Getting to Yes: The Sustainable Energy Modeling Project (SEMPro) Model of Infrastructure Siting

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Abstract. Social, economic and political constraints are critical barriers to the development of new renewable energy supplies. SEMPro is an agent-based, predictive analytics model that simulates how competing interests shape energy siting outcomes. Using a Southern California high voltage transmission line as a case study, we integrate project engineering, institutional, land use attributes and residential demographics. We model citizen attitudinal, Community Based Organization emergence and behavioral diffusion of support and opposition with cooperative game theory. We also simulate the competitive policy process and interaction between agency stakeholders using a non-cooperative game theory. We find CBO formation, utility and NGO messaging have a positive impact on citizen comments submitted as a part of the Environmental Impact Statement process, while project need and procedure have a negative impact. NGO and utility messaging modestly influences citizen opinions, but have the counterintuitive effect of increasing citizen opposition as citizens are mobilized by stronger messaging. As citizens communicate and across greater distances, less CBOs form but they are more effective and increase the number of citizen messages.

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1 Introduction

Technical, environment, social, economic and political constraints are critical barriers to the development of new renewable energy supplies. The Sustainable Energy Modeling Project, or SEMPro, reconceptualizes how we "get to yes" on siting new renewable energy supplies. We focus on how competing interests shape siting outcomes and identify actionable strategies to help build energy infrastructure in a more timely and less conflictual manner that current processes typically allow. Traditional regulatory processes pit entrenched stakeholders with diverse interests against each other repeatedly, often in adversarial settings. This encourages opposition to the "other" side's proposals. This project is strategically different, opting for transparency in the process, asking the community to engage and respond, versus react and oppose.

SEMPro is an agent-based, predictive analytics model of the energy siting policy in the techno-social space [27]. Agents are homeowners, regulators, US resource agencies, utilities, power producers, environmental organizations, and others with an interest in siting that interact against the backdrop of political institutions, proposed infrastructure siting routes, the local populace and the environment. Agents' preferences are fed into the model which uses game theory, bargaining dynamics, and network theory to predict agents' actions and reactions in the policy mileau. Cutting-edge social science tools like SEMPro can enable regions to meet their climate and energy targets from renewables.

The SEMPro simulation results offer ideas about policy levers, issue linkage strategies, bargaining positions, and other tactical and strategic advice to users about how to reach consensus on any issue given its dynamics. This illuminates both what matters for moving from stewardship to sustainability, in terms of tactics and strategies for any particular situation, but more importantly how-to align disparate interests, towards sustainability. We believe that approaches like SEMPro can serve as an exploratory platform for ideas about issue framing, enable regions to meet their climate and energy targets from renewables, scenarios analysis to explore key uncertainties, and can identify equitable solutions supported by communities.

2 Electricity Policy Dynamics Background

Growing consumer demand for environmental sustainability coupled with new regulatory requirements have increased pressure on utilities, stakeholders, and government officials to find new and creative solutions to the complex problems of sustainable resource use. But because of the complexity of these issues, public policy debates have typically occurred at the elite level without significant input by ordinary citizens, especially those in underserved communities.

While most everyone can agree that reducing carbon emissions and increasing use of renewable energy are worthy goals, competing interests among various constituencies can make implementation difficult. This is particularly problematic in most areas where urban demands for power are increasing but the most cost-effective renewable resources are located outside load centers. While regulators and consumers are demanding more energy from renewable sources, stakeholders, including a variety of regulatory agencies with jurisdiction over various aspects of such projects, property owners who typically do not want new power plants or transmission lines in their field of view. Environmental activists who are concerned about biodiversity, aesthetic, and water quality issues are effectively delaying or blocking new transmission siting.

SEMPro's results-oriented processes and outputs address a vacuum of social science computational research on technosocial issues in sustainability. The current application of SEMPro is high voltage electricity transmission line expansion, but the model and data collection methodology can be applied to any infrastructure siting project with significant externalities, including roads, recycling facilities, water treatment plants, natural gas and oil pipelines, and electricity generation facilities.

2.1 Modeling Policy Components and Benefits

SEMPro modeling, simulation and planning tool that combines uses Geographical Information System (GIS) data to identify communities with strategic interests that compliment key stakeholders' positions. The GIS data provides a measure of "political sensitivity" by census block groups. This data include demographics, economic and political variables for territory identified in the study: income, housing type and density, educational attainment, project engineering and geophysical characteristics.

Agent Based Models (ABMs) are 'bottom up' micro simulations of heterogeneous individual agents, that allow users to create, analyze, and experiment with models composed of multiple agents (NGOs, regulators, individuals) that simultaneously interact with each other in an environment that includes the legal and social framework of a policy issue. The model represents complex social realities by formally representing various stakeholders and their interests [27].

