Tackling Complex End-of-Life Rooftop Solar Photovoltaic Problems in Australia

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Introduction

The rapid growth of residential solar photovoltaic and battery energy storage installation in Australia (Figure 1) raises a concern on the impending waste crisis which will impact the environment and human health.

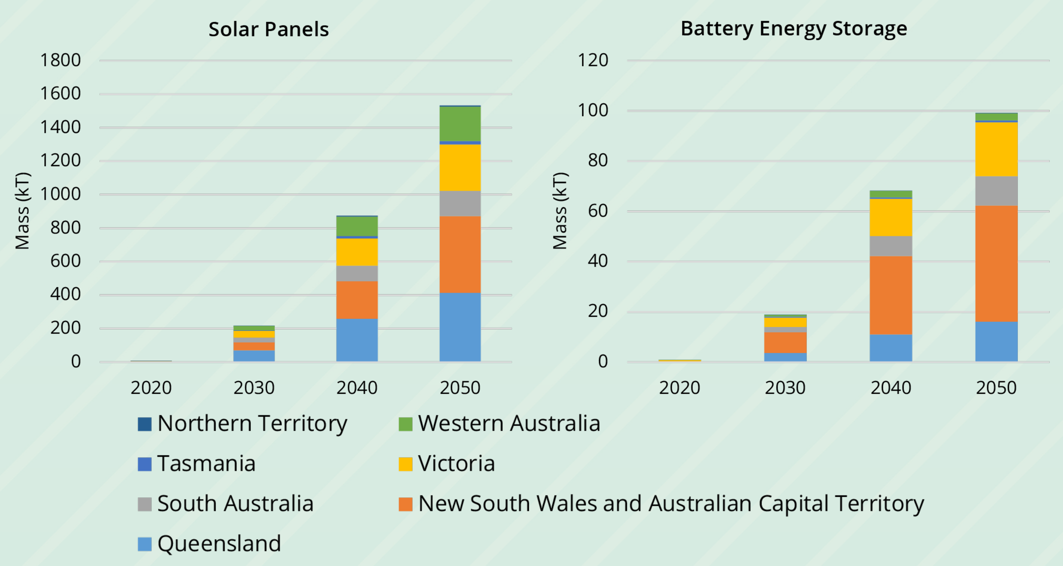

Figure 1. Waste projection of rooftop solar and batteries in Australia

In order to reduce product life-cycle impacts (from the product design stage to end-of-life stage), Australia has a *Product Stewardship Act 2011* for establishing a national scheme.

This legislation outlines different approaches in managing product impacts, including a voluntary, co-regulatory, or mandatory approach.

Designing an effective scheme for end-of-life rooftop solar and batteries requires an understanding on the complexity and the dynamic nature of the system (Sterman, 2000).

System dynamics is a powerful approach to analyse system behaviour over time by integrating interdepent system components.

Objectives

This study is an on-going research project developing a system dynamics model to evaluate different transition pathways for end-of-life management of rooftop solar panels and batteries in Australia.

This model will be linked to a serious gaming platform.

Problem scoping results has been published in Salim et al. (2019) and was utilised as a basis to develop the conceptual model.

The objective of this research is to develop a causal loop diagram and identify system archetypes.

Methods

This research utilised a participatory systems thinking approach to develop the causal loop diagram. Different stakeholders were consulted during the model development process, including governments, research institutions, academics, consultants, manufacturers, and system installers; thus, supporting model validity.

The first stage of this research is '*Problem Scoping*':

Systematic Literature Review - Preliminary list of drivers, barriers and enablers was retreived from 191 literature in Web of Knowledge and Scopus databases.

Expert review - The list of drivers, barriers and enablers were validated through phone interview with eight different experts. Follow-up questions were made to discuss problematic situations and potential solutions.

Stakeholder Survey - The survey quantified the drivers, barriers and enablers and the results were compared between different Australian stakeholders. There were 57 stakeholders who had completed the survey.

The second stage involve '*Model Conceptualisation*' stage:

Variables Identification - System variables were identified on the basis of authors' interpretation on the problem scoping stage results as well as relevant literatures (i.e. academic articles, government reports).

Preliminary Causal Loop Diagram - Causal relationships were drawn based on the problem scoping results, particularly from the expert interviews. System archetypes were also identified once the preliminary causal loop diagram is constructed.

Stakeholder Workshops - Two stakeholder workshops were conducted in Melbourne and Brisbane to validate the variables and causal relationships. System archetypes were also dicussed. Stakeholders were satisfied with the variables inclusion with minor comments on the causal relationships. Causal loop diagram and system archetypes were finalised based on these inputs.

Results

Figure 2. Causal loop diagram. Green coloured variables reflect the waste generation, collection and disposal sub-system. Black coloured variables indicate the end-of-life management strategies sub-system. Red coloured variables are indicative of cost and benefit analysis sub-system.

The final causal loop diagram (Figure 2) can be explained in three sub-systems:

Waste generation, collection and disposal - Describes the amount of generated end-of-life rooftop solar panels and batteries, collection rate, as well as disposal and stockpiling of waste.

It captured important balancing loops (B1a and B1b) where the increasing amount of landfill disposal will diminish materials supply for future solar system demand.

End-of-life management strategies - Focuses on the possible strategies from different stakeholders. Governments may introduce a product stewardship scheme for solar panels and batteries. This scheme may establish liable parties, approved arrangements, scheme target as well as monitoring and reporting system.

Landfill restrictions (B2a) and circular business models (B2b) may also be complimentary to this scheme to promote collection rate. Trade-off between liable parties and free-riders was also outlined in the diagram (R2).

It also depicts key balancing loops, which are investment on developing on-shore recycling capacity (B2c) and capability (B2d).

Cost and benefit analysis - Depicts the costs and benefits arise from the end-of-life management strategies. Balancing loop B3 in this sub-system depicts the economies of scale achieved through increased supply of waste for recycling.

Two system archetypes were identified based on the causal loop diagram: 1) growth and underinvestment and 2) drifting goals.

Conclusions

- The participatory approach has allowed the development of a comprehensive and relevant conceptual model.
- End-of-life management system of rooftop solar panels and batteries in Australia are characterised by complex and dynamic interactions of drivers, factors, and processes.
- The model consists of three sub-systems and governed with eight balancing loops as well as one reinforcing loop.
- The dominance of balancing loops indicate that there are numerous potential sources that can limit the growth of system performance.
- Based on this conceptual model, a quantitative system dynamics model will be constructed to evaluate different policy scenarios (e.g. voluntary, co-regulatory, and mandatory approaches). The model will be validated through stakeholder workshops.
- The quantitative model will be linked to a serious gaming platform and will be presented in a stakeholder workshop.

References

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