Environmental Life Cycle Assessment in MECS

MECS Modern Energy Cooking Services

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1.1 Background to the environmental assessment needs for MECS

To ensure that any MECS solution proposed delivers economic, social and environmental benefits to the target audience, careful assessment of options is required. For environmental concerns, a life cycle approach that considers the entire value chain (from suppliers through the disposal systems) is necessary. This holistic approach minimizes the potential for 'burden shifting', where an impact is simply shifted from one stage of the life cycle to another and the overall impact may have changed in form, but has not been minimized or eliminated. Without this systems approach, there is the possibility that inefficient and environmentally damaging systems are 'locked into' infrastructure provision, leading to costly and sometimes extremely difficult issues to resolve.

The environmental assessment programme for MECS will provide data that can be utilized in a number of ways: to provide feedback on detailed cooking/power design to minimize environmental impact, to identify particular design features that may be necessary to support the integration of MECS into evolving infrastructure provision and to provide insights into policy and regulatory frameworks for infrastructure provision, tailored to the differing conditions found in the regions where MECS will be applied.

The environmental assessment for MECS is an iterative process, and based on the ISO 14040 Life Cycle Assessment standard. Initially, the approach will use existing data from other studies on the component parts of cooking appliances and power supplies. Where primary data is appropriate and available, this will be added to the LCA model to improve relevance. Qualitative assessment will be used to review system boundaries and scope throughout the analysis.

The first stages of the assessment will provide details on the proposed product life cycle of innovations from a cradle to gate perspective to identify what design issues are of key importance for business model development. Uncertainty assessment will be employed to understand the true state of knowledge about the modelled system and any stages that merit deeper and more quantitative investigation will be highlighted.

The latter stages of investigation will incorporate data on expected product lifetimes, the cultural, social and geographical norms, user cooking profiles and values. Generic guidelines and insights into the most appropriate environmental iMEC cooking system(s) will be developed. The outputs of these analyses will be available to guide policy actors feeding back into policy decisions as innovations for WS3 are considered in the light of WS2 theory of change.

1.2 Background to Environmental Life Cycle Assessment (eLCA)

Life cycle assessment (LCA) is a tool that allows us to calculate the environmental impact of a product, process or system over its full life cycle. It is based on the concept of Life Cycle Thinking (LCT) and covers to everything from raw materials extraction, manufacture, assembly,

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transportation, use and end of life (EOL). EOL should incorporate recovery and recycling loops as well as final disposal.

There are three main approaches for LCA studies, broadly separated into stand alone, attributional and consequential approaches. A ‘stand-alone’ study is descriptive and here the objective is to look within the one system only, and not compare with others. This can be used to identify areas of concerns or ‘hotspots’, guiding the user to where attention should be focused. This type of study covers the vast majority of LCA’s undertaken. Attributional studies are accounting type, they are comparative and retrospective, i.e. the product/process/system is established and known. Consequential studies look at changes to systems, they can also be comparative but look at systems prospectively, i.e. the product/process/system has unknown aspects and these can be varied to see the effect they have on the projected environmental impact.

The ISO 14040 standard describes the method that needs to be followed for an LCA study to meet a required standard, be validated and provide confidence in the study results and conclusions.

LCA can be used to deliver various outcomes, depending on the user (government, industry, consumer etc.) and what they are hoping to achieve. Table 1 below covers some examples of the different applications, and hence approaches of LCA.

Application	Methodological requirements
Decision making, choice between alternative actions	Reflection of consequences of possible actions
Market communication e.g. environmental product declarations	Fairness and potential to compare Credibility, transparency and external review
Product Development	Aggregated results
Decisions on national level e.g. waste treatment strategies	Data representing national averages
Identification of improvement possibilities for own products.	Site specific data requirements.

Table 1: Different methods required for different applications. Source: Baumann and Tillman, from Table 1.3 (p40)) of The Hitch Hikers guide to LCA. Studentlitteratur, 2004

1.2.1 Method

A LCA has four distinct stages, and is an iterative process. The ISO standard has both compulsory and voluntary sections within the impact assessment stage, and completion of the voluntary actions is dependent on the reason the study was commissioned. Studies that wish to publicly assert comparative statements based on LCA studies must follow the ISO guidelines and be validated.

