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Emergent Stakeholder Opinion Formation in Multi-use Geothermal Fields

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ABSTRACT

The social license to operate (SLO) is a concept that has been used to understand and measure the feelings of a host community toward the focal organizations in development projects such as the mining and oil and gas sectors for several years. While useful, the SLO is a simple static snapshot of sentiment at a given time and place, whereas in reality, the sentiment of stakeholders is dynamic and complex. It is not merely the opinion of the most influential stakeholders, nor the summation of the opinions of all stakeholders, but an emergent phenomenon that takes into account both the opinion of stakeholders, and the structure of the stakeholder network on which information is distributed.

In geothermal development projects, the multi-use flexibility of the resource leads to additional complexity, since there may be multiple industries operating in an area that are using the same resource. In Japan, for example, there is a very strong and culturally-important direct-use community that uses geothermal waters for bathing (*onsen* or 温泉 in Japanese), which may exist alongside small and large-scale power generation projects or other industrial direct-use applications. In these stakeholder communities, it is often difficult to define the focal organization whose SLO is to be measured. In this paper, the authors present the results of a comparative case-study in which the SLO of different types of focal organization were measured in different stakeholder communities.

In addition to measuring the SLO, the authors also created an agent-based model (ABM) in order to capture the dynamics of opinion formation and propagation over time and explore policy scenarios through the use of simulation. This model was parameterized and validated using the results of the SLO case study, and the findings are discussed herein.

1. INTRODUCTION

The social license to operate (SLO) is a concept coined in the traditional extractive industries to denote the feelings, attitudes, and actions of the stakeholders in a local host community toward a particular development entity or industry, called the "focal organization" (Thomson and Boutilier 2011). While the term has mostly been used in mining and other traditional development projects, it can also be applied to other types of development, including the broad area of renewable energy resources, and more specifically, to geothermal energy. Several methodologies have been developed to measure and understand the social license of a focal organization, each of which give insight into some element of the social forces that drive the social license. For example, Que and Awah-Offei used discrete choice theory to discuss the effects that economic, social, environmental and governance impacts of a mining project have on the public perception of that project (Que, Awuah-Offei, and Samaranayake 2015), while Moffat and Zhang have focused on a statistical approach to the relationships between impacts and relationships on trust and acceptance (Moffat and Zhang 2014). Boutilier and Thomson take the view that the SLO is dependent upon both individual opinions and relationships, not only between stakeholders and the focal organization, but also between individuals and organizations within a wider stakeholder network (Boutilier 2009a, 2009b; Boutilier and Thomson 2011).

Geothermal development differs somewhat from traditional mineral extraction, because the nature of the resource makes development much more flexible. Whereas stakeholders in a mining claim face a fairly narrow decision when considering the development of mineral resources—to mine or not to mine, and who should be responsible—geothermal stakeholders face a wide range of decisions, including the binary choice whether to develop or not, but also the scale and nature of development to consider; should the resource be used directly by locals on a small or industrial scale, used in a limited capacity to produce electricity, or used to its full capacity to produce electricity on a large scale? Or perhaps some combination of development schemes? The question then becomes, "who has what right to how much of the resource?" The extent of the resource utilization potential of geothermal energy is both a boon and a challenge, as it widens the possibilities for the usefulness of the resource, but it also increases the potential for competition and conflict between stakeholders with claims of varying legitimacy of the resource.

This multi-use nature of geothermal energy also makes the SLO more difficult to measure, as there can be multiple different focal organizations with varying degrees of social license in a single geothermal field. Figure 1 shows a conceptualization of the combinations of usage application and usage SLO level that can be measured, with two example areas (Rico Colorado and Tsuchiyu Japan) that will be the basis for the case study presented later in this paper. The chart shows 4 separate areas of measurement, including past SLO stages that may have been passed through to reach the current state, current states, in which the SLO can be measured for an organization that is currently operating in the area, potential states, in which the SLO for a higher level of development can be theoretically measured, and the critical area of SLO measured for large-scale development in an area that currently has a strong direct-use community. The reason for singling out this critical area is that it represents an area with high potential for conflict between stakeholders and resource developers. The conflicts between geothermal developers and direct-use hot-spring stakeholders in Japan provide an illustrative example. Kubota et al, Bahr et al, Shortall and Kharrazi, and others have discussed many of the social and cultural factors that have impacted Japan's geothermal development over the past several decades (Bahr et al. 2017; Kubota et al.

