UN Project: Climate, Land, Energy and Water (CLEWs)
Participants: Rutgers University
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Technical Report

Introduction and Literature Review

The access to and the consumption of energy is essential to a country's social well-being, health, education, and environment, which also affect industrial and agricultural developments (Brew-Hammond & Kemausuor, 2009). However, some parts of the world - particularly developing countries - are still affected by energy poverty and are behind in creating and using energy technologies (Kammen & Kirubi, 2008). Developing an effective energy system is an important but challenging task that involves complex interactions among energy supply, distributors, and consumer demand (Bazilian et al., 2012).

With the widespread use of the Internet and other modern computer technologies, a growing trend is for individuals or organizations to obtain information, knowledge, or services from other Internet users - known as crowdsourcing. Crowdsourcing has been recognized as an effective and efficient way to create and maintain valuable datasets, resources, and tools. Since the ability of one individual or organization to accomplish tasks is limited, crowdsourcing can be an effective way to dissimulate tasks to broader communities. A good example is Amazon's Mechanical Turk (also known as MTurk) (https://www.mturk.com/mturk/welcome), which is a crowdsourcing platform from which individuals and businesses (known as Requesters) can recruit workers from all over the world to perform tasks that require human intelligence (e.g., transcribing, filling out surveys, translating). It has gained increased popularity because organizations could complete their required tasks on MTurk at a relatively lower labor cost compared to working by hiring full-time employees.

Crowdsourcing may also benefit the international energy modeling community by facilitating the development of publicly accessible modeling tools and datasets that can help in enhancing data reuse and reducing the cost of data collection, management, and energy modeling (Howe, 2006). It may facilitate the collection of geographically-specific data relating to energy systems (Bazilian et al., 2012). Employing open software and data for energy modeling may also be able to satisfy both the environmental conditions and human needs of using the tools and interpreting the results. It may have low adoption cost and the flexibility for revising, making it suitable for developing countries. This technical paper reviews the relevant literature of existing energy modeling tools including OSeMOSYS (the Open Source Energy Modeling System) and discusses the limitations of existing tools as well as directions for developing new tools or modifying current tools to achieve better user experience and more effective outcomes.

Currently, there are a set of existing tools that can be used for energy modeling such as BALMOREL (an open source electricity and district heating tool) and MARKAL developed by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA), which can be used for national and local energy planning (Connolly, Lund, Mathiesen, & Leahy, 2010; Seebregts, Goldstein, & Smekens, 2002). Most of these tools require significant efforts for model development. OSeMOSYS was designed to ease the difficulty on model developing and operating, and to allow flexibilities in updating and modifying (Howells et al., 2011). Models can be built in the OSeMOSYS in a series of blocks that can be combined in multiple ways to form customized models.

Pfenninger, Hawkes, and Keirstead (2014) pointed out the challenges in energy systems modeling: (1) resolving details in time and space; (2) balancing uncertainty and transparency; (3) addressing the growing complexity across scales, and (4) integrating human behavior and social risks and opportunities. Among which, we are specifically interested in incorporating human factors into energy modeling. Current methods are focusing heavily on technical and economic aspects while relatively neglecting the human dimension, which may be of equal importance. A lack of understanding in the human aspect may also increase model uncertainty.

The remainder of the paper is organized as follows. In the following sections, we discuss the OSeMOSYS model and how the quality of life can be considered an important factor while designing sustainable energy models. The last section highlights the challenges that we face to integrate human factors into the CLEWs computational model.

OSeMOSYS

The OSeMOSYS is an open source model which was developed to assist in energy planning. Along with its web-based interface MoMani, this tool requires no upfront investment and less significant learning curve. Being an open source model, it is not limited by proprietary litigations and is freely available for developers, researchers and policy makers.