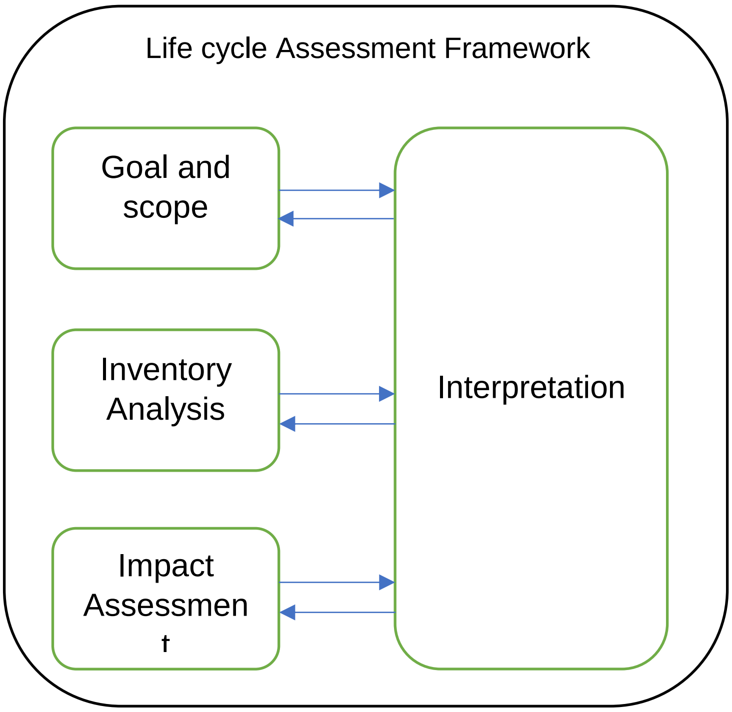

Figure 1: Modified from: Figure 1 ISO 14040 (2006), Stages of a life cycle assessment

a) Goal and Scope

Goal definition refers to all the thinking, preliminary data gathering, and determination of the reason for undertaking the assessment that happens before any detailed work is undertaken. It should answer the following questions: what is the intended application, why is the study being carried out, who is the intended audience and finally, will the results be used for comparative assertions in the public domain.

The scope defines the issues within the study that will ensure the results will address the stated goal. There are several issues that need to be considered; the system boundaries (i.e. what is to be included, excluded and why), the functional unit (i.e. what you are trying to measure or understand), the approach to be used, data sources and data quality, allocation system, impacts to be considered, any assumptions and limitations, critical reviews required (if necessary), how the results will be delivered (report, presentation etc.)

b) Life Cycle Inventory (LCI)

This stage refers to the collection and preliminary analysis of all flows that cross the system boundary, both inputs and outputs. A flow chart showing the relevant flows, foreground and background[1], and any allocation issues where process yield more than one product is useful. Once the data has been collected, documented and validated, calculation of environmental loads (e.g. quantities of resources used or pollutants emitted) relative to the functional unit is

[1] The foreground system consist of processes on which measures may be taken concerning their selection or mode of operation as a result of the decisions based on the study. The background system consists of all other modelled processes. Clift et al 1999

required. Frequently, as knowledge about the system under review grows, it is necessary to revisit the goal and scope to ensure they do not require updating in light of any new information found.

c) Life cycle impact assessment (LCIA)

This stage of the life cycle assessment describes the potential environmental consequence that can result from the environmental loads calculated in the inventory stage. ISO 14040 (2006) prescribes mandatory and optional elements of this process, see figure 2.

It is possible to assess the environmental consequences of the system in two ways, most commonly referred to as midpoint and endpoint category indicators. These assessment processes are not mutually exclusive. Midpoint category indicators focus on a single environmental impact, such as GHG emissions, or eutrophication. End point category indicators combine these individual impact indicators to three wider issues, impact on human health, impact on ecological systems, and effect on resource scarcity.

A number of systems have been developed to facilitate the translation of environmental loads to create the LCIA profile and detailed in the ILCD Handbook (2010).

