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Exploring the challenges in developing a multi-criteria assessment for smart local energy systems

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ABSTRACT

Several countries worldwide, including the United Kingdom, are investing in and introducing policies to foster the development and deployment of Smart Local Energy Systems. Smart Local Energy Systems are complex and socio-technical, with a wide range of stakeholders and multiple social, technical, environmental and economic aims. It is, therefore, essential to develop a standardised assessment tool to monitor the implementation of these systems and their social, technological, environmental and economic benefits and impacts. This paper presents work related to developing such a multi-criteria assessment tool, focusing on exploring and identifying the challenges of applying multi-criteria assessment to the development and deployment of Smart Local Energy Systems. The research involved semi-structured interviews with relevant expert stakeholders concerning six core assessment themes, corresponding sub-themes, and associated criteria/metrics. The results provide insights into the challenges of applying multi-criteria assessment to Smart Local Energy Systems and highlight the complex nature of these systems. Furthermore, stakeholder burnout (due to too many stakeholder engagement activities), data collection issues, and the broad definition and/or limited scope of assessment criteria were identified as the principal challenges faced in developing such an assessment tool, potentially affecting the reliability of its outputs.

Introduction

This paper explores the challenges faced in developing a Multi-Criteria Assessment (MCA) tool to analyse the performance of a Smart Local Energy System (SLES) in relation to planned Key Performance Indicators (KPIs) and additional multi-dimensional benefits (environmental, social, technical and economic).

There has been increased attention to the development and deployment of SLES due to the influence of the energy transition on local energy planning strategies with an emphasis on decarbonisation, renewable generation and smarter, more efficient energy systems (Rae, Kerr and Maroto-Valer 2020; Ford et al., 2021). The development and deployment of SLES are enabled by energy system strategies that include retrofitting, re-designing and improving energy systems through more digitalisation and decentralisation. This facilitates a transition in energy production, supply and distribution, and energy resource utilisation and consumption (Rae, Kerr and Maroto-Valer, 2020; Ford et al., 2021; Francis et al., 2022).

It is important to ensure that the success of these complex, multi-dimensional, multi-objective and multi-actor systems can be properly assessed (Cherp et al., 2018; Rae, Kerr and Maroto-Valer, 2020; Ford et al., 2021; Francis et al., 2022). This paper focuses on two key aspects of the process of development of this MCA-SLES tool, the stakeholder engagement and the core themes and associated sub-themes: the use of a semi-structured

interview approach with relevant stakeholders, SLES project developers and other experts to identify the significant challenges for a usable MCA tool. This assessed the functionality of the key components of the MCA-SLES tool concerning six core assessment themes: Data Management, Technical Performance, Business & Economics, Governance, People & Living, and Environment. In this paper, the term MCA is used to include a type of assessment often classified or referred to as Multi-Criteria Decision Analysis (MCDA) or Multi-Criteria Decision-Making (MCDM) (Kurka and Blackwood, 2013; Huang, Keisler and Linkov, 2011; Kumar et al., 2017; Francis et al., 2022).

MCA methods and tools have been used to assess and evaluate different problems associated with the energy transition, energy planning and integration of renewables to provide support for decision-making (Wang et al., 2009; Kumar et al., 2017; Volkart et al., 2017; Mardani et al., 2017). Furthermore, MCA methods can interpret and analyse qualitative and quantitative criteria and evaluate, rank or score these to identify the most feasible and advisable choice and the trade-off between different alternatives (Huang, Keisler and Linkov, 2011; Kumar et al., 2017). Therefore, the development of an MCA-SLES tool plays a key role in the development and deployment of SLES.

Core assessment themes (macro level overview perspective), corresponding sub-themes (meso level perspective (Schenk, Mool and Uiterkamp 2007)), and associated /metrics (micro level perspective) are pivotal components to any assessment tool due to the versatile nature of the application (Hák et al., 2016; Gunnarsdottir et al., 2020, 2022). The core assessment themes, corresponding sub-themes, and associated criteria/metrics are often applied to help understand, benchmark, provide insights that help with decision making, and measure the progress of specific projects (Hák et al., 2016; Gunnarsdottir et al., 2020, 2022). Furthermore, the selection and validation approach of the identified assessment themes, corresponding sub-themes and associated criteria/metrics plays a crucial role in the development of any assessment tool and provides a context-specific set of assessment themes and associated assessment criteria (Hák et al., 2016; Gunnarsdottir et al., 2020, 2022). In addition to surveys, interviews are considered an important and effective qualitative data collection method that allows the researcher to gain a good understanding of the specific topic and capture opinions and insights from relevant stakeholders or experts (Cohen and Crabtree, 2006; Qu and Dumay, 2011).

