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

10.1 Factors Affecting Bristol's SLE ICT sub-system

Drawing on the interview data analysis, we have formulated the causal model of Bristol's ICT for SLE sub-system, as shown in Figure 16 [16], and briefly explained below.

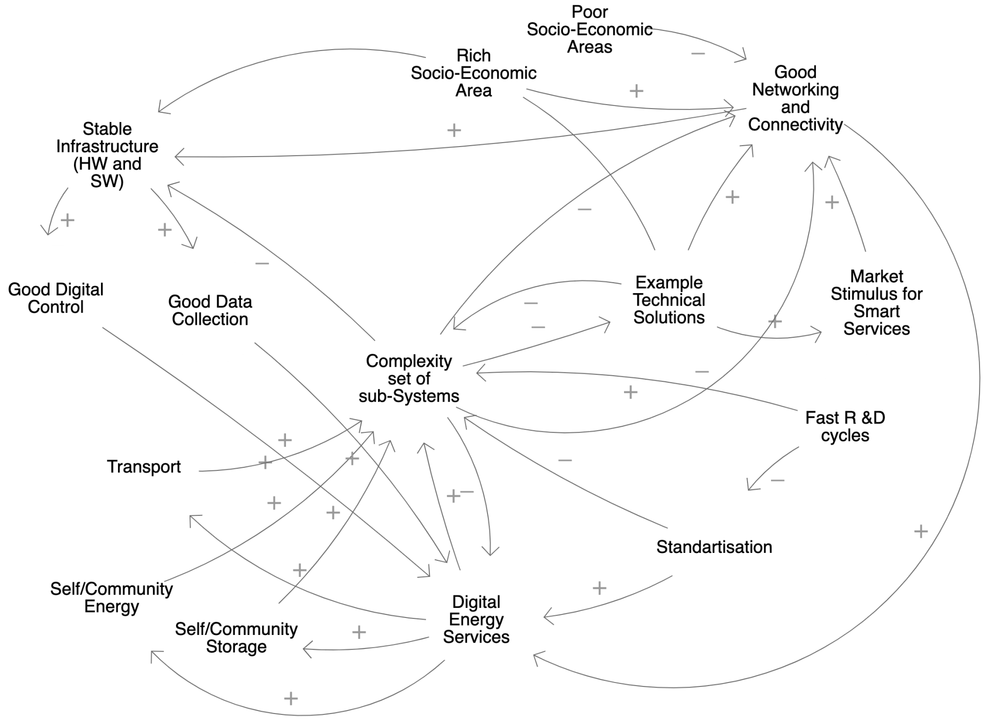

Figure 16: Causal model of the Bristol's ICT for SLE Sub-system.

Our interviewees note that the key defining feature of the SLE ICT projects are in:

Complexity due to the need to integrate multiple hardware and software interfaces. This emanates form the fact that SLE projects face the need to integrate across multiple energy vectors (e.g., PV, wind, bio fuels) and SLE SoS sub-domains (e.g., transport and mobility, household consumption, community generation, digital elegy services). Each of these vectors and domains (by necessity) is supported with custom hardware and software solutions. Orchestrating a consistent solution across these heterogeneous set of hardware and software solutions is a complex challenge by itself. It is further aggravated by the varied provision of networking and connectivity infrastructure as well as by the fast evolution of the renewable-based technologies with their supporting software services.

The *Networking and Connectivity* is essential for data exchange for monitoring and control that the ICT solutions are expected to exercise within the SLE. Yet, availability of this infrastructure is uneven across the city of Bristol (as well as UK). In localities with high income and dense economic activity, the networking provision is assured, while in more deprived areas, it is scarce.

[16] This model can be simulated through this url: `https://energysystems.blogs.bristol.ac.uk/2021/03/08/ict/`

Given the unprecedented rate of research and development dedicated to the zero-carbon SLE technologies, it is not surprising that the *technological progress* leads to the fast cycle of hardware and software obsolescence. This fast technological change, in turn, *disrupts convergence to standards* and emergence of stable SLE SoS infrastructures.

