The Approaches to Social Impacts of Energy Efficiency Projects

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Summary

The need to reduce energy use while maintaining the standard of living has led to energy efficiency measures. The energy efficiency measures focuses on mostly the energy efficient machines, reduction of carbon footprints and the economic impact with an introduction of incentives and subsidies of energy efficiency projects. The human and social contributions are rarely acknowledged when quantifying energy savings although humans are the ones that use the energy. The use of energy by individuals is affected by certain factors that sometimes seem random, but these factors are not random. Humans are the ones who implement the energy efficiency measures and as such quantifying the social impacts of energy efficiency project aids the predication of the energy savings of that project.

It is often assumed that the "end use" technology is what advocates the energy efficiency. This is not true, people and the use of the technology consumes energy and therefore determines the viability of the energy efficiency of any project. Generalizing how energy efficiency projects affect the entire population is inaccurate and as such, the actual target of the projects may be missed. Studying the social structures of society or network reveals the actual impact each individual has on his/her society when an energy efficiency project is done.

In this paper, a mathematical model is formulated based on social interactions to quantify the social impact an individual has on his/her network when he/she performs any energy efficiency project. The social impact is quantified by using the small world phenomenon to describe the connectedness of an individual to his/her neighbour and the information theory to explain the probability that the individual has influenced his/her neighbour directly or indirectly with his energy efficiency project.

The example used in the poster illustrates the usefulness of the estimated power saving model when considering a free installation of a solar water heater for a household within in a rural community. The model gives the combined savings (direct and indirect) of each individual in the network using the entropy of information theory. The savings determine which household receives the free heater. The aim is to encourage people to buy the solar water heaters that will help reduce the use of electricity within the community.

Further work that needs to be done on this research includes, using a weighted graph and considering a dynamic graph. With the graphs mentioned above, the examples below can be determined.

1. To estimate potential customers in residential mass roll out programs.
2. Comparing how the social impact affects the socio-economic aspect of the society for example job creation.
3. Considering the demand response to a renewable energy technology introduced.
4. Incorporating the model as part of the generator maintenance scheduling problem of a power plant.

THE APPROACHES TO SOCIAL IMPACTS OF ENERGY EFFICIENCY PROJECT

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INTRODUCTION

- The social impact is quantified by using the small world phenomenon to describe the connectedness of an individual to his/her neighbour and the information entropy estimates the information transfer within the network. Small world networks are networks with connection topologies between the regular networks and random networks [1]. The information entropy is obtained from C. E. Shannon in his famous article "A mathematical theory of communication" [2].
- Combining the small world and information entropy, gives an estimation of how much influence an individual has within his/her community.
- In this presentation, a demonstration of the social impact of individuals within a community of thirty-six is shown. The influence each person has on the entire community with regards to information transfer determines which household should receive the free solar water heater.

BENEFITS

There are several benefit associated with this study, a few are listed below:

- Estimation of how fast the spread of an energy efficiency measure can be, for example using CFL bulbs.
- Estimation of how much power is saved within an network through interactions.
- Prediction of an optimal location for an energy efficiency project that will yield maximum savings.
- The effect of using renewable power within a network can be calculated.
- Measurement of how much jobs are created due to energy efficiency projects within a network.
- The calculation of acceptability of an energy efficiency project considering a network

EXAMPLE

- In a rural community of thirty-six households one free solar water heater is to be installed in a household.
- The aim of the project is to reduce the electricity bills of each household and reduce power usage within the community.
- The amount of power saved by each household if the heater is installed will determine which house receives the heater.
- The selection of the household to receive a free solar water heater is dependent on how much information is transferred from that household to the rest community.
- The stronger the influence of an individual on his/her community the higher the chances of people buying solar water heaters and reducing the electricity consumption in the community.
- The energy consumption profile of each household is assumed to be identical.
- It is assumed that each solar water heater installed will save 2 kW of power.

MATHEMATICAL MODEL

For an un-weighted and undirected network with N nodes, where nodes i and j are connected by the shortest path length d_{ij}. The node degree k_i of node i indicates the level of interaction it has within the network.

The probability that information is transferred within the network is dependent on the three probabilities: **the function probability ($p(i)$) , the relative probability ($p_i(j)$) , the relative function probability ($p(i,j)$)**

The Information entropy is a measure of information transfer from source to receiver. The entropy (H) of an information source is :

$$H = -\sum_{j \in N, i \neq j} p(i,j) \log_2 p_i(j)$$

where: $p(i,j) = p(i)\, p_i(j)$

From the above the estimated power saved (EPS) is calculated for an node in the network.

$$EPS = S_i + \sum_{j \in N, i \neq j} S_{i,j}$$

$$\sum_{j \in N, i \neq j} S_{i,j} = H S_i$$

The EPS comprises of two parts, the savings due to demand side management project done by that node (S_i) and the savings because of the node's interaction within the network ($\sum S_{i,j}$). The savings due to the interaction within the network is where the entropy of an information source comes in.