2013; Shortall and Kharrazi 2017). One of the major sources of social opposition comes from the owners of hot-spring spas (*onsen* or 温泉 in Japanese), which represent a historical and culturally important Japanese practice of communal bathing, over concerns about the quality and quantity of their own hot spring water in the event of new geothermal development. In this paper, the authors will explore a comparative case-study between the U.S. and Japan, in which the social license and stakeholder networks reveal important information regarding the social viability of development for geothermal resources at multiple levels of usage and social complexity.

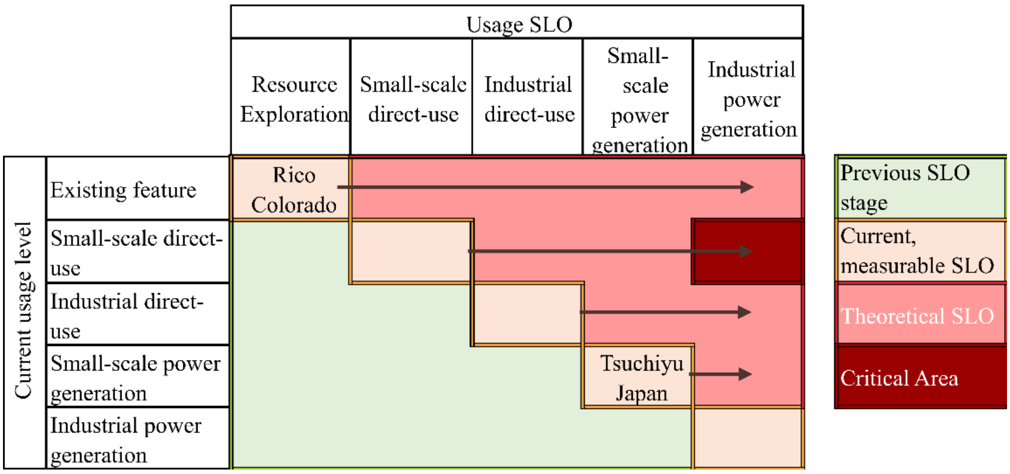

Figure 1. Resource usage and SLO domains

One other important aspect of the SLO is that it represents a static snapshot of stakeholder attitudes and relationships at a single moment in time, but those attitudes and relationships are themselves dynamic, and the SLO can be revoked at any time. Because of the inherent time-lag caused by the static measurement of a dynamic phenomenon, focal organizations and stakeholders can sometimes find dramatic changes in the SLO before they are aware and can react stakeholder concerns and criticisms. Additionally, SLO is an example of a complex emergent phenomenon, in which the aggregate or bulk behavior of the stakeholder group is not necessarily a linear scaling of the micro-scale behavior of the individual constituent parts of the overall system. In other words, because of the complex nature of the interaction between stakeholder opinions and the diffusion of those opinions on their respective network structures, the SLO cannot always be estimated by a poll of the opinions of individual stakeholders. In recent years, the complex social phenomena of which SLO is a type, have been the subject of much research in the field of agent-based modeling (ABM) (Douglas and Zhang 2011; Epstein 2008; Gilbert 2008; Jia et al. 2015; Prno and Slocombe 2014).

Agent based models, like discrete element models in material science, seek to understand the potential macroscopic behaviors of a system with simple interaction rules defined for the constituent elements (see Figure 2). The goal of ABMs, however, is not necessarily to perfectly reproduce a real behavior, but to understand some aspect of a whole by examining the underlying phenomena. They are particularly well suited to systems that have no analytical solution, have multiple scales of manifested behavior, and consist of heterogeneous constituent parts. An agent-based model is created by identifying the basic actors in a system (in this case, stakeholders), and creating computational analogues called agents, which are defined by their state variables (money, opinion, influence, etc.) and given simple rules for how they change their internal state variables through interaction with their neighbors and their environment. In addition to the comparative case-study mentioned above, the authors will also give an example of an ABM that was parameterized using the results of an SLO survey conducted in the case-study areas, as well as an example results of that model in order to illustrate the potential of ABMs for dynamically modelling the evolution of the social license and stakeholder networks.