It is also noted that *example technical solutions* have a substantial role to play in demonstrating the positive impact and role of the ICT-based SLE (SoS) solutions. This, in turn, allows other organisations/projects to replicate the said solution, thus reducing the complexity that they have to cope with. The growing number of examples also improves the state of connectivity provision: the examples demonstrate viable business use cases and reduced environmental impacts. Furthermore, such viable use cases also motivate policy makers to provide market stimulus to foster replication of such solutions.

In addition, *strong technical management* of ICT SLE projects (i.e., whereby the project manager is well familiar with the technical issues of the ICT and engineering technologies of SLE) helps to reduce the complexity of the project as well as deliver a successful sample solution.

Finally, where the intended user communities are deeply engaged with (e.g., co-designing the prospective digital SLE services), the likelihood of successful adoption and use of such services also increases (as demonstrated by the Replicate project in Bristol, for example).

10.2 What skills are needed for the ICT Sub-System presently and in the future?

While the interviewees noted a whole range of skills that are currently in use within the SLE sector, many of them were referred to as available through the traditional education and training providers. Though, for several years now, the ICT graduates have been in high demand across many industries, with demand outstripping supply of available software professionals. This trend is set to continue in Bristol (and likely across the whole of the UK economy). Thus, below we discuss only the specific skills noted as short within the SLE projects, over and above the current competition for the skilled ICT professionals across all sectors. The skills deemed particularly short within the Bristol's ICT ecosystem are detailed below, while also aggregated into generic types.

10.2.1 Engineering Skills for the ICT sub-system

- Software Engineering skills:
  - *Agile Processes and Practices* skills, so as the engineers and users from across various project partners can collaborate effectively, e.g., "communication channels between …preferably an engineering level [are needed] because …[else] politics generally takes over and you don't have as much focus on what you're actually trying to do" (P1).
  - *DevOps* skills, i.e., continuous collaborative process between the development and operations roles within the SLE projects. While the agile process integrates customers and developers, here the role of operations teams (e.g., systems engineers, system administrators, release engineers, DBAs, network engineers, security professionals, etc.) are considered equally relevant at all stages of software engineering for SLE: from system scoping to development and production support.
  - *Requirements Engineering* skills for SLE (SoS) are critical, as too often, both the customers and partners across the SLE projects have incorrect understanding of what the

intended smart solution must do (e.g., "From the beginning the possibilities of demand management were very unclear" (P1)), and what capabilities are available in technology, local environment and infrastructures, regulation and legislation's that would underpin the solutions, and from across the partners themselves (e.g., " …everyone will have in their mind a concept of what they expect this technology [or infrastructure, or partners, etc.] to do and how they expect it to be going forward" (P20)). So requirements engineers must bring along both system scoping and software engineering skills, and understanding of the energy domain and technologies.

  - *Programming skills with various environments and languages*, including, but not limited to embedded systems and internet of things, using such broad scope of technologies as LoRaWAN, Things network, Kubernetes, DockerC, NodeJ, Python, etc. It is worth pointing out that there is no single language or platform that is considered more relevant than others, as each company and product will use a different set. In most cases programmers are able to pick up new technologies and languages as necessary, though proficiency comes with some time delay. Such time delay could prove a challenge in innovative SMEs who need employees to "hit the ground running" (P29).
  - *Machine Learning and Data Science* "…are going to be [needed] more in this space in the future" (P25), where machine learning is used to both optimise the system performances, but also "to begin to understand people's behaviour" (P10) so that better and new services can be delivered.
  - *Data Engineers* are needed to both specify the type and granularity of data to be collected from specific sources (e.g, design data aggregation and dis-aggregation solutions) and routes of data use to enact a desired impact. As per P20: "You need to understand how you're going to make the world better through this data that you've got. And if you don't really have a handle on that initially then you might monitor the wrong things."
  - *Deployment skills*, whereby for a sustainable solution, the software must be integrated with the hardware and deployed in such a way as to *avoid additional dependencies on users and environment*. For example, "…getting power and comms to something" is a not-trivial task, "…even just deploying something out on the side of a road, it will only work for so long before it runs out of batteries" (P20).
  - *Privacy and Security* delivery skills are also in short supply. E.g., P1: "GDPR is always a big concern with most tech projects" as shared energy data would need to have " a lot of obfuscation" (e.g., changed names and identifiers).
  - *Robust Hardware/Software Manufacturing* skills are essential, for "building robust technology to scale up". This is because the technology is deployment is distributed across many locations (e.g., household premises) and "if you've got a thousand units and they fall over once a month, then by the end of two months all of your devices will have failed because you won't be able to go out to turn them back on again" (P20). Currently the solutions in SLE ICT projects are less than robust.