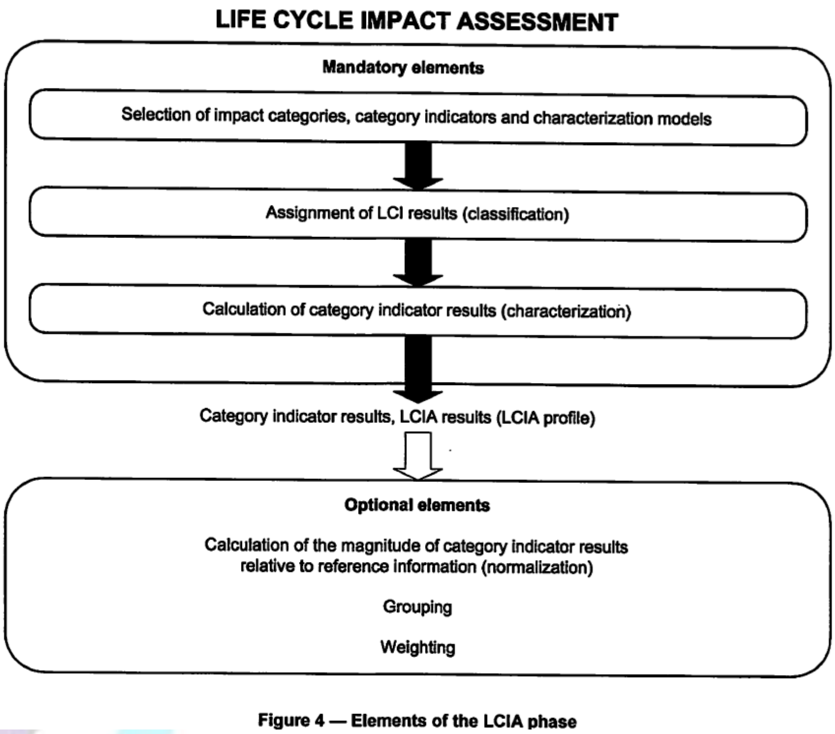

Figure 2: Mandatory and Optional elements of Life Cycle Impact Assessment from ISO 14040:2006, figure 4, p15

Both approaches require the mandatory steps listed in figure 2, but there are optional additional steps that may be followed to facilitate the presentation of the LCIA profile to the intended audience. Normalisation shows the relative impact of a particular category against a baseline, e.g. GHG emissions in comparison to regional emissions, or industry emission level.

Grouping sorts the LCIA profile into compatible sets, e.g. impacts with low/medium/high priority. Weighting applies a relative importance to the categorizations in the impact profile, this can be based on outside targets, economic incentives, expert opinion etc. All of these processes are highly subjective, and any optional elements applied must be recorded in a transparent manner such that the reasoning behind each step can be clearly understood.

d) Interpretation

The interpretation phase of the LCA process is defined as 'the phase of the life cycle assessment in which the findings from the inventory analysis and the impact assessment or, in the case of LCI studies, the findings of the inventory analysis only. The interpretation phase should deliver results that are consistent with the defined goal and scope and which reach conclusions, explain limitations and provide recommendations.' (ISO 14040: 2006).

It is important to note that the interpretation phases indicate potential environmental impacts, and cannot be used to accurately predict actual impacts, as these are determined by the local conditions at point of emission.

A key stage of interpretation is to 'sanity check' the results, and to further examine any results or values that seem out of place. Initially, uncertainty and sensitivity assessment should be carried out on the data. It is usual that data is not a single point, but a range due to slight variations in processes, or compositions. Uncertainty assessment allows for these ranges to be included in the data. Sensitivity evaluates the effect of a change in a data value, to see what effect it has on the final result. Data points that are highly sensitive should be carefully checked to ensure the values used are accurate.

Scenario analysis allows changes in the system to see what happens of a material, process or other variable is changed

1.2.2 Shortcomings

A charge frequently leveled at LCA studies is that it can be made to say whatever is wanted, through changing boundaries, choice of data sources or other manipulations of the method. Following ISO guidelines and opening the study to independent critical review limits this occurrence. Notwithstanding deliberate manipulation, LCA should not be taken as providing a definitive and absolute answer to a question. This is for two reasons

1) It is unlikely that all data for a system under review will be available and whilst data gaps can be mitigated by expert opinion and proxy information, some data used will not be absolutely relevant to the system under review. These occurrences should be noted and clear in the final report.

2) Life cycle impact characterization provides information on the potential impact a system may have, not the actual impact. Actual impact is highly dependent on where and when the emissions occur, and capturing this data can only be achieved through extensive data collection and for attributional (retrospective) studies.

However, LCA studies provide information that can be used to guide decision makers and to provide more detailed insights, e.g. into stages of a product life cycle that warrant further investigation or modification.

The environmental framework for the MECS programme

This section below defines the basis for the environmental assessment within the MECS programme.