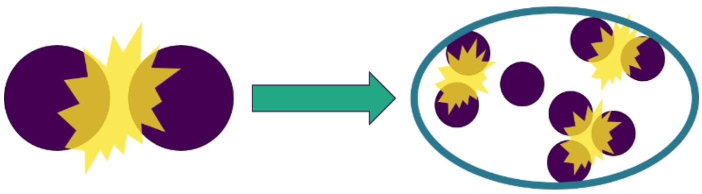

Figure 2. Complex, non-linear macro-scale behaviors from simple micro-scale interactions of constituent elements.

2. CASE STUDIES

As shown in Figure 1 above, the two case study areas presented in this paper are Rico, Colorado in the United States, and Tsuchiyu, Fukushima Prefecture in Japan (see Figure 3). The details of the social license measurement have already been published elsewhere (Bahr et al. 2017), so this paper will mainly focus on the analysis of the stakeholder networks, and how these networks affect the levels of SLO in each case.

During the Great East Japan Earthquake of 2011 and the resultant tsunami, Fukushima prefecture in Japan was devastated not only by the primary damage of the earthquake and tsunami, but also by the meltdown of Fukushima Daiichi Nuclear Powerplant, and the secondary economic impact that many tourism-dependent towns far from the nuclear plant suffered as a result of international and domestic fears regarding travel to Japan and Fukushima. Tsuchiyu village is one such area, which saw 5 of its 16 onsen hotels close in the aftermath of the nuclear disaster, due to the loss of tourism (Movellan 2015). As a result of the economic hardship, stakeholders in the town of Tsuchiyu decided to use their excess hot-spring resources to produce energy with a small (400kW) binary powerplant. As an early and successful adopter of binary geothermal power, Tsuchiyu represents a unique case of onsen owners embracing geothermal power production, at least at a small, locally owned scale. The focal organization for measuring the SLO and its related stakeholder network is the locally owned company, Genkiup Tsuchiyu, which operates the binary plant as well as a small hydro-plant in the town. The reasons for their success are hypothesized by the authors to be a result of the structure and dynamics of their stakeholder network, as discussed below.

Rico, Colorado is a small mining town in the mountains in the southwest region of the state. For most of its existence, its economy was dominated by silver mining and related services, including sulfuric acid production for use in nearby mining operations. The mining legacy caused severe environmental degradation, and it is currently undergoing cleanup as a CERCLA superfund site. Currently the town functions largely as a commuter town, with many of its residents working in the nearby ski-resort at Telluride. It is also home to several local artists. The Geothermal resource in Rico currently consists of an un-developed natural hot-spring north of the town. Because the resource is currently undeveloped the focal organization for geothermal development is more nebulous that it is in Tsuchiyu. It consist of a loose coalition of researchers who have been performing geological exploration in the town since 2012 (RPI Consulting 2012).

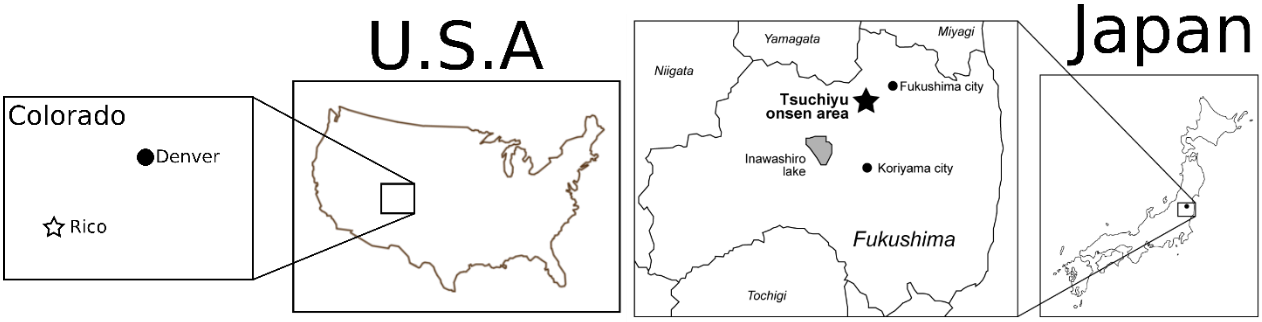

Figure 3. Rico, Colorado (U.S.A) and Tsuchiyu, Fukushima (Japan)