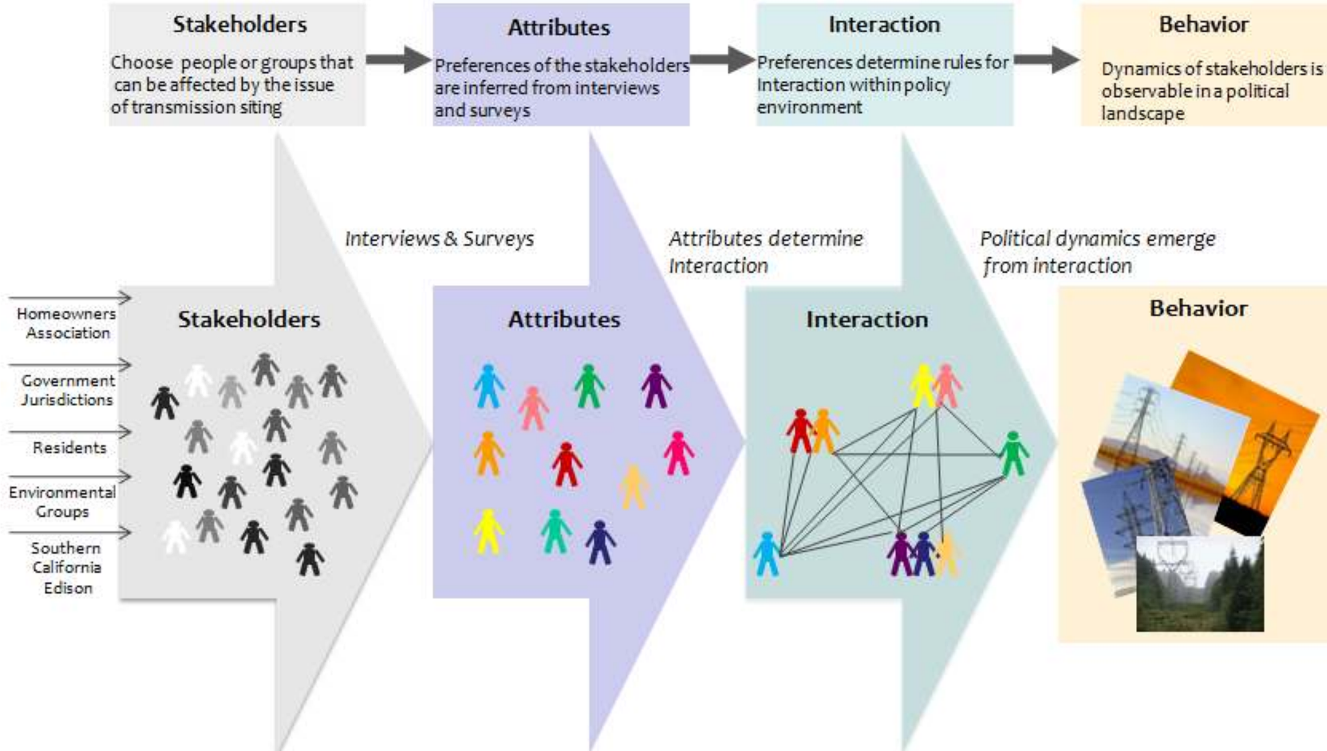

Fig. 1. SEMPro Overview

SEMPro begins with an exploration of the transmission siting issue represented in Figure 1. In this case agents are stakeholders, including community residents, homeowners associations, relevant government jurisdictions, environmental advocacy groups, and the local electric utility. The attributes of each type of agent are inferred from citizen and stakeholder surveys. These preferences determine rules for interaction within the policy environment. This element of the project is explored in more detail below.

The relative power and preferences of each agent are represented in the bargaining module of the model. Spatial bargaining theories from microeconomics simulate the potential for policy compromises and tradeoffs across groups. The intuition behind these theories models the pulling and hauling of the policy process, where groups trade what they do not want for what they do want. Groups trade concession on issues they don't have strong feelings about for issues where they do care (high salience). Between two groups, this is a simple and intuitive exercise. The actual model is much more sophisticated than this as it simulates multiple groups' preferences, power simultaneously, and overlays actual geography or other physical attributes, mapping preferences onto parcels of land for transmission siting.

To develop SEMPro for this policy issue, surveys and other data collection efforts assign each agent a project opposition score on a 0 (support) to 100 (oppose) scale, to determine the salience or importance of the issue to them, and the power that each agent has in determining the outcome. The groups' scores for salience, power, and positions are then fed into the model which uses game theory, bargaining dynamics, and network theory to predict agents' actions.

2.2 Literature Review

The SEMPro model has been developed using a range of relevant social science theories grouped into three categories.

The first type of theoretical and empirical support for the model development are siting opposition from psychometric risk analyses, land use planning, and environmental impact assessments literature. Citizen opposition is a function of a) perceived risk from the infrastructure project [13] b) proximity or distance to the project [12] c) the land use attributes of the land parcels [11] and d) expected property value impacts due to visual impairment and health and safety concerns [17].

Cain and Nelson [7] integrate and evaluate these diverse literatures and argue that understanding citizen opposition is not adequate to explain observed siting outcomes. Because infrastructure siting is typically governed under Environmental Impact Statement (EIS) processes, these institutional variables are also included in the SEMPro model. Research shows that EIS processes are typically not influenced by explicit environmental or social outcomes, but rather by political concerns and elite preferences [29, 18]. The stakeholder and regulator modules explicitly include elite preferences that shape environmental outcomes. These include citizen trust in the sponsoring entity or agency [9]. In order to support a project, citizens need to think that decisionmakers will honestly include their preferences [16].