RESULTS

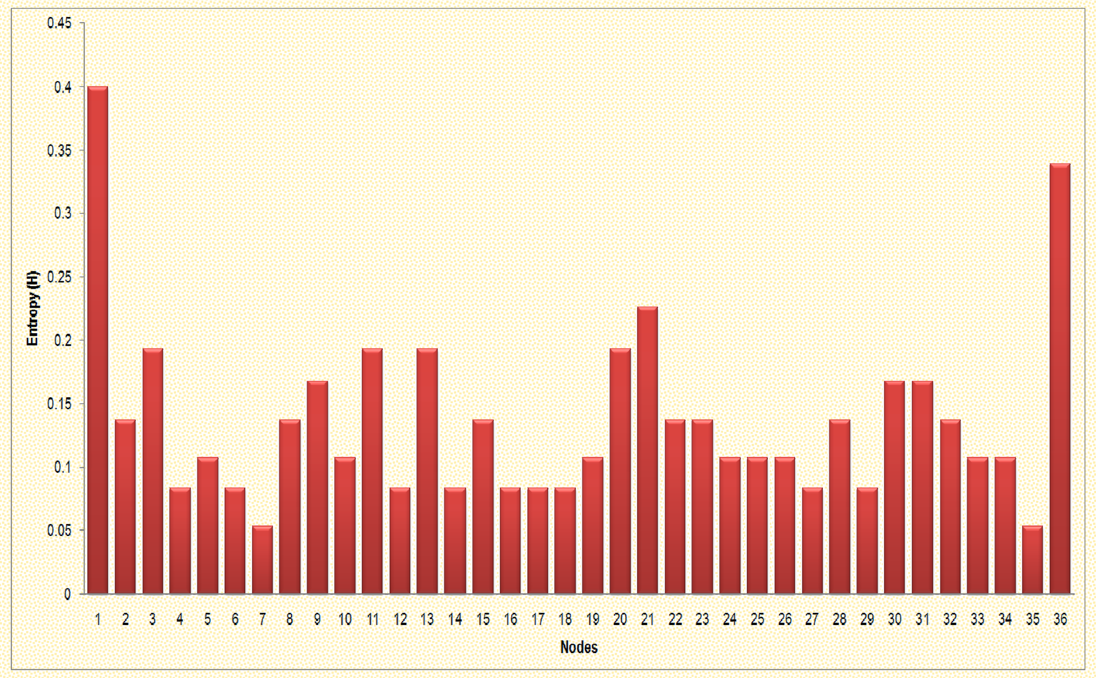

Figure: 1 The entropy of an information source for all households in the community

- *Figure 2 is the social network graph of the thirty-six households in the community. This graph is plotted using the Ucinet 6 software [3].*
- *The households of the community are referred to nodes, the Figure 1 gives the measure of information transfer (Entropy) of each node if that node is the source of the information.*
- *From Table 1 it is seen that node 1 is connected to 14 other nodes, its entropy and estimated power saved are the highest in the entire network. Therefore, node 1 is the household chosen to receive the free solar water heater.*

Table 1: The social impact of each household (comprising of their node degree and entropy) to the community and estimated power saved

Household/node	1	36	21	3	11	13	20	9	30	31	2	8
Node degree (k)	14	12	8	7	7	7	7	6	6	6	5	5
Entropy (H)	0.4	0.34	0.23	0.19	0.19	0.19	0.19	0.17	0.17	0.17	0.14	0.14
Estimated Power Saved (kW)	2.80	2.68	2.45	2.39	2.39	2.39	2.39	2.33	2.33	2.33	2.27	2.27
Household/node	15	22	23	28	32	5	10	19	24	25	26	33
Node degree (k)	5	5	5	5	5	4	4	4	4	4	4	4
Entropy (H)	0.14	0.14	0.14	0.14	0.14	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Estimated Power Saved (kW)	2.27	2.27	2.27	2.27	2.27	2.21	2.21	2.21	2.21	2.21	2.21	2.21
Household/node	34	4	6	12	14	16	17	18	27	29	7	35
Node degree (k)	4	3	3	3	3	3	3	3	3	3	2	2
Entropy (H)	0.11	0.08	0.08	0.083	0.08	0.08	0.08	0.08	0.08	0.08	0.05	0.05
Estimated Power Saved (kW)	2.21	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.11	2.11