In-person interviews were conducted at both Rico and Tsuchiyu in late 2015 and early 2016, using the method of snowball sampling to census as many stakeholders as possible. The questions were based on the Boutilier and Thomson model of SLO, incorporating questions related to economic legitimacy, socio-political legitimacy, interactional trust, and institutionalized trust between the stakeholders and the focal organization (Boutilier and Thomson 2011). Additionally, respondents were asked to name all other stakeholders (defined as any person, entity, organization, etc. that could either *affect* or *be affected by* the activities of the focal organization) with whom they had a relationship, and to rate that relationship on a 5 point scale with regard to their satisfaction with the relationship, and the extent to which they shared a similar vision on the development of the resource with the named stakeholder. This information helped to both populate the list of stakeholders to interview, and also to map the stakeholder networks at the respective sites. These stakeholder networks are shown in Figure 4 and Figure 5.

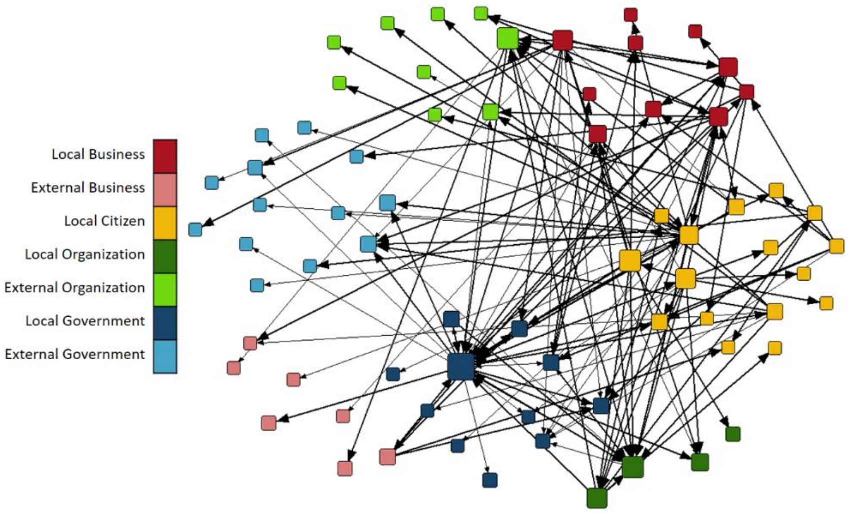

Figure 4. Stakeholder network graph for Rico CO

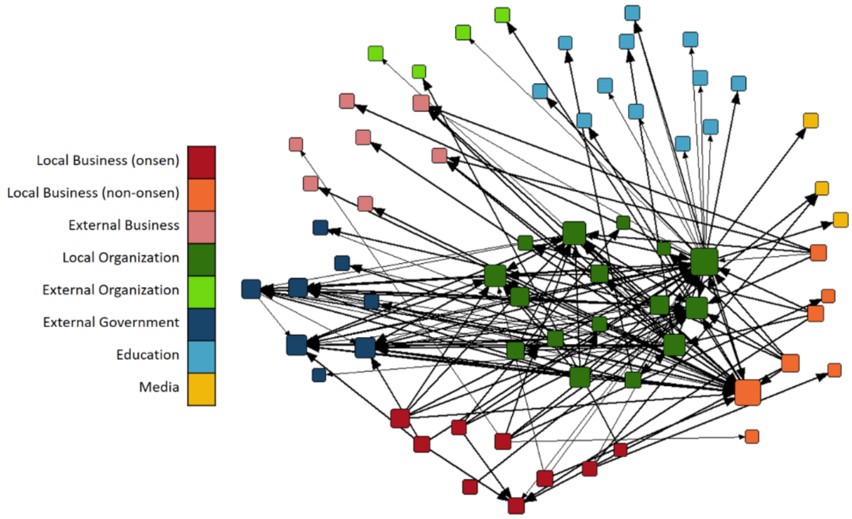

Figure 5. Stakeholder network graph for Tsuchiyu Onsen

There are several interesting differences to note about these network graphs. The first is that the core stakeholder group (local organizations in Tsuchiyu and local citizens in Rico) is much more densely connected in Tsuchiyu than in Rico. This is due to the fact that Tsuchiyu is a larger community with a more developed local economy, in which many local business owners have come together to form business-related organizations over many years. These organizations were formed and function independently of the actions of the focal organization, but stakeholders can utilize these existing relationships these when dealing with the focal organization representing a new issue for the community to form an opinion on. On the other hand, the core group in Rico is a collection of citizens who are less densely connected to each other, but have more connections to local businesses and government. Rico is a much smaller town that has a high seasonal fluctuation in population, and, apart from a few long-time residents, a high turnover rate as many people move to Rico for only a few years, as evidenced by respondents references to "new residents" and "old residents". Because of this, there are fewer long-standing relationships to be leveraged as the community collectively makes decisions about resource development.