The second body of literature that governs citizen agent interactions comes from communications. The two basic theoretical foundations of the SEMPro model are how people communicate about important societal issues, and what affect that communication has on the views people hold. Shannon and Weaver describe communication as a "source" transmitting a "message" via a "channel" to a "receiver" [10]. These messages are subject to noise and distortion. Even in an age of cheap and easy electronic communication, proximity between a source and a receiver are important. Geographic proximity leads to greater frequency of communication and building of ties [20].

Berlo's Communications Penetration Model describes how these messages may not be received or accepted because the receiver is not exposed to the message, does not pay attention to the message or does not accept the sentiment of the message [5]. Social Judgment Theory describes how the positions of two agents can be conceived along a Downsian continuum and distance between these positions affects the likelihood of one accepting the other's position.

A message that is close to a receiver's position has little effect because it is not difference enough to cause a large change, and one that is far from a receiver's position is likely to be rejected, but messages "at a moderate distance" from the receiver's position may be able to have a strong influence [25]. Messages can be repeated multiple times and via various channels to increase the likelihood of acceptance [10].

People also exhibit homophily, a tendency to associate more with people like themselves, and homophily promotes communication because messages are both more frequent and more successful between similar people [23]. Additionally, individuals with higher confidence are less likely to change their position based on communication [4]. That is, the message, the source, and the receiver are all important in determining whether a message is accepted.

The third and final category of literature comes from expected utility and game theories to govern CBO formation, as well as stakeholder and regulatory bargaining and coalition formation. Expected utility has been described as the "major paradigm in decision making" [24] CBO formation is based on cooperative game theory [26]. Citizens will join CBOs if it increases their power to potentially influence the regulatory process as long as the CBO's position is acceptable given the citizen's initial position [19].

3 The Model

SEMPro is part of a new class of techno-social modeling, fusing geophysical and social elements to understand the interactive effects and feedbacks between individual human agency, engineered physical elements and the geophysical environment.

The model description herein follows the ODD (Overview, Design Concepts, and Details) protocol to document the fundamental processes of any agent based models [14, 15]. The ODD framework provides a common ground for model overview, general concepts and detail model design, simulation, results and discussion. This makes any ABM relatively transparent, replicable and process knowledge transferrable to researchers across disparate fields and domains. The model is implemented in NetLogo [28].

3.1 Purpose

The overall goal of our model is to help people better understand the socio-political dynamics of siting energy infrastructure with the goal of improving the siting process. This model simulates how competing political and social interest shape transmission policy and identifies actionable strategies to site new infrastructure. SEMPro is part of a new class of technosocial modeling, fusing geophysical and social elements to understand the interactive effects and feedbacks between individual human agency, engineered physical elements and the geophysical environment. SEMPro can be used to anticipate, shape and decide transmission sitting routes that not only minimize political and social impedance, but maximize positive social externalities for the community.

3.2 Process Overview and Scheduling

SEMPro model has three different sequential submodels, a citizen/CBO formation module, a stakeholder lobbying module and a regulatory decision making module. Figure 2 depicts the high level process and multi-module architecture. Intuitively,

