Fostering Sustainability with Decentral Renewable Energy Systems: A Case Study in Colombia

Bachelorarbeit

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vorgelegt von

Viktoria Redecker

[redacted]

Prüfer:
Prof. Dr. Michael H. Breitner

Betreuerin:
M. Sc. Maria C. G. Hart

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1 INTRODUCTION

The world is currently facing a global energy crisis caused by a rapid increase of the world's population, the resulting strong increase in demand, and dependence on fossil fuels for generating energy. Therefore, the need to work on renewable and sustainable solutions for energy production is an urgent matter to be investigated. It is widely acknowledged that the ongoing increase in greenhouse gas (GHG) concentrations will lead to significant changes in the global climate with corresponding impacts on our society and economy. Those changes in the climate already manifest themselves in form of increased numbers of extreme weather events and a rise in temperature (Coyle & Simons, 2014). As a result, representatives from over 150 countries committed to the 1.5-degree target at the UN Climate Change Conference 2021 by scaling down the use of fossil fuels in the energy sector and by encouraging renewable energies as clean alternatives (United Nations, 2021). This paper will focus on Colombia being a country with a strong commitment to climate goals and high renewable energy potential that are barely made use of so far (Eras, 2019). One possible solution is the implementation of decentral renewable energy systems in the shape of micro grids which are designed to function in small areas considering individual electricity demand and local geographic features as well as the climate. Decentralizing the energy production away from one central power grid towards smaller regional grids brings several advantages. The produced energy is consumed on site avoiding transmission losses due to long transportation routes. Particularly for countries with more challenging geographic conditions, decentralized energy systems provide more resilience and autarky from the central power grid (Adil & Ko, 2016). Many developing countries are part of the stakeholders, but especially here the conditions to manage a transition to a sustainable energy production are difficult. For one, the financial load for research on possible renewable energy components, their applicability in local sites, and the high initial costs present an obstacle. Moreover, there is little information on energy consumption on a smaller scale such as communities and private households. This type of detailed data, however, is urgently needed for the proper scaling of energy systems (Debnath & Mourshed, 2018). In order to assist stakeholders in taking actions on the named challenges the following research questions (RQ) are explored:

RQ1: *How can representative detailed load profiles be created for Colombian communities?*

RQ2: *What is a suitable design of decentral renewable energy systems for Colombian communities?*

RQ3: *What are potential policy measures to promote the use of renewable energy technologies in Colombia?*

To achieve this paper's goal of fostering sustainability with decentral renewable energy systems in Colombia and to address the RQs, the countries energy consumption is examined. This is done with a survey which is conducted in two different Colombian cities inquiring local and household specific electricity demand. The participants are asked about their hourly use of devices such as televisions, smartphones and washing machines. Using the obtained data, respective load profiles are synthesized that show daily peaks and lows of the electricity consumption. By creating the load profiles, the annual electricity demand of a model community can now be represented and suitable, alternative, renewable energy systems are identified. Those energy systems are provided with the aid of the simulation software NESSI4D which includes technical settings for the energy components and local-specific geographic conditions and climate. Finally, the newly offered energy systems are analysed and possible policy measures are recommended.

For this purpose, this paper is structured as follows. Section 2 provides background information of the research variables, on Colombia's current energy situation and on the software RAMP. Subsequently, the methodology and the research approach for this paper are presented in Section 3. Here the conducted survey is examined in detail, as well as the generation of load profiles. The simulations of the renewable energy systems are conducted and evaluated in Section 4 using the software NESSI4D. Reviewing the analysis and considering limitations, the discussion is given in Section 5. Lastly, the paper is concluded in Section 6.

6 CONCLUSION

Due to an increasing electricity demand and a current global energy supply which mainly relies on fossil fuels, many countries want to take action to reduce GHG emissions. As a country expected to experience the effects of climate change particularly strongly, Colombia has a pronounced interest in making its contribution towards a cleaner energy production (United States National Intelligence Council, 2021). The goal of this paper is to support Colombian stakeholders in their decisions regarding the implementation of renewable energy systems.

The first step is to obtain detailed data on the electricity consumption of individual households. Information on demand peaks and lows is necessary to choose suitable renewable energy systems with the right sizing. Hence, two Colombian cities, Bogotá and Fusagasugá, are chosen to conduct a survey and to serve as model communities for later simulations. The questionnaire is designed to query data of the 54 participating households such as the number of devices owned and the corresponding time of use. After the survey data is analysed, load profiles are generated for potential combinations of renewable energy systems with the aid of the software NESSI4D. The chosen components for the new energy systems consist of PV modules, a WT, a battery and the existing central power grid. The results assess the degree of autarky and self-consumption and the economic and ecological dimension of the different energy systems. Then, a comparison among the renewable systems and with the current reference scenario of the central power grid as sole energy supplier is drawn.

The analysis examines both surveyed sites and intends to recommend effective policy measures. With significantly higher average wind speeds in the capital Bogotá, the systems including a WT present a greater reduction of GHG emissions than in Fusagasugá. However, the corresponding rise in total costs causes those systems to be unfeasible for stakeholders at present. Nevertheless, the separate consideration of each city demonstrates the importance of examining even local differences regarding geographic conditions, the climate and electricity demands. Based on the survey results, electric vehicles are also considered as a component of energy systems since they consume additional electricity. Corresponding simulations prove that the acquisition costs for electric vehicles are too high in Colombia. Those are not bearable in comparison to the low average income.

A promising solution for both locations is given with the expansion of the central grid with PV modules and battery storage. This simulated combination provides noticeable economic and ecologic improvements combined with a higher degree of self-consumption and less dependency on the central power grid. Even though the advantages are clear on paper, the implementation of the new energy systems needs to be further encouraged by the state. To lighten individual costs, feed-in tariffs have proven to be an effective way of promoting the purchase of renewable energy plants. In addition to that, possible policy measures could include

a shift of production to the domestic market to reduce prices and create jobs. Overall, it is essential to sensitise the Colombian population to renewable energy systems. Easily accessible information should be provided to strengthen local knowledge of the subject and to highlight according advantages.

The data collection through the conducted survey has served its purpose, as it manages to provide information about hourly user behaviour. For further improvements it is suggested to conduct face-to-face interviews in larger numbers for more accurate data on electricity demands. Moreover, the consideration of GHG emissions that are emitted during the production and transport process of renewable energy plants is proposed. Their inclusion makes the ecologic calculations more sensible.

To conclude, the aim of pre-designing renewable energy systems for the two model communities in Colombia is reached. It is shown that PV modules combined with batteries have high potential in the two Colombian model communities and provide a sustainable development of the energy production with economic and ecological improvements. The simulation tool NESSI4D has proven its value in providing suitable designs for sustainable energy systems and stakeholders are encouraged to use the software as an aid in the decision-making process. With an increasingly complex world and many interdependencies, the methodology presented offers a good approach to contributing to climate protection with an uncomplicated process on a small scale and to inhabiting the planet in a more sustainable way.