The second distinctive feature about these two network graphs is the basic unit that makes up the core group of stakeholders. In Rico, many of the respondents were local citizens (individuals) who responded to the survey as representatives only of themselves or their businesses. In Tsuchiyu, respondents represented local businesses and organizations. This higher level of social complexity in the organizations is a product of the strong social cohesion mentioned above, but also relates to the more advanced stages of development of their geothermal resource. Many of the organizations and most of the businesses interviewed were directly related to the exploitation or management of the resource. For example, there were many spa hotels and trade organizations of which those spa hotels were members, as well as organizations that managed the collective hot water supply for the onsen. The fact that the constituent elements were formed around the usage of the resource means that stakeholders in Tsuchiyu have a higher stake and more urgent interest in the future development of the resource. Thus, when faced with the economic crisis in the wake of the nuclear disaster stakeholders were able to leverage their existing relationships to make decisions about new ways to utilize their collective resource. It is expected that as the resource development in Rico progresses, organizations and businesses formed with the express purpose of managing the resource will form a new core of stakeholders around the issue, which will eventually become the main network of stakeholders to make future decisions regarding the development of the resource.

3. AGENT-BASED MODEL

One of the authors' main conclusions regarding the success of Genki-up Tsuchiyu relative to other geothermal developers in Japan and elsewhere is that the local ownership and status of the focal organization in the existing social network were major contributing factors in the success of the binary powerplant. It is theorized (and evidenced in many responses during interviews in both Tsuchiyu and Rico) that one of the main barriers to geothermal development (or development of any kind) is the feelings of mistrust that exists between an in-group of local stakeholders, and geothermal developers, who are considered to be outsiders and often perceived to wield an inordinate amount of power, which stakeholders feel will be detrimental to their community. Whether or not this is actually the case is an ethical and philosophical question beyond the scope of this paper, but it also raises an interesting technical question: "How and to what extent can external stakeholders introduce and reinforce their opinions in existing stakeholder networks?" For example, the focal organization in Tsuchiyu is locally situated, with well-established local stakeholders, but many other geothermal companies in Japan are not so ideally situated. Is successful development, therefore, a matter of local ownership and internal motivation, or can external stakeholders become trusted members of the local group by forming relationships with key stakeholders? In order to explore this question, the authors built an agent-based model to probe the system and gain insights about the structure and insulation of the stakeholder network.