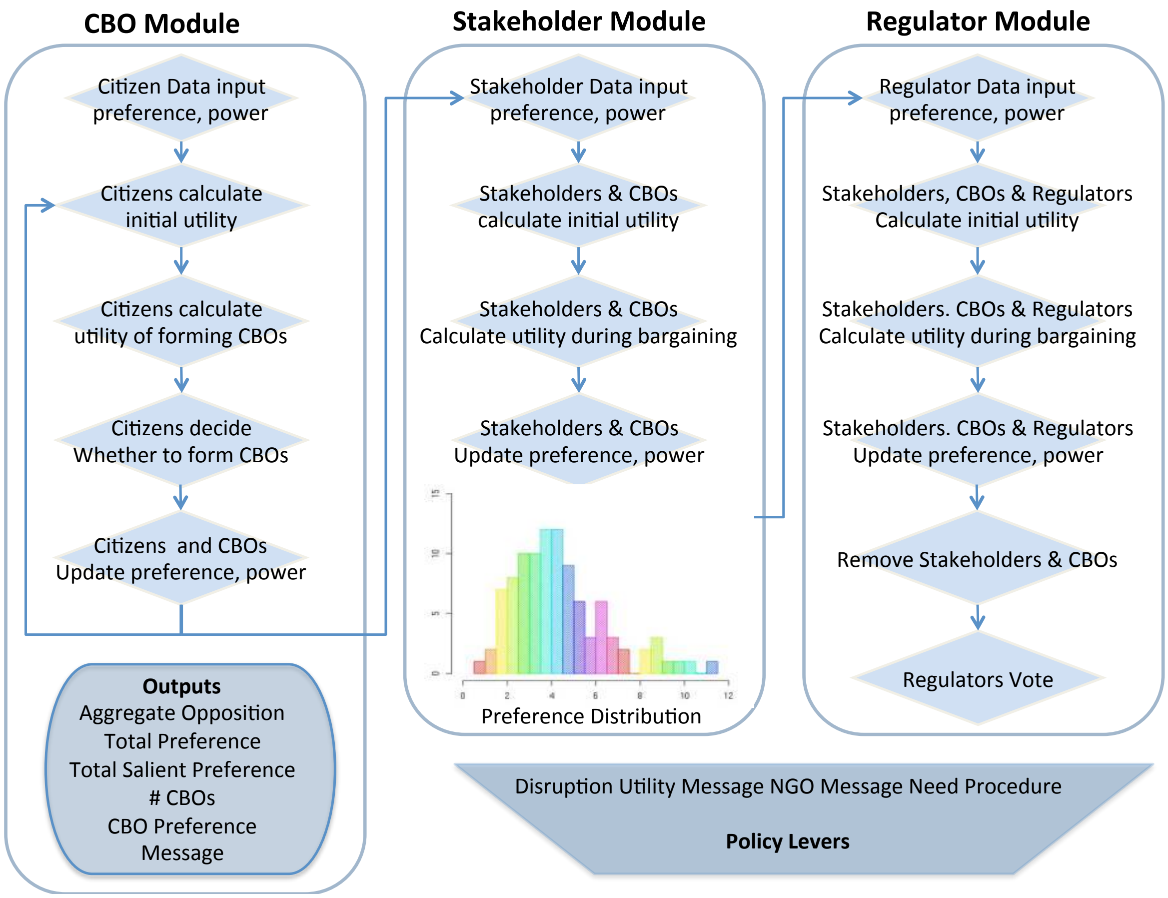

Fig. 2. SEMPro Modules

citizens react to transmission siting projects forming opinions and shaping those of others, which can result in the formation of Community Based Organizations that either support or oppose such projects. Against this backdrop of political and social opinion formation and transmission processes, organized stakeholders seek to lobby not only citizen opinions and the emergent CBOs that forms as inputs into the siting process, but also other stakeholders to maximize their specific, organizational interests. Finally in given the interplay between citizens, stakeholders and society, the regulatory decision making process models how regulators ultimately approve or deny siting activities given the constantly shifting techno-social landscape. Actionable policy levers for shaping the transmission siting process include the disruption engineering of the project, utility and NGO messaging outreach, as well as perceived project need and procedure surrounding the process.

A benefit of our approach is to identify actionable policy levers to beneficially impact the sitting process. Disruption is the engineering characteristics of the transmission line, where zero is the status quo land use and a value of 1 is calibrated to simulate a giant, 200ft 500Kv high voltage transmission tower. Disruption has dramatic impacts across several agent attributes, including salience, salient preference, influence message and the resulting citizen comments. The number of utility messages impacts citizens' preference. This value is calibrated between 1 and 10. The number of NGO messages also impacts the level of attitude as it makes citizens either more supportive or more opposed to the transmission line. This parameter is set at a range between 1 and 10.

One key question is how do utility outreach messages influence citizen attitudes and actions on siting projects [2]. The utility influences the citizen agents through the utility-info procedure. The utility sends out a message to all citizen agents. This message can take the form of flyers, phone calls, town halls, neighborhood coffee meetings. If utility message values are smaller than project need, citizens can change their attitude closer to the utility's preference. The stronger the utility message the more citizens can move closer, while the shorter the preference distance between citizens and the utility, the more citizens will be receptive to utility messages. However, if utility message values are greater than project need, citizens have an adverse reaction to high messaging, and can react similarly away from utility preferences.

NGO messages also influence citizens in a similar manner. The idea is that there are NGOs, such as the Sierra Club or Wildlands Conservancy or others, that try to influence people against siting transmission projects. If NGO message is smaller than procedure, citizen change their attitude closer to NGO's according to the strength of NGO message and the distance between their preferences. However, if NGO message is too strong, citizens' attitude moves in the opposite direction.

Figure 3 shows the NetLogo interface. In the center we represent the technosocial output space with the geo-physical environment—citizen agents at block groups with transmission line, which is taken from Census Data 2010. White lines separate block groups of LA county Riverside county. The black line indicates the transmission line. Parks are represented in green and yellow. Citizen and CBO agents are sized by the number of influence messages that they send. Citizen and CBO preference is differentiated by color gradations where red indicates opposition and blue indicates support for the project.

The dots arranged in a circle is a simple static depiction of the 16 stakeholders that comprise the bargaining process. Stakeholders are labeled and the size of these stakeholders is constant; the color is set by five preference ranges where blue indicates support and red indicates opposition to the siting project. Data is from citizen response surveys. However, the lines connecting stakeholders to other stakeholders, individual citizens and CBOs show the network of interactive messaging and utility comparison effects at any tick.

On the left side, are ten sliders to control model parameter settings and input data. *Disruption* indicates the level of physical disruption the proposed siting project causes, which is measured as the height/type of tower, with 0 indicating an underground routing while 1 indicates maximum aboveground disruption of a 200 ft tall 500 kilovolt high voltage transmission line. *Initial-Number* is the sample number of citizen agents we run in the model randomly selected from the census block group data. *Talk-Span* is the neighborhood grid distance in which citizen agents talk with each other and make decisions on whether to form CBOs. *Need* is the perceived project need. The highest value is when the project has been approved by the state transmission operator and provides reliability for the communities affected by the power line. Need is lower when the power line carries power to other regions without significant local benefits (reliability). *Process* is an indicator for procedural justice, or how the citizens think their preferences will be included in regulatory decision-making. *Utility-Message* indicates the number of utility, pro-development outreach messages the utility sends to citizens to shape public attitudes. *NGO-Message* is the number of anti-development outreach messages the NGO sends to citizens to help inform and shape public opinion.