- *Networking and Telecommunications* skills relate to the set up of networks for commutation and data exchange between the devices as well as individuals within the SLE (SoS) subsystem (e.g., data on location, speed and charge/fuel level of buses, locations and routes of electric bicycles, excess/shortage of available electricity, etc.). Often the SLE projects suffer, as they expect networking/telecommunications infrastructure, which turns out to simply not be available (e.g., the project expected to "…leverage the software defined networks technology …but the networks were not available at the deprived areas …" (P25)). At the same time, the available connectivity solutions (e.g., wifi, 4G and 5G phone networks) tend to be too expensive. As a result, the SLE ICT projects could benefit from skillsets allowing them to set up own networking solutions.

- *Systems Engineering* skills refer to the ability to inter-connect the software and hardware components within and across the various sub-systems of SLE SoS, for this the following skills are noted:
  - *Systems Architect* skills to oversee the "complex web of different partners doing different things" (P29) with " different technologies and background ITs" (P28) and put these together into an integrated, working system.
  - Considering *Scalability of the system-to-be* is another key skill. Often trade-offs would need to be made, for instance, between the level of control that can be exercised over a solution (e.g.: implement everything in-house from scratch) and the convenient, readily scalable technologies (e.g., AWS for data storage); security vs speed of system response, etc.
- *Multidisciplinary Engineering* requires that engineers within SLE SoS are able to either collaborate closely, or draw on more than one engineering discipline. This is because electronics, civil, mechanical, software and other engineering disciplines are often expected to be applied together, as solutions are often multidisciplinary "…in how they're put together so you might be a mechanical engineer but you're also working in software electronics" (P21), or needing to install sensors along with software solutions (P20) and so on.

10.2.2 Energy Domain Skills for ICT sub-system

- Understanding of the *Fundamentals of Power Systems and Renewable Energy* is considered to be relevant for the ICT in SLE. Though this is not novel knowledge per-se, it is relevant for ICT professionals working with the SLE solutions.

10.2.3 Trades Skills for ICT sub-system

- *Installation engineers* are noted as necessary for "installing stuff into people's homes" (P20) and elsewhere, over which an ICT solution could be developed. Though installers are not currently in short supply from the ICT domain's perspective, it is noted that the scaling up of the SLE activities will require proportional scaling up of the trained installation providers as well.

10.2.4 Managerial Skills for ICT sub-system

A critical point to note is that an ICT project manager must have sound understanding of the ICT technologies. The specific skills noted as short within Bristol's ICT SLE projects are:

- “Technical project management is …definitely desperately lacking from [SLE ICT] industry” (P20). Yet, the SLE projects that succeed are generally those where “…the engineers were also the project managers”.
- *Systems Integration Management*, whereby the manager would ensure that the team members:
  - have a clear *understanding of the capabilities of the chosen technologies*; these technologies must work together, across the organisational boundaries, for the integrated system to function;
  - *build collaborative relationships between project team* (which could often be distributed across several organisations);
  - provide the “coordination clout” that enables the team work while maintains “oversight to critically appraise” (P29) the progress.

  Without this there is a risk making “code a complete mess” due to needing to “switch technology” midway through the project (P30).
- *Team Management with Remote Working* has been a skill utilised in ICT teams for a while, and now“should be an area of focus” (P1) even more, due to the COVID-19 impact.
- “*Research Skills* …in terms of being able to find out what else is out there and bring that in” is considered particularly relevant under the “fast moving pace” (P29) of SLE.
- *Procurement* is another skill that drives the capability of the project to deliver, and the project manager must ensure that the groups that undertake procurement for SLE projects have “…ICT representation on” and have clear understanding of how and what the obtained hardware/software will be utilised for the smart monitoring and control.