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This model comprises seven functional blocks – objective, costs, storage, capacity adequacy, energy balance, constraints and emissions – and is written using GNU Mathprog. While this model has many advantages, it can still be extended to include few others factors related to objective and constraints. The current model focuses strongly on the economic and technology factors. Subsequent developments can focus on the influence of different sources of energy on human life in the specific countries. The quality of human life is not only dependent on economic factors, but also on perceptions of a better life. Factors like life expectancy, health benefits and hazards arising from the use of energy resources, and overall quality of everyday life can be some of the influencers for selecting particular energy sources over others. Through carefully constructed studies, large-scale data may be collected from various countries, and the objectives may be refined to ensure cheapest energy solution and maximum citizen satisfaction with minimal degradation of the environment. By balancing these factors based on different objectives, policy makers can ensure maximum efficiency.

Quality of life as an Influencing Factor in Sustainable Energy Development

By looking at various indexes like Better Life Index and Happy Planet Index from a macro-level perspective, we are trying to find out how climate sustainability can be achieved without disrupting the daily life of the people.

Better Life Index was launched by Organization for Economic Co-operation and Development (OECD)[1] to compare the degree of the well-being of people around the world. This Index also allows for comparison of well-being across countries. OECD has identified 11 areas which are essential for quality of life and living standards. While this index does not reflect the inequalities in society, it highlights the child poverty rates in various OECD countries. Better Life Index allows users to interact with the tool and set their preferences about which factors are more important for a better life.The various factors considered for this index are as follows:

1. Housing: housing conditions and spending;
2. Income: household income and financial wealth;
3. Jobs: earnings, job security and unemployment;
4. Community: quality of social support network;

[1] http://www.oecdbetterlifeindex.org/#/11111111111

5. Education: education and what you get out of it;
6. Environment: quality of environment;
7. Civic Engagement: involvement in democracy;
8. Health: the degree of being healthy;
9. Life Satisfaction: level of happiness;
10. Safety: murder and assault rates; and
11. Work-life balance: the work-play balance.

Similarly, the Happy Planet Index[2] measures the sustainable wellbeing for everyone. This index provides insight on the efficiency with which different nations are promoting and achieving long, happy, and sustainable lives. This index is an indicator of the fact that the wealth of the nation is by no means a viable indicator of the quality of life of its citizens. Citizens of several countries in Asia and South America have achieved better well-being and higher life expectancy than their richer Western counterparts. Happy Planet Index (HPI) also points to the fact that the quality of life need not come at a price to the planet (Abdallah et al., 2009).

$$HPI \approx \frac{Life\ Expectancy * Experienced\ wellbeing * Inequality\ of\ outcomes}{Ecological\ Footprint}$$

where Experienced wellbeing is the measure of how satisfied the residents of the country are with the quality of life, on a scale of 1 to 10, collected as part of Gallup World Poll; Life Expectancy is the number of years a person is expected to live in a specific country (data collected by United Nations); Inequality of outcomes is the inequalities between people of the country expressed as percentage; and Ecological Footprint is the average impact of each citizen on the environment measured in global hectares per person.

Both the indexes highlight the eagerness of nations to strive for better economic growth, which is wrongly regarded as one of the key measures of better life. This short-termism has led to the deterioration of social conditions and degradations of the environment. As various methods and indexes are being developed to promote and measure sustainable energy models, we must consider the impact that these models will have on the quality of life of the people. Conversely, we must also consider how various socio-economic measures can adversely affect the climate and other natural resources.

[2] http://happyplanetindex.org/

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Challenges for Integrating Human Factors into CLEWs Computational Models

In the ubiquitous interactions among water, land use, energy use, and climate change, human activities have served as bridges connecting all of these factors together in various ecological systems. For example, the industrialization of a developing country leads to a great demand and long-term exploitation for natural energy, especially fossil fuel. Without proper regulations and policies, the overuse of natural energy often cause severe air pollution, water pollution, and misuse of lands, and also negatively change the local climate. Therefore, incorporating human factors into the theoretical framework and quantifying human activities in modeling and data analysis are critical steps for building a relatively comprehensive CLEWs computational model. Also, how and to what extent human activities (both as individual and collective) affect CLEWs is an interesting and critical topic for policy makers in various nations. A thorough analysis of human factors is in need in both academic research (i.e., theoretical and computational modeling) and policy making (i.e., making and adjusting policies based on the prediction of effects caused by individual energy need, land use, and industries on ecological systems).