The semi-structured interview method is based on a flexible, systematic, and conversational process that often facilities a more in-depth discussion and allows the interviewee to respond more individually to the guided topic (Cohen and Crabtree 2006; Qu and Dumay 2011). The application of a semi-structured interview approach creates an opportunity to capture individual opinions and insights that are important for assessing the functionality and validation of the core assessment themes, associated sub-themes and criteria/metrics of the MCA-SLES tool and identifying the major challenges of the MCA process.

This paper describes the challenges for the MCA-SLES tool identified through a series of semi-structured interviews. These were carried out with selected experts involved in the development and deployment of SLES in the United Kingdom. The interviews involved asking an array of pre-set open-ended questions that could be reliably compared between the experts. The results focus on the major challenges faced when applying the MCA-SLES tool to assess SLES project implementation and associated benefits. In addition, the paper validates previous work concerning six core assessment themes and corresponding sub-themes and associated criteria/metrics that has been carried out in relation to developing an MCA-SLES tool as part of the Energy Revolutions Research Consortium Project Work Package 5.2, "*Multi-criteria Assessment of PFER Demonstration Project*" (EnergyREV, 2022).

Multi-criteria Assessment of Smart Local Energy Systems

The development of SLES is driven by the increased focus on decarbonisation and renewable energy technology integration within energy planning policy, strategies associated with the energy transition, and energy system development. The cornerstone of SLES development is enhancing energy system capabilities to deliver stable, clean and affordable energy. The abilities of SLES to achieve this are based on the integration of

digital technologies and renewable energy to improve the monitoring and operational capacity of an energy system. This, in turn, creates opportunities to optimise energy resource utilisation and improve energy production, energy distribution, and energy storage capabilities (Rae, Kerr and Maroto-Valer 2020; Ford et al. 2021; Francis et al. 2022).

Successful development and deployment of SLES are expected to play a key role in tackling key social issues and combating climate change (Ford et al., 2021). SLES can help social issues, such as fuel poverty, through a decrease in energy prices and increasing access to a secure and resilient energy supply. At the same time, they can be designed to minimise climate change impacts (through reduced greenhouse gas emissions) and mitigate wider ecosystem impacts (Ford et al., 2021).

MCA is an effective method to analyse complex and multi-dimensional problems that include a vast number of stakeholders and multiple objectives to provide recommendations to support the decision-making process. MCA has previously been applied to other aspects of the energy transition, energy system development and sustainability: Volkart et al. (2017) applied an MCA method to carry out an extensive sustainability analysis of 12 interdisciplinary indicators to understand the different trade-offs between plausible strategies and pathways to support policymaking for the Swiss energy transition; Malkawi and Azizi (2017) used an MCA method to evaluate and hierarchically rank different energy portfolios for Jordan's energy system in relation to six clusters of criteria covering environmental, social, technological, risk and economic dimensions; Zhang et al. (2019) applied MCA methods to assess and identify the most favourable micro-energy generation technology for the Lithuanian domestic energy system.

The application and development of an MCA tool follow a generic six-step process outlined in Figure 1 (Belton and Stewart, 2002; Francis et al., 2022). The work presented in this paper is part of the test and refine actions in the "model building" phase linked to "stakeholder engagement" and "aggregation and assigning weight". The focus is on identifying assessment challenges and refining components of the MCA-SLES tool, such as themes, sub-themes and weighting. This will be used to improve the reliability of the final MCA-SLES tool and its outputs.