The three sliders at the bottom are model processing control switches: for *Influence-Model*, when set a 1, attitude is pent up and then released; at 2, agents convey their attitude every iteration; at 3, agents convey their attitude every iteration only after reaching a certain threshold, which is set by *Influence-Threshold* slider. In this paper, we set model processing at 2 using agent's conveying attitudes at each time step. *Shed-length* can be adjusted to show the viewshed or area of disturbance where citizens can see the siting tower given it's particular height or disruption. *View-shed-green* toggles displaying the viewshed, while turning on *powdif?* calculates citizens' power by education and income census data, instead of assigning a equal constant weight across, such as one-person, one-vote schema. This is useful to explore the socioeconomic impact of political power and social formation compared to an explicitly egalitarian population.

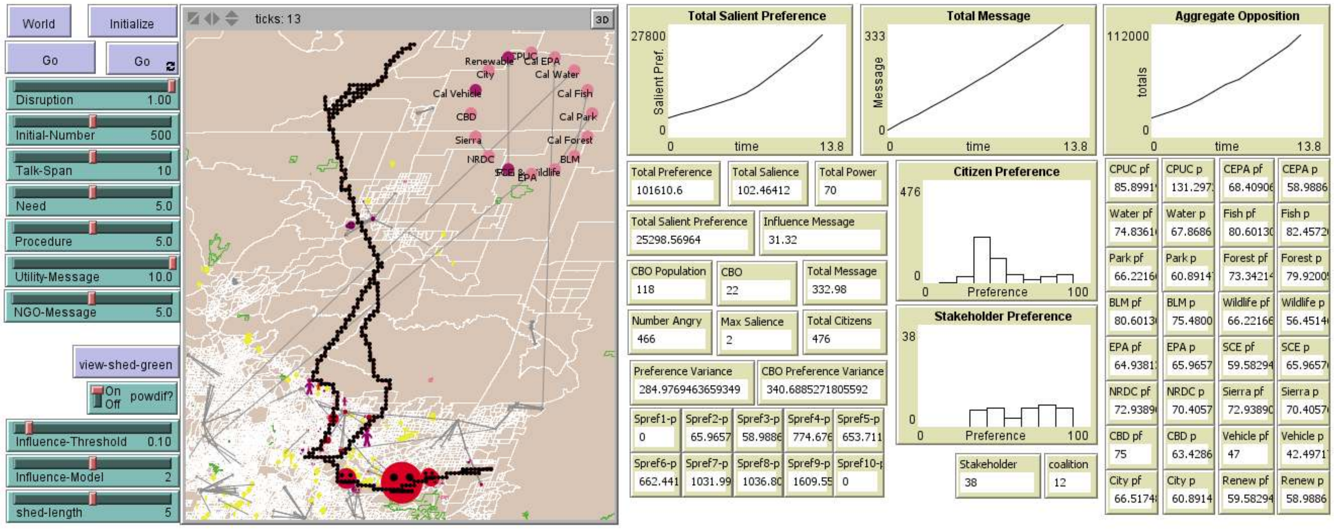

Fig. 3. SEMPro Dashboard

4 Parameterization and Simulations Experiments

4.1 Calibration

The citizen module of SEMPro was validated against historical spatial and outcome data. First, we compared the number of messages generated in the citizen module against the approximately 600 actual comments received during the EIS process for the Tehachapi project from 2007-2009 [8]. The mean number of comments generated in the current initialization of SEMPro tends to be about 10% less than the observed data, a bias that we find acceptable given the stage of the model's development. Second, we validate the location of the citizen opposition against the addresses of citizens who submitted written or email comments in the actual EIS process. The model predicts opposition in high residential population density areas, which is consistent with observed data.

In previous research we reported the results of applying the SEMPro model to three case studies of siting transmission lines in California [21]. These case studies presented varied project attributes as well as siting outcomes. The input parameters for each case study were varied to represent project attributes and the model outcomes were consistent with observed data.

4.2 Simulation Experiments

We conducted a quasi-global sensitivity analysis by varying all input parameters across their entire range in quintile steps for 20 time steps, which resulted in 2500 runs. All state variables and model attributes were recorded. Specific output variables captured besides the ones detailed above include both preference and CBO preference variance. OLS estimation was used to create standardized β coefficients for input parameter comparability and model performance.