NOTE: The details in this section will be disseminated to the MECS modelling community for comment and agreement, and therefor may be subject to slight modification and review as the project progresses.

Goal

a. Intended Application and Audience

It is intended that the outcome from the environmental assessment will provide two levels of information.

- Provide insights into appropriate design criteria for cooking appliances and power combinations to ensure the needs of the users are met with a product that demonstrates high environmental performance. This may include recommendations on choices of materials, how materials are joined together, manufacturing processes, and design for EOL
- Provide policy makers at national, regional and local levels with understanding of the environmental consequences of decisions with respect to future clean energy for cooking options. This may include knowledge relating to appropriateness of cooking solutions dependent on local conditions, national energy policy directions, and needs of the local populations.
- At the later stages of the project, the LCA model built will be used to provide data to 'reverse engineer' or backcast to key indicators, i.e. for an annual GHG emission from cooking from a particular region, a X% of the pollution must be using a modern energy cooking system.

Scope

a. System Boundaries

The system will cover the full life cycle covering the materials extraction, manufacturing, use and end of life of a range of cooking appliances and power sources. The initial analysis will focus on cradle to gate, to deliver outcome (a), and then proceed to include use and EOL when the MECS system(s) of interest have been more clearly identified and defined.

The boundaries have been set as described to ensure that evaluation of the proposed cooking systems in the different geographic locations is comparable through the functional unit.

b. Functional Unit

There are a number of options for the functional unit for the system but ideally one is needed that is both relevant for insights into the design of the cooking devices, and trends for the policymaker.

Energy or CO2 per meal cooked cannot used as meals are not homogenous throughout the day, or the regions covered by the system.

Energy or CO2 to provide cooking services for a defined time period removes this homogeniality issue, and allows for products with different product life length to be compared. Length of time could be related to battery or PV solar cell life or life of cooking appliance. It is likely that PV solar cells will have the longest life at approximately 20 years, and this time frame fits well for policy related activities.

For design improvement insights, 20 years is not appropriate as it is unlikely that a cooking device would last and it is unlikely that the technology available for cooking devices would remain constant for the time period. For design improvements, the functional unit is more suited to energy or CO2 to provide meals over 1 year – this covers the natural variability in diet over all seasons and is well within the technological lifetime of the device.

c. Proposed approach

Within MECS, there are many potential combinations of power source, geographic location, cooking appliance type, cooking profile and local skills and facilities. In addition, whilst some of these options are not yet fully defined, others have been in existence and use in varying capacities for some time. To undertake a comprehensive LCA for all possible combinations in all locations would be both time consuming, even assuming that data of appropriate rigour and quality could be found.

The combination of existing known systems or parts of systems, with the multiple combinations of unknown systems, requires a mix of both attributional and consequential approaches. This will allow the system to provide useful insights at both the design and policy level.

The environmental model will be built as an 'elastic' model, using variables to switch different module on/off according to requirements. This allows for a quicker method of assessing different combinations of location, cooking appliance and power source and does not require a new model to be built from scratch for each set of combination of interest. It has the added advantage that the data source, boundaries etc will be consistent across each combination. A matrix has been developed that identifies the variables that exist within the MECS programme see section 1.2.2.

d. Data

- For Raw Material extraction and processing

The data for the raw materials required for the cooking devices and power sources will come from existing LCA databases and be country specific where possible, else global averaged data will be used.

- For Product Manufacture

It is highly likely that initially both cooking devices and power systems will not be manufactured in the geographical places where they will be deployed. It will be ascertained where the manufacture has occurred and data from exiting databases will be used to create the product manufacturing models, taking into consideration the country of manufacture. Transportation from place of manufacture to place of use will be included, using standardized transport data (road, rail and sea).

Where local manufacturing facilities exist, primary data from these businesses will be collected where feasible.