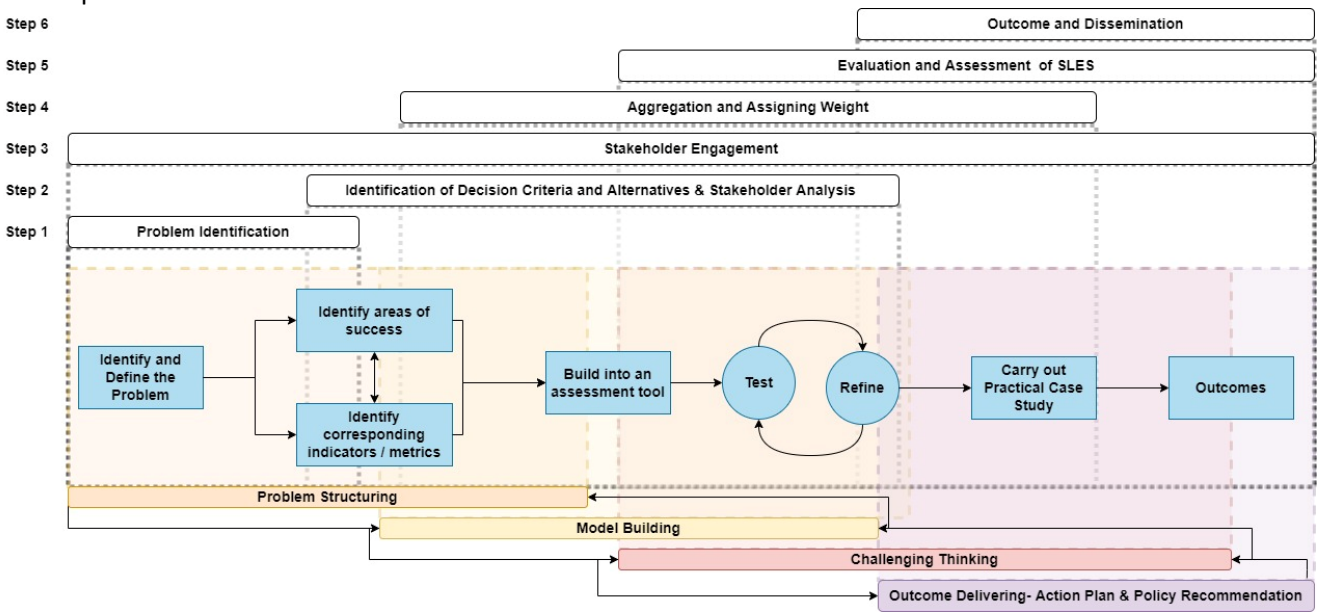

Figure 1. MCA development process chart, highlighting the six steps and four MCA development phases (adapted from Belton and Stewart, 2002; Francis et al. 2020a)

The first step consisted of identifying the main criteria for success (or failure) of a SLES project and the corresponding metrics. The selected metrics were analysed and grouped into six core themes: technical performance, data management, governance, people & living, business & economics, and environment. The details of this process are summarised in Francis et al. (2020a, 2020b). This was then followed by the next step of understanding the relative importance and ranking of the core themes among different stakeholders. This was achieved by conducting a set of Discrete Choice Experiments (DCE) to elicit preferences from different stakeholders. The results from the DCE surveys presented in Francis et al. (2022) revealed that Environment was considered the most important core theme, with a mean weight of 21.6%. This was followed by People and Living with 18.9%, Technical Performance with 17.8%, Data Management with 14.7% and Business & Economics and Governance were ranked as the least important criteria with 13.9% and 13.1%, respectively. The standard deviation for each criterion ranged from 5% to 7%. The DCE survey results, six core assessment themes and corresponding sub-themes, and associated criteria/metrics were further analysed with a more in-depth approach using semi-structured interviews with subject matter experts.

Interviews are a highly effective method for conducting qualitative research tools to understand central themes. Hargreaves, Chilvers and Hargreaves (2015) utilised an in-depth interview technique to conduct a multi-criteria mapping procedure exploring the complex interpretation of smart grid among varying stakeholders. Bush and Bale (2019) used semi-structured interviews for thematic analysis in the design of an energy planning decision-making tool aimed at the low-carbon energy transition, specifically supporting district heating development. Gunnarsdottir et al. (2022) employed semi-structured interviews in an iterative stakeholder engagement process to develop and identify sustainable energy development indicators for the Icelandic energy system.

Methodology

Building on the results obtained using the Discrete Choice Experiments (DCE) discussed by Francis et al. (2022), a series of semi-structured interviews were conducted to refine the weights and assessment methods that will be used as part of the EnergyRev MCA tool. Rather than the broad approach taken in the DCEs, interviews were conducted with project developers and technical experts. Semi-structured interviews enable a flexible, systematic, and conversational interview process. They facilitate more in-depth discussions and allow the interviewees to answer the questions in a more personal way while still following the guided topic (Cohen and Crabtree 2006; Qu and Dumay 2011). The specific aims of the interview process were to: co-create the MCA toolkit with the SLES Demonstrator Project Partners; review the DCE results for the ranking of the core assessment themes and corresponding sub-themes; determine the appropriate weightings for the associated metrics and indicators; test the functionality of the individual theme, sub-theme and metric; identify any missing areas within the MCA-SLES toolkit, and refine and simplify the MCA-SLES toolkit.

Seven interviewees were selected based on: affiliation with the SLES Demonstrator Projects, subject matter expertise & practical knowledge, and understanding of the six core assessment themes. Table 1 outlines expert knowledge areas and the themes reviewed. Apart from data management and governance, each area was reviewed by multiple interviewees.