5 Results

5.1 Sensitivity

Below we detail the results from the global sensitivity analysis for three outcome variables of interest. In Table 1 we look at the impact of input parameters on CBOs formation, a key emergent property. The R^2 indicates that over 80% of the variation in CBO formation is explained by the model. Utility message is significant albeit with a small positive impact ($\beta = .0317$) on CBO formation. This interesting finding indicates that utility might have a positive impact on citizen demands for CBO formation when other conditions like project need do not meet. Need is negative and significant ($\beta = -.0179$) as expected, as a necessary project receives less organized opposition. Total preference is significant and negative ($\beta = -.2602$), which is unexpected. Most surprisingly, talkspan is not only highly significant but has the largest negative impact ($\beta = -.6763$) on the number of CBOs that form. As citizens are able to communicate and exchange political opinions across greater distances with more neighbors, the number of CBOs declines precipitously however the number of individual citizens within a CBO increases greatly. A parameter heat map was generated to explore interactive effects of Talk-Span and Utility-Message on CBO formation. Here we can see the relatively linear effects of high CBO formation when both utility messaging and talk span is low, although CBO formation is more sensitive to changes in talk span.

Table 2 details the impact of input parameters on citizen messages sent to the utility regarding the siting project. The R^2 indicates that 46% % of the variation in citizen messages is explained by the model., Here we can see that all input parameters are significant. CBO formation has a small positive impact (β = .0116) as expected on citizen comments. Talkspan has a small and significant positive impact (β = .0156) on citizen comments consistent with the observations that CBOs form in larger, less tight knit communities. Total preference is strongly positive (β = .1825) as should be expected, when citizens are more displeased and opposed to the project, they should naturally be more expressive in their comments. NGO message is also significant and negative (β = .0210) and expected as credible NGO messaging can serve as a catalyst for citizen activism. Utility message is positive (β =.0045) but has less impact than other parameters, indicating that utility outreach programs maybe less effective at shaping citizen opposition in project siting that previously thought. Need is significant and negative as expected, but its impact is not very strong. The accompanying heat map shows the interactive effects of both NGO and Utility message on the resulting number of citizen project comments, where high levels of both NGO and utility messaging produce the largest levels of citizen comments, and low levels of both messaging produce the smallest levels of citizen comments. This fits well with polarized project environments where both NGO and utility participation produce citizen activism.

The fit and impact of input parameters on the sum of total salient preference is in Table 3. The R^2 indicates that 26% of the variation in citizen preferences are explained by the model.. Here utility message has the highest positive impact (β =.1092) on salient preferences, indicating that increased utility messaging can definitely sway citizen preferences towards opposing the project. As expected, Need has a large and negative impact on citizen project opposition (β =-.0668). NGO also has a dampening effect on negative project attitudes, but at small levels (β =-.0231). As expected from the NIMBY literature, CBO formation has a positive impact (β = .0025) on accelerating negative citizen preferences on projects. The accompanying heat map shows the interactive effects of project need and utility messages on shaping citizen preferences. At low levels of need and high levels utility messaging, citizens are highly opposed to the siting project, while low levels of utility messaging and high levels of need result in 64% reduction in citizen opposition which often can make the difference in project success or failure.

```
. reg cbo2 talkspan ltotalpref2 ngo utility need procedure

      Source |       SS       df       MS              Number of obs =    2500
-------------+------------------------------           F(  6,  2493) = 1885.49
       Model |  31662.9424     6  5277.15707           Prob > F      =  0.0000
    Residual |  6977.45579  2493  2.79881901           R-squared     =  0.8194
-------------+------------------------------           Adj R-squared =  0.8190
       Total |  38640.3982  2499  15.4623442           Root MSE      =   1.673

------------------------------------------------------------------------------
        cbo2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    talkspan |  -.6762656   .0063616  -106.30   0.000    -.6887402   -.6637911
 ltotalpref2 |  -.2602185   .0398887    -6.52   0.000    -.3384369   -.1820001
         ngo |  -.0038832   .0102894    -0.38   0.706    -.0240599    .0162934
     utility |   .0317442   .0111362     2.85   0.004      .009907    .0535814
        need |  -.0179938   .0105897    -1.70   0.089    -.0387594    .0027717
   procedure |   .0117656   .0107267     1.10   0.273    -.0092686    .0327998
       _cons |   9.442479   .1699934    55.55   0.000     9.109136    9.775822
------------------------------------------------------------------------------
```

	Utility-Message				
Talk-Span	1	2.5	5	7.5	10
1	114.3	112.5	112.5	112.6	114.1
5	48.4	48.4	48.4	49.1	48.9
10	23.0	23.1	23.1	23.5	22.7
15	13.3	13.4	13.7	13.8	13.7

Avg. No.CBOs 10.0 120.0

Table 1. CBO Formation and Policy Lever Heat Map

```
. reg lmessage2 cbopop2 talkspan ltotalpref2 ngo utility need procedure

      Source |       SS       df       MS              Number of obs =    2500
-------------+------------------------------           F(  7,  2492) =  308.85
       Model |  101.251316     7  14.4644737           Prob > F      =  0.0000
    Residual |  116.709639  2492  .046833723           R-squared     =  0.4645
-------------+------------------------------           Adj R-squared =  0.4630
       Total |  217.960954  2499  .087219269           Root MSE      =  .21641

------------------------------------------------------------------------------
   lmessage2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     cbopop2 |   .0115831   .0014944     7.75   0.000     .0086527    .0145134
    talkspan |   .0156573    .003365     4.65   0.000     .0090589    .0222558
 ltotalpref2 |   .1825985    .005162    35.37   0.000     .1724763    .1927207
         ngo |   .0210787   .0013315    15.83   0.000     .0184676    .0236897
     utility |   .0045018   .0014406     3.13   0.002      .001677    .0073267
        need |  -.0044998   .0013699    -3.28   0.001     -.007186   -.0018136
   procedure |  -.0137265   .0013879    -9.89   0.000     -.016448   -.0110051
       _cons |  -2.799726   .0627497   -44.62   0.000    -2.922773    -2.67668
------------------------------------------------------------------------------
```