A detailed description of the model is given in Masuda, Bahr, and Tsuchiya 2017, but a general description will be given here. The ABM is a type of "diffusion" model, in which opinions are transferred between agents who are connected by network links. The rate at which opinion is transferred between agents is a function of their relative influence (measured by their network centrality), and their "tendency of opinion," which is calculated based on Bayesian network analysis of the opinions and characteristics of the respondents interviewed in the above interviews. The probability that any two agents in the network will interact and exchange opinion is proportional to their geodesic distance (the number of links in the shortest path between them). In order to replicate conditions in a real network, one of the agents in the network was an “internal opinion leader” (IOL), an agent who’s opinion does not change, who acts as a net source of directional (positive or negative) opinion. Additionally, an external opinion leader (EOL) was added to the model, to represent a developer or other outside stakeholder. This external opinion leader also had a fixed opinion, but the direction of their opinion was opposite that of the IOL. So, for example, if the IOL represents a negative opinion on a given topic, the EOL represents a positive opinion, and vice-versa. The simulation was initialized with a random network, with the EOL only having one link into the network. The simulation was run until a steady-state was reached, in which the bulk opinion of the network did not significantly change, and the simulation was re-run 100 times with the exact same starting conditions. This procedure was repeated with the EOL having *two* links to the network, and so on until simulation was finally run with the EOL having 100 links to the network. The links were sequentially added in order of the decreasing centrality of the internal agent being connected to by the EOL. The authors analyzed the amount of time it took for the system to reach steady state in each of these simulations, and observed the state of the network at various points throughout the simulations. This procedure was also re-run using a variety of different centrality measures to assign influence values to the agents, which did not produce significant variation in the results for the purpose of this analysis.

Figure 6 shows the results of this series of simulations, in which 3 distinct zones appear. The first (when there are fewer than 20 links to the EOL) is the IOL dominant region, in which the EOL has not established enough connections to the network to significantly impact the bulk opinion. These simulations reach steady-state quickly, after less than 500 timesteps, essentially remaining unchanged from their initial conditions. In the second zone, the EOL has gained enough connections to the internal stakeholders that they begin to challenge the dominant opinion, and the time it takes to reach a steady state increases due to the conflicting opinions. Eventually, the EOL gains enough links to override the opinion of the IOL, and the EOL dominant zone occurs, in which the EOL is able to quickly change the opinion of the network, and the IOL is unable to regain the consensus. This result indicates that at some point an external stakeholder may become and internal stakeholder, and affect the opinion of the majority in the network. This result has obvious implications in many areas, including geothermal development by external stakeholders.

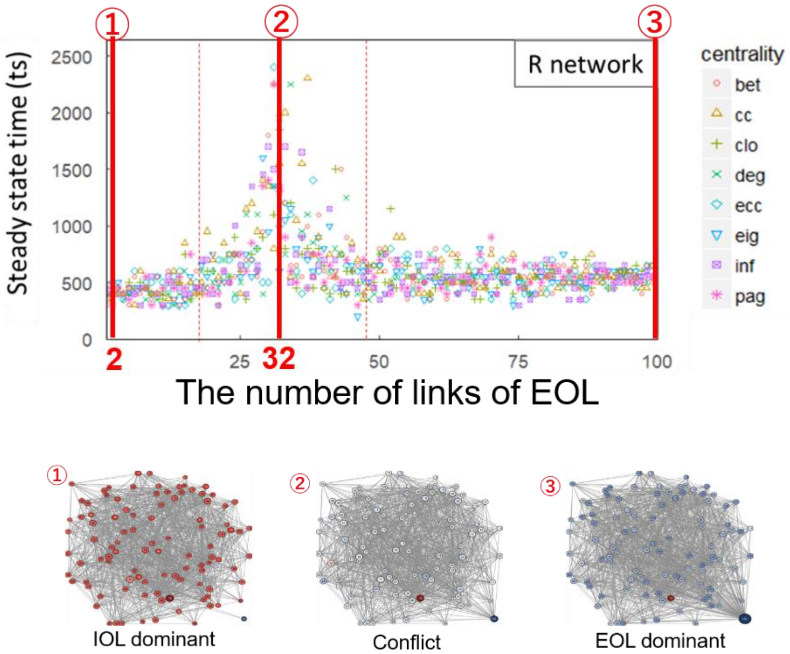

Figure 6. Conflict in bulk opinion formation with increasing links from an external opinion leader

In order to further explore the relationship between internal and external stakeholders, the authors performed the same series of simulations that were initialized with two other well-known network graph structures: scale-free and small-world networks. Scale-free networks are characterized by a fractal-like structure (hence the name “scale-free”), in which a few key nodes are well connected to each other and to several “pendants” that only have one connection, and thus, the degree centrality in these networks follows a power-law distribution (the middle structure in Figure 7). In small-world networks (Figure 7, bottom) the average distance between any two nodes tends to be small, and there tends to be a high degree of clustering around “hubs” that connect clusters to each other.