Table 1. Participants of the Semi-Structured Interviews

Identification No.	Knowledge Area	Theme Reviewed
1	Customer Engagement	People & Living Environment
2	Development & Infrastructure	People & Living Environment Technical Performance
3	Renewable and Environmental Law & Policy	Data Management Environment

4	Community Energy	People & Living Environment
5	Renewable Energy, and Project Management	Governance Environment
6	Renewable Energy	Technical Performance Business & Economics
7	Smart Energy Solutions, and Project Management	Technical Performance Business & Economics

Prior to the interview, each interviewee was provided with an Excel workbook which acted as an interview guide, ensuring that reliable, comparable, qualitative data was collected. Each workbook contained the six spreadsheets described in Table 2. This started with a summary of the criteria associated with each of the themes being reviewed, followed by the results from the DCE and a list of the applicable UN Sustainable Development Goals (SDGs). An annexe provided additional detail on the SDGs.

For each of the core themes being reviewed, interview questions mainly focused on the corresponding criteria and proposed metrics. Where appropriate, the choice of units and time scales and their effect on data collection was discussed. This enabled experts to highlight areas where information such as half-hourly market rates was readily available and should be used in preference to metrics from the literature. A detailed breakdown of the Governance Theme, criteria and weightings from the DCE survey are given in Table 3.

Due to UK-wide travel and meeting restrictions introduced in March 2020 in response to the COVID-19 outbreak, interviews were not held face-to-face. Instead, Microsoft Teams was used to facilitate real-time, online video interviews. Each interview lasted for approximately one hour. The first 3 - 5 minutes were used to allow the interviewee and interviewer to introduce themselves to each other. It was assumed that the interviewee had no prior knowledge of the EnergyREV Consortium, so a short, 5-minute presentation was shown giving an overview of the work to date on the MCA-SLES toolkit. Consent was checked, and the remainder of the interview was recorded on video, and the interviewer also took notes.

Table 2. Interview Guide Workbook

Spreadsheet No.	Spreadsheet Title	Description
1	Theme 1 (e.g. People & Living)	Provides a breakdown of the one of themes into criteria with proposed metrics and relevant units.
2	Theme 2 (e.g. Environment)	Provides a breakdown of the one of the themes into criteria with proposed metrics and relevant units.
3	Main Discrete Choice Experiment (DCE) Survey Results	Illustrate the results for the relative weightings of the six themes obtained from the DCE main survey.
4	Thematic DCE Survey Results for Theme 1 & 2	Illustrate the relative criteria weightings for the themes listed in spreadsheets 1 and 2 from the themed DCE survey.
5	Applicable Sustainable Development Goals (SDGs)	Showcase the 11 SDGs which were aligned with the EnergyREV WP 5.2. SLES Taxonomy Themes.
6	United Nations SDG Annex	Reference for the Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development.

Table 3 Example of Spreadsheet 4 showing Governance Criteria descriptions and corresponding weightings calculated from the DCE survey results (Francis et. al (2022))

Governance Criteria	Description	Weights (%)
Governance Strategy	Clearly defined governance strategy with strong and clearly defined principles, management goals and targets, transparent leadership and governance arrangements, etc.	23.3
Accountability and Decision Making Process	Shared architecture for multi-level governance and inter-organisation collaboration across the members of the SLES.	19.7
Standards & Regulation	Accountability of the SLES to key stakeholders (e.g. local authority, shareholders, end-users, etc.), and provision. Clear transparent roles, responsibilities, ownership and decision-making process for project partners and funders.	16.0
Integrated Management and Digital Planning	Hierarchy indicating open access to information, meeting minutes etc. to public and/or stakeholders. Established procedures to address complaints including minimum response time.	15.2
Knowledge Exchange & Experience	Lessons learnt and best practices being documented, shared, promulgated and otherwise published both within and outside the organisation of the SLES.	13.4
Transparency and Consumer Redress	The alignment of the SLES with current and incoming regulations, and/or the ability to identify restrictions that limit the potential of SLES for discussion with regulators and other agencies.	12.4
Governance Strategy	Clearly defined governance strategy with strong and clearly defined principles, management goals and targets, transparent leadership and governance arrangements, etc.	9.2

During the interview, the experts were guided through the individual spreadsheets (Table 2) and asked a series of technical questions designed to provoke discussion. For spreadsheets 1 & 2 relating to specific themes, the expert was asked a set of pre-defined questions relating to the corresponding sub-theme and metrics for each core theme, illustrated in Figure 2.