	Utility-Message				
NGO-Messa..	1	2.5	5	7.5	10
1	597.6	612.7	619.2	646.7	653.2
2.5	607.1	617.0	629.8	648.4	671.0
5	612.9	622.0	655.9	662.6	696.5
7.5	647.8	638.4	652.8	674.5	701.0
10	624.7	654.3	676.1	702.5	697.8

Avg. Message 590.0 720.0

Table 2. Citizen Messages and Policy Lever Heat Map

```
. reg ltotalpref2 cbopop2 ngo utility need procedure

      Source |       SS       df       MS              Number of obs =    2500
-------------+------------------------------           F(  5,  2494) =  176.47
       Model |   622.07211     5  124.414422           Prob > F      =  0.0000
    Residual |  1758.34195  2494  .705028848           R-squared     =  0.2613
-------------+------------------------------           Adj R-squared =  0.2598
       Total |  2380.41406  2499  .952546641           Root MSE      =  .83966

------------------------------------------------------------------------------
 ltotalpref2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     cbopop2 |   .0025241    .001417     1.78   0.075    -.0002546    .0053028
         ngo |  -.0231767   .0051436    -4.51   0.000    -.0332628   -.0130906
     utility |   .1092243   .0051435    21.24   0.000     .0991384    .1193103
        need |  -.0668955   .0051435   -13.01   0.000    -.0769814   -.0568096
   procedure |   .0794688   .0051435    15.45   0.000     .0693829    .0895547
       _cons |  -3.057678   .0642274   -47.61   0.000    -3.183623   -2.931734
------------------------------------------------------------------------------
```

	Utility-Message				
Need	1	2.5	5	7.5	10
1	976	1,888	1,969	2,015	2,129
2.5	986	1,008	1,970	2,008	2,108
5	855	1,052	1,037	2,095	2,175
7.5	766	947	1,005	1,353	2,082
10	757	850	1,040	1,118	1,321

Avg. Total Salient-Prefe..
750 2,200

Table 3. Total Preferenced and Policy Lever Heat Map

5.2 Model Testing

In assessing the overall results of the citizen module in siting opposition, Figure 5 shows the resulting geophysical and political space outcomes as a response across four state variable input levels (y-axis). The size of the CBO circles indicates the number of messages sent by the CBO while color indicates support for or against the project, with red indicating opposition and blue showing support.