Figure 7 shows the results of the simulations initialized with each of the three network structures. All three networks structures show the same dominance and conflict zones, but the conflict and EOL dominance zones occur with a fewer number of links from the EOL. In fact, the clustered nature of the small-world network results in almost immediate conflict, as the EOL is able to make connections with hubs that are situated relatively far from the IOL, and thus the EOL can dominate the opinion of at least part of the network with very few connections. The other feature of note is that while the random and small-world networks have fairly consistent time-scales (~500-3000 timesteps to steady-state), the timescale for the scale-free network is two orders of magnitude larger. The lack of density in the scale-free network means that it takes much longer for an opinion to travel from one part of the network to another, and thus a small change in opinion at one point will ripple through the network causing noticeable changes at every timestep and delaying steady-state.

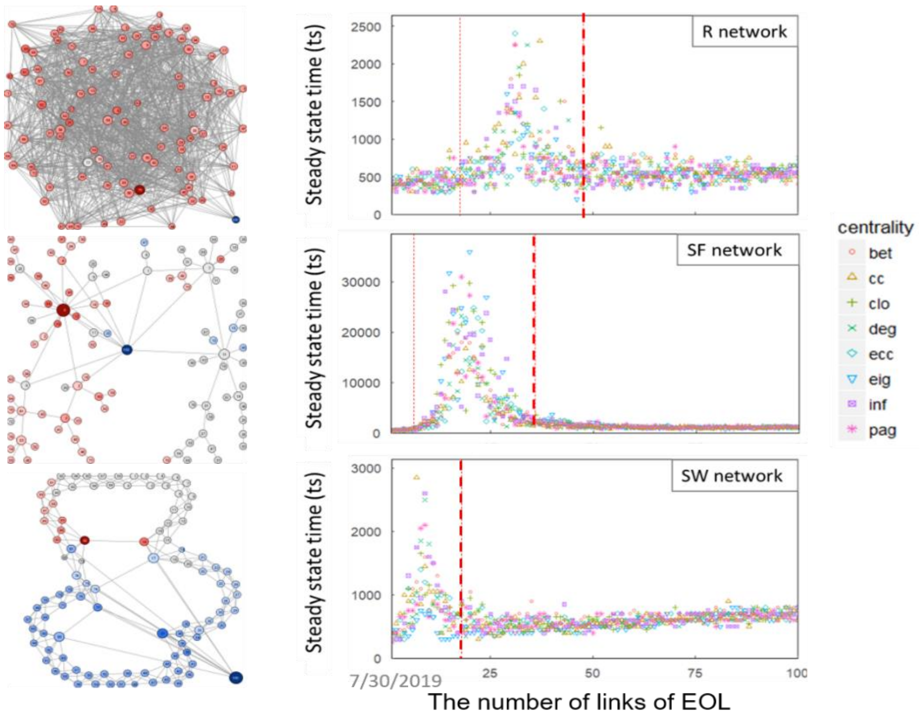

Figure 7. Opinion leader conflict in random, scale-free, and small-world networks

These results indicate that the structure and characteristics of the stakeholder network structure are of significant importance to external developers seeking the social license to develop in established stakeholder networks. This example serves to illustrate the usefulness of agent-based modeling in understanding complex social phenomena such as SLO formation, and the model was subjected to further tests and simulations, the detailed results of which will be published at a later date.

4. CONCLUSIONS

Social license is a useful metric for geothermal developers to understand the social potential and risk of developing in a given area, though the multi-use nature of geothermal resources requires some adaptation of the concept. Specifically, the target focal organization and usage scheme must be carefully defined before the SLO is measured, in order to be sure that the opinions being given by respondents are relevant to the social license being sought. Additionally, the nature and structure of a stakeholder network is likely to change depending on the overall social cohesion of the stakeholder group, and as the resource usage and the institutional structures that support its usage develop and evolve. Social exploration of this type is often overlooked in development projects of all kinds, and development projects often fail due to a lack of understanding of the social landscape with its resources and challenges. The complex, emergent nature of bulk opinion in cases like SLO make agent-based modelling an attractive tool for interrogating the effects of initial conditions, perturbations, and structural effects on the overall macro-level attitudes, opinions, and actions of stakeholders, and can be used to explore policy strategies that cannot be tested in other ways.