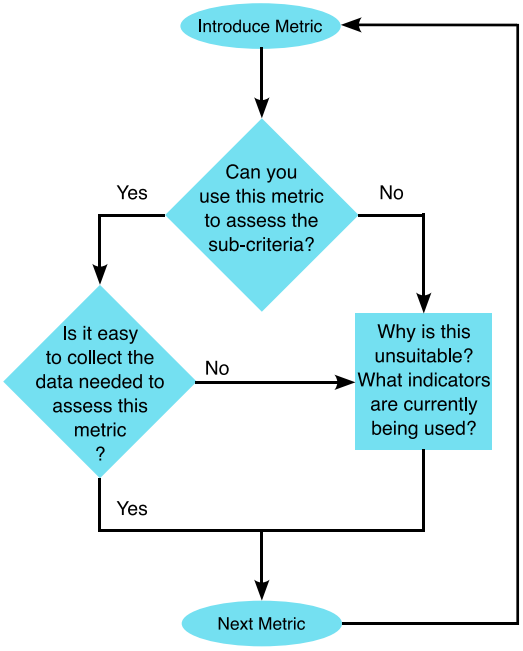

Figure 2 Flow chart showing the question sequence for each metric within a particular theme.

After reviewing the six core assessment themes and corresponding sub-themes and associated criteria/metrics, the experts were asked to comment on the weights obtained from the DCE (Francis et al., 2022). The weightings were presented on spreadsheet 3, and the experts were asked two questions: firstly, did they agree or disagree with the ranking results and scores from the DCE survey; secondly, were any areas missing from the DCE analysis? If the expert felt an area was missing, they were asked to describe it and comment on the relative importance compared to the weighted criteria presented.

Finally, the experts were asked if they wanted to discuss the UN Sustainable Development Goals. The previous MCA-SLES work found that 11 of the 17 SDGs could be directly supported through the outcomes of SLES (Francis et al. 2020a, 2020b). Spreadsheets 5 and 6 in the interview guide workbook reviewed the SDGs and identified applicable targets and indicators. These spreadsheets were used as a reference guide to support the discussions on core themes, sub-themes and metrics and their importance. They were also used to inform the discussion if the expert wanted to know why certain targets or goals were excluded from the MCA or were not aligned with the SLES KPIs.

Results and discussion

This section summarises the qualitative feedback on each of the core assessment themes and corresponding sub-themes considered by the field experts, divided into the six core assessment themes. In general, the experts largely agreed with the weightings obtained from the DCE and the alignment with the SDGs. This section, therefore, focuses on particular challenges for measuring or otherwise evaluating the proposed metrics for each core assessment theme and corresponding sub-theme and also summarises the recommendations for additional metrics to be introduced.

Business & Economics

Key metrics in this theme were reviewed by two experts (*No. 6* and *No. 7*). These metrics were classed into several criteria: the **business case** for an SLES, how **investable** an SLES is, **economics** and **techno-economics**. The experts both agreed on the value and appropriateness of many of the metrics; for example, both agreed that

rate of return and return on investment would be appropriate indicators to assess *financial performance.* Similarly, there was agreement that the value of *decarbonisation* (such as the cost/value of carbon offsets) is a particularly important metric underpinning the projects, and a key source of cost reduction for consumers. There was, however, disagreement about several metrics, particularly those pertaining to the **business case**.

Some of the disagreement appears to depend on the specific design of SLES being considered by the expert; for example, *No. 7* recommended competitive energy pricing as a suitable metric for the assessment of the *fair allocation of transaction costs,* but this assumes that the key area is behind-the-meter generation, which may not be the case for all SLES designs. Both experts questioned whether it was necessary to include an assessment of *market bids and different time scales*, as these are high resolution (half-hourly), complex and unlikely to be passed on to consumers, but this might vary depending on the specific design of the SLES and future developments. Similarly, with regards to the metric of *economic growth*, *No. 7* highlighted that this may not be relevant in certain cases as in the case of Orkney Islands. These aspects will need to be considered when translating this into the MCA-SLES tool.

The experts also highlighted challenges in accessing data for specific metrics; for example, data on *access to capital* or the *debt-equity ratio* may be difficult to access, as it is commercially sensitive for the relevant investment funds.

Expert *No. 6* also highlighted that this theme was missing a criteria or metric that focuses on the consumer or customer and assesses issues concerning retailing, finance, data legislation and consumer protection. This comment also tied in with similar comment made by *No. 1*, who reviewed People & Living Theme (see People & Living for further details).

Data Management

Only expert *No. 3* reviewed the metrics and KPIs in the data management theme, across the criteria of **digital technology enablers, ICT infrastructure,** data **visibility**, data **privacy**, **grid management, planning** the SLES, and **decision/risk**.

Their input mostly focused on providing recommendations for best practice against which to measure many of the metrics, but also highlighted specific areas where information was missing from the current assessment. This included recommending that EVs be included as an asset (not just buildings) when it comes to *smart meters and devices*, and that the existence of *data sharing agreements* should be assessed in addition to the existing metrics focusing on planning, decision making and risk.

Expert *No. 3* also raised some interesting challenges with regards to assessing the data management provision for **grid management**, observing that in some SLES the necessary stakeholders and gatekeepers (e.g. DNOs) are not involved, and therefore this would not be under the control of the SLES. They also recommended that additional metrics be gathered for **demand-side management**; for example, EV assets can provide data from vehicles, batteries and chargers rolled out as part of the SLES development.