10.2.5 Finance Skills for ICT sub-system

The key shortages around finance within the ICT sub-system are not in ICT finance per se, but in using the capabilities delivered through ICT, thus:

- Skills for *Planning Commercialisation Pathways* are noted to be in short supply, as most SLE projects lead to an ICT-based system development, but with no thought thorugh commercialisation pathways. This, in turn, results in disused solutions, for which “ …example being Smart City platform. Another example being the energy management system. None of those …have had a clear commercialisation plan throughout” (P29).
- Similarly, skills to *Utilise Data for Business Improvement* could be very valuable, particularly for small businesses, where data might be available, but the business owners “…don’t themselves have either the opportunity or the knowledge to use it” (P20).

10.2.6 Policy Skills for ICT sub-system

Policy skills discussed within the ICT-related projects are centred on the policy skills that would **support the delivered ICT solutions**, e.g.,

- "People who have *Insight into Markets Overseas*" (P10) are very valued within the smart mobility sector, as they can help inform the local policies improvement based on the other countries experiences.
- Skills for *Lobbying Regulators*, are also noted as particularly relevant, e.g., for (de-)regulating various aspects of the SLE sub-systems, e.g., ability to purchase from multiple suppliers and sell small quantities of electricity for peer-to-peer trading solutions, or selling electricity stored within a battery, etc.

10.2.7 Soft Skills for ICT sub-system

- *Engineers with skills to Engage Citizens* with SLE projects are in short supply. As a result, in many cases "engagement seems to be completely decoupled from the engineering and …[the projects] end up with just a gap in the communication" (P20).
- To *Manage Public Expectations of Technology*, the engineers need to be able to convey exactly what the technology is and what its limitations are, so as the pubic can have a realistic expectations of the gains and pains they would encounter, rather than starting with overexerted expectations that result in disappoint in SLE overall.
- *Fundamental ICT Skills and Understanding of Engineering Technologies in Public* are necessary as presently the SLE projects "can't really expect people to be IT savvy or even [know] the basics really", which impedes their participation in the SLE projects (P27).

10.3 Training needs ICT sub-System

10.3.1 Areas of Training Needs

The key areas for training in ICT sub-system are primarily focused on Engineering and Technical Management, including:

- The *Software Engineering* set of skills, form requirements elicitation to algorithms development, systems programming, and deployment. This is not surprising, as any software development project is critically dependant on all these skills;
- *Data collection, storage, exchange, standardisation, interpretation, analysis and management* is another critical area, as all decision making is SLES SoS (and so the services delivered by the ICT sub-system to this SoS) are based on the results of the (nearly) real time data analysis.
- *Systems Integration Engineering* is an area where the SLE projects are somewhat more diverse (i.e., require integration of heterogeneous hardware and software APIs, across differently networked (and sometimes with missing network access) localities with differing additional constraints (e.g., on telecommunication network's bandwidth availability, etc.). Despite these characteristics, we note that the SLE domain is not the only one with these very demands, but so is, for instance, any domain that relies on Internet of Things architecture. Thus, the *combination of Software and Embedded Systems/Electronics Engineering skills training* would be particularly popular in the SLE domain at present (or until the telecommunications infrastructure is modernised, standardised, and stabilised across the UK.

- *Installation Engineering* (i.e., installing PV/wind turbines, EV charge points, etc.) is another area of training needs, as the ICT solutions are to be developed for the hardware that is installed across the SLE sub-systems to support ”smart” optimisation of energy and resource use.

- *Technical management skills, along with the ability to manage very large projects* with a multitude of stakeholders is not a new challenge for the ICT sector, but is still open and equally relevant for the SLE.

10.3.2 Modes of Training

When discussing how training should be delivered, the respondents noted that:

- *University education* (or equivalent) is a clearly assumed expectation for most entrants into the ICT area. Yet, they note that this is (necessary but) an insufficient level of training to work within the SLE ICT sub-system, as many skills are not "…skills that someone would get as a computer science degree. It's usually experience that you'd get from …working with this kind of scale of software" (P1). Thus, *practical training top up* is considered essential.

