands on the kit. … And spending time working on it" (E7).
- **Example (Blueprint)-based Learning**: e.g., "… what we're trying to focus on really strongly in ESO is developing a blueprint alongside what we've done…to then give a kind of a cheat sheet to any other city that wants to do it. And I think that is part of the training" (E4).
- **PhD level education** is also very relevant get a "…good understanding of the bigger picture, how different things fit in…" (E5) as well as to undertake focused research into novel technologies and solutions.

- **ICT professionals very often engage into self-directed learning** by using materials/lecture slides and web resources to pick up a particular skill or knowledge that they need.

8.3.3 Recruitment

Innovative SLE ICT organisations tend to be smaller with “limited resources and big ambitions” (E4) so, when they recruit, they are looking for “specific types of people for that job. You’re not just a cog in a machine, you’re one of 20, it’s a small group, it has to be very obvious how you would fit in and what benefit you would provide” (E4).

These companies recruit primarily well qualified ICT professionals (at least degree level graduates), but also look to attract experienced developers and data scientists to “hit the ground running” where possible.

8.4 Insights and recommendations

8.4.1 Nature of ESO ICT companies and employees

Given the novel and often innovation-focused work that the hires of such organisations would undertake, the employers look at attracting graduates who are **able to undertake self-directed learning**, have **broader than the degree interests** (e.g., have not only completed a degree, but have taken part in various clubs and hackathons, applied and expanded their knowledge in development projects). In terms of **ICT skills**, these organisations are looking for:

- Software engineers for platform/service implementation,
- Algorithm designers for optimised control and trade solution design, as well as
- senior and junior data scientists for data analysis and machine learning solutions. **Project managers** at premium are those with:
- DevOps skills,
- multi-stakeholder management experience, and
- good grasp of energy and ICT technologies.

8.4.2 Data-centric and replicable solutions

While the ICT-part of the ESO project requires provision of software development and networking solutions, these are primarily relevant to domain-specific businesses (e.g., heat pump control, EV charge point installation and remote maintenance, etc.). For the ESO SLE system, the assets of the paramount value are **data and experience**. The project is committing significant resources to **collecting and analysing data** (e.g., on how the batteries with vanadium and lithium flows compare in charge/discharge/degradation properties, how home owners behave with respect to heat pumps, etc.). This data is then used to refine the piloted business models and demonstrate their economic viability. Notably, data from across different business and application domains will be integrated and **new knowledge on cross-domain properties** will be developed. Thus, the data and software engineers working on such demonstrator projects will, by the virtue of participating in these projects, be **uniquely upskilled in cross-domain knowledge and data analysis**. At the same time, the project partners **explore, define, and test processes and practices** (e.g., what environmental regulation is relevant for transmission-connected battery installation? How to best engage the local authorities? How to manage project which cuts across local authority boundaries? etc.) for replicating the ESO solutions in other locations. Thus, the project partners will **uniquely upskill their respective employees** (e.g., city planners, legal experts, project managers, etc.) and produce new processes and practices which could prove very relevant to other businesses wishing to replicate the ESO business models. To maximise the positive impact of the project, both the unique profiles of their ICT and data analysts and the novel business practices and processes should be made publicly available. Indeed, some of these "blueprints" are shared (as per E4), but a wider transparency of the relevant skills is relevant.

9 Local Authorities Subsystem: Findings from Data Analysis

Oxford City Council (OCC) is one of the core partners of the project and has a key position as 'the landowner and the local authority for the centre of the project … a fleet owner and operator… owns a reasonable amount of land in and around Oxford and a number of quite forward-thinking targets in terms of decarbonisation targets, net zero and things like the zero emission zone' (E14) .

OCC's specific role in the project is around the electrification of some of its vehicle fleet along with associated infrastructure but it also has a wider role as indicated above as planning authority, and with 'responsibilities for the Redbridge Park and Ride because we own the land' for the EV CP installations.

Internally, OCC 'already had a strategy to electrify 25% of our fleet by 2023 and this pot of funding is really helpful and supportive of all of that' (E14). The city council operates its fleet through a wholly owned subsidiary organisation 'Oxford Direct Services' (ODS).

ESO therefore has a clear role in helping the council to meet its decarbonisation and air quality targets through accelerating EV uptake.

9.1 Barriers and enablers for the local government sub-system

Factors impacting the local government sub-system are summarised in Fig. 8 below.

As previously discussed, the **support of the local authority** makes SLES initiatives much easier to develop: 'the city council I think sits at the heart of everything' (E11). However, this comes with leadership responsibilities: 'You really need that clear governance and that clear strategy at the outset …. You need the … head councillors of the authorities to be really backing this to make it happen" (E14).

A local authority is a wide-ranging operation, and a number of **different departments need to work collaboratively and consistently** towards initiatives that might originate from the sustainability team. For other parts of the authority, this is unfamiliar ground, dealing in areas that are not normally within their remit so 'the biggest challenge is having a local authority with the skills and capacity and experience to pull everything together' (E11). While council-wide "institutional knowledge and a team" (E11) working towards net zero are needed, there **is no 'joined up thinking** at the Council… That is just an organisational issue' (E3). This is because the local authorities are large organisations with **many priorities and tight budgets** so this connection and drive across