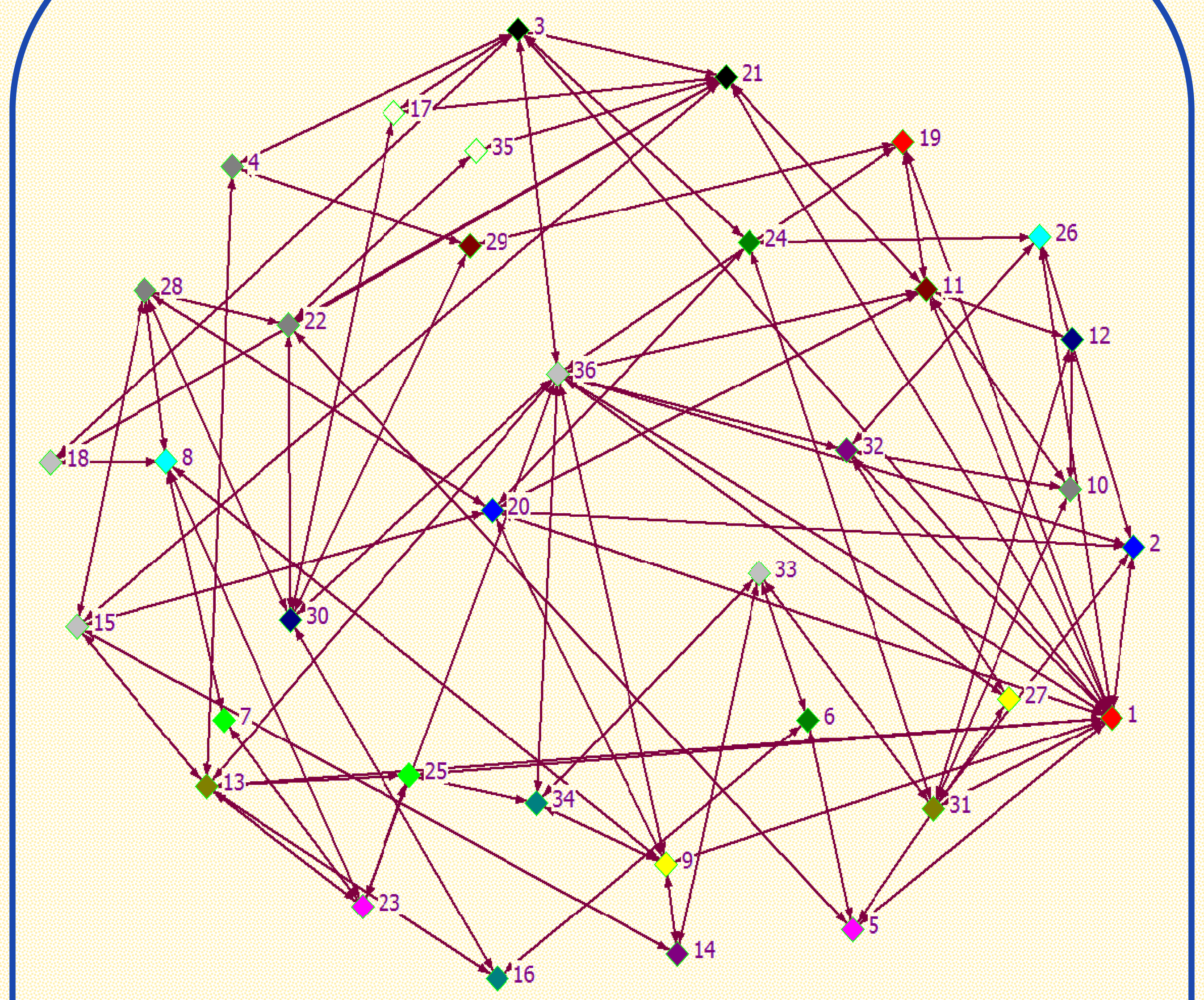

Figure: 2 Social connections of the thirty-six households in the community

CONCLUSION AND FURTHER STUDIES

- The information entropy aids in quantifying the social impact of individuals within a network.
- For a solar water heating project where a free heater is to be installed in a household, the power saved by each household due to their interaction with others within the network determines which household should have the heater installed.
- The social impact model will be extended to consider directed, weighted and dynamic graphs. These considerations will follow with examples.

References

[1] D. J. Watts, S. H. Strongatz, "Collective dynamics of "world" network", *Nature*, vol. 393, 1998

[2] C. E. Shannon, "A mathematical theory of communication", *The Bell System Technical Journal*, v vol. 27, pp. 376 - 423, 623 - 656, 1948.

[3] S.P. Borgatti, M.G. Everett, and L.C. Freeman, Ucinet for Windows: Software for Social Net work Analysis. Harvard, MA: Analytic Technologies, 2002.

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