Technical Performance

The Technical Performance theme was again reviewed by Experts *No. 6* and *No. 7* as well as *No. 2*. They reviewed key criteria on the **provided energy services** (heat, mobility, fuel, and electricity), **Electric Vehicle (EV) infrastructure, reliability, resilience, flexibility, scalability, replicability, efficiency, maturity, grid accessibility** and **generation** mix**.**

One challenge identified here was that the SLES experts tended to exclude certain criteria as being challenging for the SLES to implement, such as **scalability** or **maturity**. This highlights the importance of making the purpose of the MCA-SLES tool clear, which is to provide a measure of the progress of an SLES towards its planned KPIs while also identifying any co-benefits or unintended consequences. There is, therefore, no negative implication of using immature technology, particularly if providing a practical, commercial demonstration of this

technology is one of the project's key aims. Instead the tool might be useful in tracking the maturity of the applied technology over time.

One key recommendation for this theme was that measurement of **energy services** needs to be further divided into *energy storage*¸ *generation* and *demand* (such as demand-side management). There were also concerns raised that some of the metrics in this category tend to focus on accounting for the carbon emissions reduction due to the new services provided, but that this would be dependent on the original sources of energy. This is a useful observation as it suggests that SLES located in areas with existing high-carbon energy services should be able to meet more ambitious carbon-reduction targets.

The three experts considered that **reliability** was not an easy criterion to measure, particularly the suggested metrics of *availability* and *quality*. Similarly, they identified that the suggested **resilience** metrics were not appropriate for all types of SLES, as not all SLES will be able to be fully disconnected from the national grid. This will be further refined as the MCA-SLES tool is developed.

People and Living

Three experts (*No. 1*, *No. 2* and *No. 4*) reviewed the metrics in the People & Living theme, which generated considerable discussion of the challenges of assessing the criteria of **engagement, acceptance and participation, equity, added benefits from services/convenience,** and **employment.**

A particular set of challenges were identified in assessing the **equity** criterion. Although there is consensus that indicators such as *fuel poverty* and *cost reduction* are important to evaluate (with the former being one of the key goals of SLES), both *No. 2* and *No. 4* highlighted that reliably gathering data to measure these and assess progress towards achieving targets is difficult and expensive. Assessing *fuel poverty* requires access to sensitive information about household incomes which may be viewed as invasive and infringing on the dignities of the end-users; hence, data collection would require people with the right skills and training, and SLES partners may not readily have these resources in-house. Furthermore, *No. 2* commented that the methodology to calculate fuel poverty has changed which has led to different interpretations in the UK and consequently a moving goal post. A comparison of the definitions described in Scotland and England illuminates this matter: the Scottish Government defines a household as being in fuel poverty if they spend more than 10% of their income on energy after housing costs have been deducted (Energy Action Scotland, 2021); in England, a household is considered fuel poor if they are living in a property with an energy efficiency rating of band D or below, and their residual income after heating expenses is below the official poverty line (Department for Business, Energy & Industrial Strategy, 2022).

The deployment of energy monitoring devices to assess end-user *cost reductions* or calculate the percentage of electricity consumed as a proportion of total household energy use (from which *fuel poverty* may be estimated) were identified as potential solutions to the challenges of collecting **equity** data; however, both *No. 2* and *No. 4* highlighted that this is a labour intensive and involved process that may well be out of scope for many SLES projects. Further investigations will be made to make use of other tools that might be able to support assessment in this area, such as the Energy Systems Catapult Social Inclusivity Tool: LetsBetaFuelPoverty (Energy Systems Catapult, 2018).

With regards to *stakeholder engagement* and *acceptance*, *No. 2* and *No. 4* highlighted that measurements of hit rates on websites and stakeholder enquiry rates will not be able to provide feedback on the number of different people engaging, and that these might also be considered the same indicator. Further work is required to assess whether there is value in assessing the level of acceptance of the SLES project among stakeholders who may or may not actively engage with it.

Expert *No. 1* also recommended that **customer support** should be included in the MCA-SLES tool for this theme. It is critical that the experience of the customer must be a top priority for a viable SLES commercial business. SLES are customer-facing, involving customer relationship management, asset roll out, monthly invoicing and sales that have an entirely different structure from a business-to-business model. Often,

stakeholders involved at the planning and management level have limited knowledge, lack of understanding and measurement and, as such, *No. 1* observed this aspect gets ignored. A **customer support** criteria should be included to consider the different legal frameworks (consumer rights and protection laws), financial challenges and risks (such as convenience of payment transactions). This may, however, fit more comfortably into the ***Business & Economics*** or ***Governance*** themes.