- ***Use***

Cooking diaries will be used and the main source of raw data to develop the usage models for the cooking appliance system. These will be supplemented by local averaged data for energy production (if using a grid, weak grid or mini grid)

- ***End of Life***

End of life is highly dependent on local facilities and behaviours. Primary data will be collected where available from the local population, and supplemented with existing EOL data from databases.

e. Data Gaps

It is inevitable that there will be significant data gaps in the MECS system, either because data simply does not exist, or because it is unaccessible. Where possible, primary data (where needed) will be collected. Where this is not a realistic proposition, existing LCA databases will be the initial starting point for additional data. Academic literature will also be used as an alternative source of data. Both of these quantitative approaches will be supported by a qualitative expert judgement process, where experts in the appropriate fields will be asked to provide comment/data on the proposed data values.

f. Data Quality

Data will be scrutinized and logged to demonstrate that it is fit for purpose, i.e. timely, from the right location and covering the right material/process. Where proxy data/ expert judgement has been used, this will be clearly noted.

g. Allocation

The primary method of allocation impacts between multiple outputs will be via partitioning by mass of the outputs. Where this is not sufficient, system expansion will be applied (this is most likely to occur when considering EOL options)

h. Impact categories of interest

Impact categories will cover all three types of categories, inventory, midpoint and end point.

Data from the Inventory stage, quantities of raw materials, emissions etc. will be presented. Key data of interest will be determined through discussion with the wider MECS programme team. Initial data of interest include Energy Consumption KWh, and materials on the EU 27 critical material list (EU Publications).

There are no environmental assessment systems that currently focus on the African continent. For global impacts, such as climate change, this is not a concern. However, for local pathways and associated impacts, the different regions can affect the potential impacts created. The ReCiPe system (which has built on CML 2002 and Eco indicator 99 systems) will be used to assess the midpoint and endpoint environmental categories. ReCiPe integrates the midpoint and endpoint approaches in a consistent framework. See Table 2 for details of ReCiPe approach.

i. Uncertainty and sensitivity assessment

Uncertainty and sensitivity assessment will be combined in a bespoke method to identify which data points require further investigation, i.e. those that are both uncertain (through for example, data variability, wide range or qualitative) and sensitive for the system (those for which the impacts change significantly if these data are varied). This approach streamlines the interpretation stage as it creates a priority list of data that need supplementing, and identifies data that is not so critical to a representative model.

j. User stories

User stories will be used to identify the initial system parameters, the geographic location, population type, cooking appliance etc. The options available have been detailed in the Variable Matrix (see section 1.2.2) and one option from each column can be chosen to determine the user story. Two basic stories covering the most common set ups (User Stories 1 and 2) will be analysed initially. Learnings from these will be used to identify a further three stories. Finally, when the elastic model is more complete, additional stories, as identified by the wider MECS programme team, can be modeled and analysed.

Initial suggestions for User Stories 1 and 2 have been suggested. These will be discussed, modified (where necessary) and agreed by the MECS modelling team.

- User story, option 1: Zambia/Myanmar, peri urban weak grid, with lithium ion, simple pressure.
- User story, option 2: Kenya, rural, EPC, fuel stacking with mini-grid, lithium ion, simple pressure cooker.
- User story, option 3: Tanzania, rural, PV solar cell, Lithium ion, hot plate.

Principle	Comment
Intended purpose of the method:	Combining midpoint and endpoint methodologies in a consistent way
Midpoint/endpoint:	Midpoint and endpoint characterisation factors are calculated on the basis of a consistent environmental cause-effect chain, except for land-use and resources
Handling of choices:	Cultural perspectives are used to distinguish three different sets of subjective choices. User can choose which version to apply.
Data uncertainties:	Data uncertainties are discussed in the text but not always quantified.
Regional validity:	Europe. Global for Climate change, Ozone layer depletion and resources
Temporal validity:	Present time
Time horizon:	20 years, 100 years or indefinite, depending on the cultural perspective
How is consistency ensured in the treatment of different impacts In characterisation In normalisation and weighting?	For all emission based categories similar principles and choices are used. All impacts are marginal. All impact categories of the same area of protection have the same indicator unit. Same environmental mechanism for midpoint and endpoint calculations is used.
Midpoint impacts covered:	climate change; ozone depletion; terrestrial acidification; freshwater eutrophication; marine eutrophication; human toxicity; photochemical oxidant formation; particulate matter formation; terrestrial ecotoxicity; freshwater ecotoxicity; marine ecotoxicity; ionising radiation; agricultural land occupation; urban land occupation; natural land transformation; depletion of fossil fuel resources; depletion of mineral resources; depletion of freshwater resources
Endpoint impacts covered:	Human health (DALY); ecosystem quality (biodiversity, PDF.m^2.yr); resources (surplus cost)
Approximate number of substances covered:	Approximately 3000 substances