5. REFERENCES

Bahr, K., S. Masuda, H. Saishu, H. Kubota, and N. Tsuchiya. 2017. “Adaptation of Social License Measurement and Analysis Techniques for Geothermal Usage and Development.” in *Transactions - Geothermal Resources Council*. Vol. 41.

Boutilier, Robert. 2009a. “How To Measure the Socio-Political Risk in a Project.” 438–44.

Boutilier, Robert. 2009b. *Stakeholder Politics Social Capital, Sustainable Development, and the Corporation*. Stanford, CA: Stanford University Press.

Boutilier, Robert and Ian Thomson. 2011. “Modelling and Measuring the Social License to Operate: Fruits of a Dialogue Between Theory and Practice.” *Social Licence to Operate …* 1–10.

Douglas, Adam and Cun-quan Zhang. 2011. “Emergence of Segregation in Evolving Social Networks.” 108(21).

Epstein, Joshua. 2008. “WHY MODEL?” *Journal of Artificial Societies and Social Simulation* 11(4):12.

Gilbert, Nigel. 2008. *Agent-Based Models*. edited by T. Liao. Thousand Oaks, CA: Sage Publications Inc.

Jia, Peng, Anahita Mirtabatabaei, Noah E. Friedkin, and Francesco Bullo. 2015. “Opinion Dynamics and the Evolution of Social Power in Influence Networks.” *Society for Industrial and Applied Mathematics Review* 57(3):367–97.

Kubota, Hiromi, Hiroki Hondo, Shunichi Hienuki, and Hideshi Kaieda. 2013. “Determining Barriers to Developing Geothermal Power Generation in Japan: Societal Acceptance by Stakeholders Involved in Hot Springs.” *Energy Policy* 61:1079–87.

Masuda, S., K. Bahr, and N. Tsuchiya. 2017. "Agent-Based Model Coupled with Bayesian Estimation for Evaluation of Social Acceptance of Geothermal Development." in *Transactions - Geothermal Resources Council*. Vol. 41. Salt Lake City, UT.

Moffat, Kieren and Airong Zhang. 2014. "The Paths to Social Licence to Operate: An Integrative Model Explaining Community Acceptance of Mining." *Resources Policy* 39(1):61–70.

Movellan, Junko. 2015. "Popular Hot Springs in Japan Co-Exist with Binary Geothermal Power Plants - Renewable Energy World." *Renewable Energy World*. Retrieved July 30, 2019 (https://www.renewableenergyworld.com/articles/2015/12/popular-hot-springs-in-japan-co-exist-with-binary-geothermal-power-plants.html).

Prno, Jason and D. Scott Slocombe. 2014. "A Systems-Based Conceptual Framework for Assessing the Determinants of a Social License to Operate in the Mining Industry." *Environmental Management* 53(3):672–89.

Que, Sisi, Kwame Awuah-Offei, and V. A. Samaranayake. 2015. "Classifying Critical Factors That Influence Community Acceptance of Mining Projects for Discrete Choice Experiments in the United States." *Journal of Cleaner Production* 87(1):489–500.

RPI Consulting. 2012. *Geothermal Energy Master Plan Town of Rico, Colorado*. Durango Colorado.

Shortall, Ruth and Ali Kharrazi. 2017. "Cultural Factors of Sustainable Energy Development: A Case Study of Geothermal Energy in Iceland and Japan." *Renewable and Sustainable Energy Reviews* 79(November 2016):101–9.

Thomson, Ian and Robert G. Boutilier. 2011. "Social License to Operate." Pp. 1779–96 in *SME Mining Engineering Handbook*, edited by P. Darling. Englewood, CO: Society for Mining, Metallurgy, and Exploration, INC.