- *Apprenticeship* "is a good opportunity of obviously training …" (P31) through apprenticeships tend to be more used by larger organisations.

- *On the Job* training is considered particularly relevant, as given the wide range of new contexts and projects that arise, the employees are " pushed me to learn a bit more" (P26) while working. This is often done through online code repository searches and reading, as well as through peer-learning. Most importantly, as noted before, the *practical skills around handling projects of very large scale* and interacting with many stakeholders and collaborators from across various organisations can only be acquired through such on-the-job experience.

- *Peer-training* capacity is often accounted for during the hiring process as well, as the company would "need a couple of key people and seniors who have that background experience that could be training and upskilling people from other backgrounds" (P1) to help them gain the practical skill, such as, for instance, handling production scale platforms and projects.

- *Doctoral Training* is another method mentioned for both algorithms development and networking areas. These skills are relevant particularly at present because most SLE projects come with a large Research and Development component since much of the required work is new with no pre-set solutions to draw upon. Interestingly, the research for SLE does not seem to require any other that "traditional ICT" research and development skills, e.g.: "I think a couple of postdocs were recruited, networking and embedded systems people so we didn't deviate from the typical ICT skillset that we would recruit on a technical project like this" (P28). Though Maths degree graduates are also well regarded for algorithm development work (P10).

10.4 Insights and Recommendations on Bristol's ICT for SLE Sub-System

10.4.1 Reduce SLE Project Complexity through Good SE Practice

As noted in section 10.1, the ICT sub-system in Bristol's SLE SoS suffers from the complexity due to need to integrate multiple heterogeneous devices and interfaces, coupled with the fast technological change and evolution of the physical and software components of these devices. Moreover, many of the SLE projects are intended as trials with the real users of new SLE solutions and services. Thus, our interviewees noted the need to reduce this complexity in SLE projects as much as possible, which can be done by:

- *Plan for Flexibility in Work Process*: given that the hardware and software planned to be used within the SLES are likely to evolved within the project lifetime, it is only prudent to expect this change, and so a methodology which incorporates co-design and iteration cycles would suite such projects best. Moreover, "putting a bit more co-design …and not having [the work plan] really fixed" (P27) also allows for better integration of end user concerns, as the project progresses.

- *Minimised Technology in Trial*: SLE projects expect to integrate a large set of technologies and devices. Yet, when trailing a solution, it is essential to start with the bear minimum, as trials of the full set of intended technologies together are likely to fail both due to technology immaturity within some components, and evolution of others. Thus, P30 suggests to "…start with the minimum amount of failure points" in a skeleton solution, and only then add one aspect of technology at at a time (e.g., "an insecure VPN-less architecture for a start" P30).

- *Small Number of Initial Users* is also helpful in complexity reduction, as this too reduces the number of "failure points" both in communication with the users, and in setting up the technical solution within the situated use environment. To illustrate this, one of the failure points in Bristol's Replicate Smart Home trial was the need to " install several pieces of hardware which were supposed to be kept connected to the mains" however, as trial participants at times wanted to use the power outlets for other purposes " the hardware was often disconnected" (P26). Given that the solution was rolled out to 150 households without an initial limited trial, the project wasted a vast number of person hours chasing trial participants and asking them to re-connect the equipment to the mains sockets.

- *Use Mature Technology* where available, as that would help reduce complexity due to the technological flux.

- Engage *Experienced Systems Integration Engineer* as practical experience is particularly helpful in quickly identifying and addressing integration and inseparability challenges.

We observe that all the above noted practices have also been proposed within the agile software development paradigms in the the "traditional" ICT sector [44, 45]. We observe that the project management and decision making within the SLE projects is often not led by a professional Software Engineers, and so the good practice within the software engineering domain remains unknown and unavailable to members of such multidisciplinary SLE projects. Thus, ***as an implication to the skills, we recommend that the technical management as well as the development teams across all areas of the SLE projects be introduced to agile development and management practices***.