Environment

Five experts (*No. 1*, *No. 2*, *No. 3*, *No. 4*, and *No. 5*) reviewed the metrics in the environment theme, which generated discussion of the challenges assessing the associated criteria in, **climate change** (greenhouse gas emissions), **other ecosystem impacts, human health, environmental impacts on resource,** and **environmental impact risks** (resilience to environmental factors)**.**

There was agreement among the experts that understanding and evaluating the environmental aspects are important; however, they identified that data availability and collection would be the principal challenges in assessing all the criteria related to the environment theme. The need for specialist expertise, equipment, planning, permission from local authorities and end-users and long-term monitoring were concerns raised by all five experts, particularly with regards to **climate change, ecosystem impacts** and **human health.** There is a clear need to clarify the language around these metrics, particularly in comparison with the two **environmental impact** categories. Discussion from the experts around the latter two categories highlighted that Life Cycle Assessment (LCA) and Environmental Impact Analysis (EIA) tend to be carried out to assess the impact of the SLES on the environment. These two methods are existing tools for assessing climate change, human health impacts and ecosystem impacts, so would be more appropriate for generating metrics for the first three criteria (the two criteria of **environmental impacts on resource**, and **environmental impact risks** are focussed more on the risks or impact of environmental factors on the SLES). There is a clear need to clarify the language for the MCA-SLES tool here, but there is clear potential to facilitate assessment in these criteria by aligning the MCA process with LCA and EIA methods, along with environmentally-focussed research being carried out elsewhere in the EnergyREV project consortium

No. 1 also raised the issue of the main objective of an SLES project being to reduce greenhouse gas emissions, so other environmental, ecosystem and human health impacts are generally not considered. This highlights the importance of including these criteria in the MCA-SLES tool, to highlight any unintended negative impacts.

With regards to the specific **human health** metric of *noise pollution*, *No. 1* and *No. 5* highlighted that the deployment of technologies associated with SLES such as heat pumps and electrolysers do often increase the noise pollution when in use, so this metric is worth including, and the weighting suggested by the DCE should be reviewed.

No. 3, No. 4 and *No. 5* all commented that neither the potential **impact of environmental factors on resources** nor the **risks introduced by the environment** are currently being considered by SLES stakeholders. The former will be dependent on the specific technologies being deployed in the given SLES system, while the latter should be addressed by the high level of risk management carried out on key aspects of an SLES to ensure that equipment is protected and not easily compromised by the natural environment. The MCA-SLES tool, therefore, presents an opportunity to incorporate data from research in these areas to provide additional insights to stakeholders.

Governance

The Governance theme was reviewed by expert *No. 5* considering the key areas of **strategic direction, transparency/openness, legal and regulatory issues.** They agreed that this was a valuable set of metrics and KPIs and provided several recommendations of specific metrics/sources of evidence and examples of best practice. No challenges or difficulties were identified for the assessment of this theme.

Limitations and Next Steps

As highlighted in the introduction is selecting and identifying core assessment themes, corresponding sub-themes and associated criteria/metrics a vital components of any assessment tool. One of the major drawbacks of the selection and validation process of assessment themes, corresponding sub-themes and associated criteria/metrics is the lack of a standardised approach to carrying out the selection and validation (Hák et al., 2016; Gunnarsdottir et al., 2020, 2022).

This lack of standardised approach often highlights other limitations and challenges associated with identifying assessment themes, corresponding sub-themes, and associated criteria/metrics, such as a large volume of selected sub-theme or criteria/metrics, which can be related to inconsistencies in the selection process, and cause an imbalance in the number of sub-themes or criteria/metrics within each core assessment theme leading to over complexity in assessment and often cause a double counting of sub-themes or criteria/metrics. One challenge that is often highlighted in relation to core assessment themes, sub-themes and criteria/metrics set is that these sets are often homogenous in nature, which can cause an inability to capture the geographical situation and condition in relation to, e.g., energy system development and energy transition within a specific location (Hák et al., 2016; Gunnarsdottir et al., 2020, 2022).

From the analysis, it can be noticed that some core assessment themes were reviewed extensively by more than one expert, e.g. People and Living and Environment, whereas others, such as Data Management and Governance, were reviewed by one personnel. Consequently, there may be underlying challenges in the proposed metrics that were not uncovered. Another point to note is that other SLES projects may encounter different challenges based on the geographical region, available renewable sources, and infrastructure. For instance, the issues faced with a SLES in an urban setting using community housing with shared facilities will be different from one in a rural island location with individual buildings. Another limitation concerns the number of interviewees and whether this number managed to capture wider views and inputs of the larger and more complex environment of energy system stakeholders. Therefore, it is important to keep in mind that in the next steps of MCA-SLES tool development, more stakeholder engagement activities will be carried out as part of the iterative process of refining and adjusting the components of the tool to ensure its robustness and reliability.