Table 2: Features of the ReCiPe approach, reproduced from ILCD Handbook: Analysing of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment First edition

k. *Scenario assessment*

The top-level scenarios will be developed through the user stories. Within each of the user stories, there will be smaller variations that can be tested, through the elastic model, to assess the 'what if' questions that arise. For example, what would be the effect of moving production from a global base to local factories, or increasing the power of a battery system. These lower level scenario options will be driven by the initial findings of the cooking appliances under test in the field, and from consultation with the design authorities for the cooking devices/battery systems.

l. Critical review process

Since there is a high likelihood that outcomes from the LCA study will be used to make comparative statements in the public domain, this report will need to be critically reviewed. This will be undertaken in two ways

- Oversight of data sources to confirm relevance and accuracy. This will be undertaken through regular review with the MECS modelling team and expert witnesses where appropriate
- Review of the final system and report by external person/body who has not been involved in the construction of the model, or its testing.

The review should cover the following aspects

- Are the methods used consistent and appropriate and relevant to the described goal and scope?
- Are the data appropriate and reasonable?
- Are calculations carried out correctly?
- Are the conclusions supported by the data and within the limitations of the goal and scope?
- Is the model and report transparent?

m. Assumptions

Given that there are no impact characterization systems available for the specific regions included in this study, it is assumed that the ReCiPe system will provide a comparative basis for the analysis of different cooking /power systems.

n. Limitations

This system can only be used to deliver comparative views in different cooking/power systems. Whilst it can identify areas of interest within the design for said system, it should not be used to provide data to be published on absolute values.

Variable Matrix

The purpose of the variable matrix is twofold

- To identify the ‘modules’ that are required to build the environmental system model and the variables that will allow enhanced scenario analysis within those modules
- To identify and create ‘User Stories’ that are representative of the wide range of possible system structures.

Discussions with the MECS community have identified a number of possible variations that can occur for modern energy cooking services. These have been tabulated, and an assessment of the linkages between the variables undertaken. For example, battery power requirement is dependent on size of cooking pot, which is dependent on the type and style of food cooked, which is dependent on location and local traditions and norms. Whilst this may appear overly complex, an oversized pot leads to extra power requirement, which could lead to unnecessary drain on batteries/ gird/mini grid PV cell systems and hence system inefficiency. This could also lead to the equipment being too expensive to run, reducing uptake and potentially limiting the success of the technology implementation.

Within the matrix there will also be some ‘illegal’ combinations, for example, a particular battery type may not provide sufficient power for a particular cooking appliance. Alternatively, local end of life options may prohibit a particular cooking appliance. These illegal combinations will become apparent over time with increasing specification of the MECS system design(s).

1.4 References

Baumann and Tillman 2004: The Hitch Hikers guide to LCA, Studentlitteratur, 2004

Clift et al 1999: Report from the SETAC working Group of the Inventory Enhancement. SETAC-Europe News Vol 10, no 3, pp14-20

EU Publications 2017: Study on the review of the list of critical raw material, EU publications https://publications.europa.eu/en/publication-detail/-/publication/08fdab5f-9766-11e7-b92d-01aa75ed71a1/language-en

ISO 14040: 2006 Environmental management — Life cycle assessment — Principles and framework

ILCD Handbook 2010: Analysing of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment First edition https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-LCIA-Background-analysis-online-12March2010.pdf

Annex 1: Table of Consultation

Date	Activity	Summary of Discussion	Outcome/Actions
14 Jan 2019	MECS planning meeting		
3/4 April 2019	MECS programme meeting and Official Launch		
27 June 2019	MECS telecon	All MECS modelling community to understand what each will be developing, how and when results will be available	
12 Aug 2019	MECS Model	Attendees: Matt Leach (ML), Chris Mullen (CM), Jaqi Lee (JL) Discussion on the how the LCA and Energy modelling will feed into the work to be undertaken by Newcastle to integrate the various modelling aspects together. A framework was proposed by Chris, and then discussed and modified in light of the LCA modelling.	CM to provide updated schematic on integrative model for next MECS modelling meeting on 29th August JL to provide spreadsheet outlining data and variables for user stories for 29th August
29th August	MECS modelling meeting, Loughborough	Detailed catch up from all contributors to modelling. Discussion and partial agreement to use User Stories as a way to define initial model parameters	All: to review exiting user stories from ML energy paper and define more exactly the key parameters and who will be responsible for creating/collecting the necessary data.

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