As discussed above, incorporating human factors into the computational model will be beneficial for both CLEWs-related studies and policy design. However, the operationalization of this idea is often faced with various challenges. This report elaborates three major challenges not only for the CLEWs computational model but also for other similar models intended to take human factors (e.g., the distribution of age, education level, work, income) and activities (e.g., average energy consumption, energy-related trades between developed and developing countries) into consideration:

- Need for reliable large-scale survey data describing human activities in various arenas (e.g., economy, politics, social movement, energy consumption);
- Finding potential indicators and related datasets which can serve as proper proxies for human activities, especially the data collected by advanced information and communication technologies (ICTs); and

- Need for open access to more comprehensive, reliable datasets owned by governments, organizations, and individuals.

Despite multiple new modalities of data, the large-scale census is still one of the most widely used types of data for analyzing macro-level human activities. Large-scale surveys, however, are often time-consuming and costly. Policy makers and leaders in poorest countries often have to make economic decisions based on limited data (Blumenstock, 2016). Under this circumstance, both the interactions among CLEW factors and the impacts from human activities on CLEWs are not fully understood, and hence are hard to analyze and predict. To deal with the issue, De Montjoye, Radaelli, and Singh (2015) and Blumenstock (2016) suggest that we develop new indicators based on the large-scale data collected by advanced ICTs (e.g., mobile devices, satellite, Bluetooth, and credit card) as proxies for human activities such as satellite photos, nightlight luminosity, and mobile phone data. Although these datasets is easier to collect compared to survey data, it still leaves many problems and challenges concerning data merging, data analysis, and the development of new useful measurements.

References

Abdallah, S., Thompson, S., Michaelson, J., Marks, N., & Steuer, N. (2009). The Happy Planet Index 2.0: Why good lives don't have to cost the Earth.

Bazilian, M., Rice, A., Rotich, J., Howells, M., DeCarolis, J., Macmillan, S., ... & Liebreich, M. (2012). Open source software and crowdsourcing for energy analysis. *Energy Policy*, *49*, 149-153.

Blumenstock, J. E. (2016). Fighting poverty with data. *Science*, 353(6301), 753-754.

Brew-Hammond, A., & Kemausuor, F. (2009). Energy for all in Africa—to be or not to be?!. *Current Opinion in Environmental Sustainability*, *1*(1), 83-88.

Connolly, D., Lund, H., Mathiesen, B. V., & Leahy, M. (2010). A review of computer tools for analysing the integration of renewable energy into various energy systems. *Applied Energy*, *87*(4), 1059-1082.

De Montjoye, Y. A., Radaelli, L., & Singh, V. K. (2015). Unique in the shopping mall: On the reidentifiability of credit card metadata. *Science*, 347(6221), 536-539.

Howe, J. (2006). The Rise of Crowdsourcing. Wired Magazine. Issue 14.06. Retrieved on 12/17/2016 from: http://www.wired.com/wired/archive/14.06/crowds.html.

Howells, M., Rogner, H., Strachan, N., Heaps, C., Huntington, H., Kypreos, S., ... & Roehrl, A. (2011). OSeMOSYS: the open source energy modeling system: an introduction to its ethos, structure and development. *Energy Policy*, *39*(10), 5850-5870.

Kammen, D. M., & Kirubi, C. (2008). Poverty, energy, and resource use in developing countries. *Annals of the New York Academy of Sciences*, *1136*(1), 348-357.

Seebregts, A. J., Goldstein, G. A., & Smekens, K. (2002). Energy/environmental modeling with the MARKAL family of models. In *Operations Research Proceedings 2001* (pp. 75-82). Springer Berlin Heidelberg.