Though the core scope of this paper is to identify and understand the major challenges relevant to the development of the MCA-SLES tool, this paper does offer a rigorous and iterative approach based on stakeholder engagement and semi-structured interviews, which mitigates the limitations associated with the selection of assessment themes, sub-themes, and metrics. Therefore, it provides an approach that can be applied to validate and assess the functionality and relevance of selected core assessment themes, sub-themes and associated criteria/metrics for the MCA-SLES. This allows for some core assessment themes and corresponding sub-themes and associated criteria/metrics to be excluded, merged, or simplified based on inputs gained from the interviews, alongside the results obtained through the application of DCE (Francis et al. 2022) and other stakeholder engagement work previously carried out (Francis et al. 2020a; 2020b).

It is crucial to acknowledge and understand that the encompassing indicators will never be exhaustive but should still be able to potentially capture, assess and monitor vital areas that help understand and enable deployment and implementation of SLES and will contribute to the sustainable energy transition. Moreover, to enable this application and further mitigate these drawbacks, it is critical that a range of SLES projects is selected for the practical case study of the MCA-SLES tool as part of the continuous improvement strategy. This will assist in validating the efficacy and robustness of the tool in assessing the performance and benefits.

The result of the work presented in this paper focuses on highlighting the challenges concerning the development of the MCA-SLES tool, alongside providing vital inputs to refining the core assessment themes, corresponding sub-themes and associated criteria/metrics. The next steps in developing an MCA-SLES tool will focus on developing a practical application of the tool to utilise to carry out assessments, refined core assessment themes, corresponding sub-themes and associated criteria/metrics, and provide SLES projects with the opportunity to assess and monitor the SLES implementation and deployment process in relation to realistically and comprehensive objectives link the dimension set forward by core assessment themes. Figure 3 below shows

a visual example of the assessment output and insight into the ongoing work in developing and applying the MCA-SLES tool.

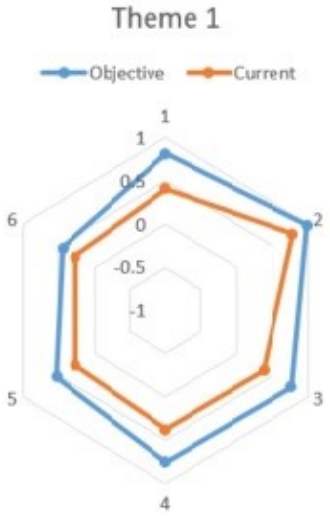

Figure 3 Example of the application of Themes and Associated Criteria/Metrics Comparative scoring of SLES Objective and SLES current status

Conclusions

This study applied a semi-structured interview approach to evaluate the challenges of applying a Multi-Criteria Assessment (MCA) tool for Smart Local Energy Systems (SLES) in relation to six core assessment themes and corresponding sub-themes, and associated criteria/metrics: Data Management, Technical Performance, Business & Economics, Governance, People & Living, and Environment.

One of the primary challenges identified by the experts interviewed was saturation or stakeholder burnout in terms of stakeholder engagement. Data collection challenges were also identified for many criteria such as *fuel poverty, access to capital, debt-equity ratio, grid management, ecosystem* and *human health impacts*, alongside specific challenges raised by the breadth of the SLES definition, which will introduce challenges for assessing core assessment themes, sub-themes and metrics across different projects. The experts also highlighted that having a clear definition of the core assessment themes, sub-themes and metrics is important and reduces miscommunication and ensures that the right data is collected and that it is representative (particularly with regards to the project stakeholders and end-users) to ensure quality and realistic outputs.

The interview process also illuminated that some sub-theme and associated criteria/metrics can be divided up and re-defined to ensure that the required data is captured; for example, when assessing the technical performance of SLES, the **energy services** criterion should be divided into *energy storage, supply* and *demand*. Emphasis was also placed on the importance of including a customer-focused criterion in the MCA SLES tool since customers play a vital role in the successful rollout of SLES. This would capture aspects related to customer satisfaction, legal frameworks, data legislation, financial challenges and consumer protection by making **customer support** an independent criterion in the People & Living theme.

The findings of this study provided insightful information from semi-structured interviews with experts and uncovered the practical challenges faced with developing an MCA tool to assess complex and interrelated deliverables of SLES in a regional context, as well as highlighting some solutions to overcome and mitigate these challenges. This will be used to inform further development of the MCA-SLES tool to provide a reliable and useful method for assessing the performance of these systems with regard to their social, technological, environmental and economic benefits and impacts.

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