10.4.2 Scale Up Considerations

While considering the prospect of scaling up the ICT solutions for SLE we note the following recommendations, based on our Bristol study:

- The principle to consider for a successful adoption of new technology is to ensure that it *"Fits into other people's business as usual"* (P20) as much as possible. This is not surprising, as the alternative is to engendered conscious behaviour change, which requires that the indented users/participants are reached, informed and on-boarded with the change programme and rewarded and motivated to carry it out - all of which requires large time, effort and cost commitments. While, if it is " very simple, very easy …to be part of the trial …people don't have to worry too much about it" (P26), then participation and engagement is much easier to achieve.
- *Using Mature and Robust Technology* makes scaling up much easier. This is because it allows for the tested and validated hardware and software (e.g., car based monitoring technology for EV monitoring, or cloud-based encryption and storage solutions for securing data (P29)) to be acquired, avoiding high risk and cost of untested or proprietary developments. Here scale up can progress through working with a:
  - *Specialist Industry Partner* as such a partner would already be developing and delivering the required hardware/software technology (e.g., as Trakm8 for car monitoring boxes) and removes the need for production/development process set up;
  - *External Skilled Professionals*, e.g., through consultants or experienced installation parties (e.g., building and retrofit service providers), avoiding the need to develop, finance, and maintain all varied skill-sets internally.
- *Planning for Commercialisation Pathways* is essential for a successful scale up of a SLE ICT projects, as only a commercially viable solution driven by the interests of (one or several) organisation(s) will maintain momentum in the longer run. Indeed, many good solutions derived through SLES R&D projects fail to gain a momentum when there is no dedicated industry partner(s) driving this (prospectively lucrative) commercial interest.
- Finally, the *Regulatory Compliance* of the proposed solution must be (reasonably) achievable, else even the most promising technologies fail to scale up. For instance, this currently is the case with the peer-to-peer electricity trading platforms. While these platforms are technically viable [46] and prospectively profitable, given that a household can have only one supplier at any given time, the local electricity trading remains impossible.

10.4.3 Capacity and Expertise

- *Capacity to create value from data*: Within the SLE ICT sub-system there is an implicit assumption that once data for a particular area of SLE SoS is available, the business that owns that data will be able to derive additional benefits by creating value form this data. This, however, is not always the case, as often the *businesses working within a specific domain have neither the capacity, nor the skill-set for such value creation*.

  Such capacity is often missing in small and medium sized companies, which, despite utilising SLE technology, are not focused on SLE SoS activities for value creation per-se. For instance, a car rental company may have to move away from fossil to electric vehicles, yet continue to see its key business in renting out vehicles, rather than charge/discharge optimisation and battery use. Indeed, the customers would rent and return the vehicles with the set ‘fuel’ levels (be it battery charge or petrol in the tank). And through the company would, by default, be able to aggregate the vehicle tracking data, as noted by P20, the company may not be “that interested in looking far and wide for other possible applications of tracking data when basically they think they’ve got all the value that they can get”.

To address this issue, we recommend that ***opportunities for value creation from SLE technologies are explained and provided to all SLE technology users*** across all SLE sub-systems. For instance, by having a choice of monetising access to own or aggregated business data, etc. The first steps towards this are already taken through the recommendations of the Data Task Force and their implementations across the UK R&D funding providers [47]. This, however, also needs ***to be scaled up and integrated at the technology distribution points (e.g., at the point of EV sale) allowing the buyer - business or citizen - to choose a value from data creation options***.

- Given the quickly evolving technological scene in SLE, and even faster evolution in its ICT sub-system, it is *difficult to maintain an up to date technical expertise* across the SLE SoS ICT sub-system. This is particularly relevant to project managers, who are not themselves technical developer’s, but need sound knowledge of the current solutions and opportunities.

  To address this, we suggest that the projects and businesses undertaking funded SLE ICT projects should periodically ***report their findings at open forums****, rather than at by invitation only only events*.

- Finally, we observe that the SLE ICT SMEs are often *reluctant to employ new graduates*, but aim to hire professionals with proven track record and past industrial experience with similar technologies, as they have no capacity for training provision, but need people who can “hit the ground running”.

  This issue can be addressed thought wider use of ‘with industry’ projects at the universities, as well as through ‘year in industry’ schemes and internships, aiming to provide a hands-on practice opportunities for all of the university graduates.