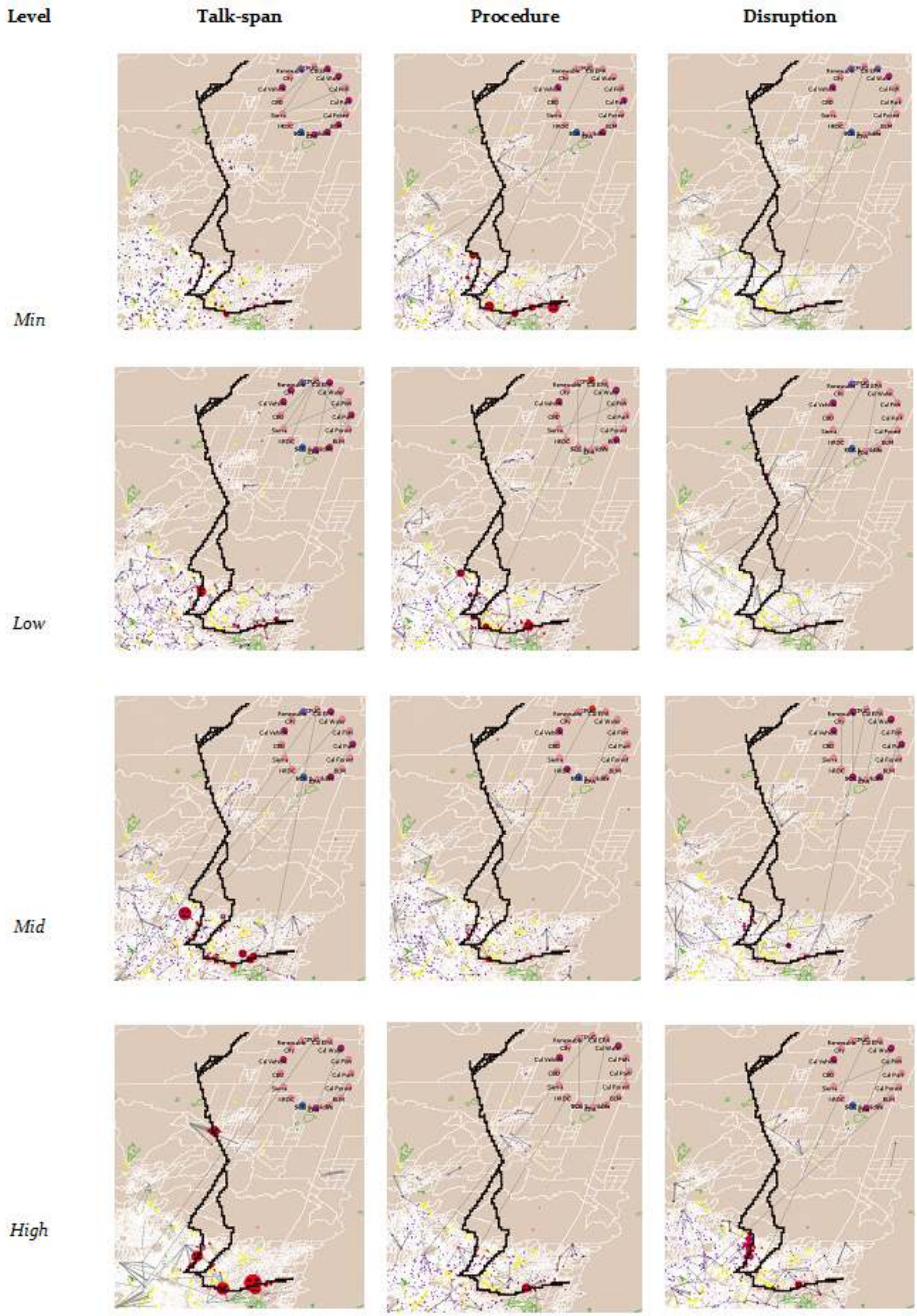

Fig. 4. State Variable Levels and Performance

In the first column, we can see that at minimum levels of talkspan, CBOs are highly dispersed and socially decentralized, with few messages being effectively sent. However, as talkspan increases, we see a marked decrease in the number of CBOs, but with more citizens within a CBO, that produces a dramatic increase in the number of citizen comments. In column two with procedural justice at its lowest levels, we see strong citizen opposition with red CBOs in high density areas. With high justice levels, purple or pro-development CBOs form in high density areas, and less citizen comments are sent. Column three shows disruption, which at minimum levels intuitively shows no CBOs form. As disruption increases, the number of CBOs, resultant messaging and the strength of opposition increase dramatically. This is intuitive and consistent with observed data.

Figure 5 below shows the social connectivity of CBO formation given individual citizen's political preference. Individual nodes are citizen agents coded by their unique agent ID number. Size of each citizen node shows the level of dynamic degree, with larger nodes more socially connected to other individual citizens. The edges connecting the nodes indicate CBO participation. The lines connect individual citizens to a particular CBO, while the width of the lines shows increasing CBO utility. Here we can clearly see for a particular simulation, that CBOs are decentralized utility of CBOs vary dramatically, as we can see about half of the lines are thick while the other half are thin.

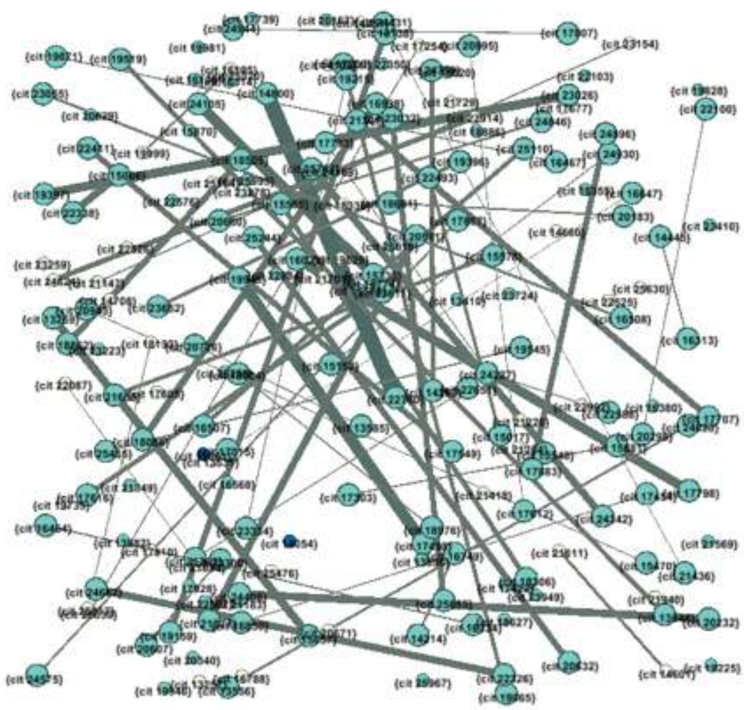

Fig. 5. Example Individual and CBO Network

6 Discussion

The dynamic landscape around siting sustainable energy provides an environment to test various siting solutions and explore "NIMBY" (Not In My BackYard)" dynamics.

The simulation results are validated by observed data about the numbers of citizen comments and the location of the citizens sending the comments to regulators. These results are consistent with the project attributes for the Tehachapi power line engineering attributes as well as the socio-economic and environmental characteristics of the areas it impacts.

One of the main theoretical contributions of the research relates to the importance of transaction costs and the size of social communication networks for citizens [1]. With high costs (low talkspan) citizen opposition is fragmented and policy entrepreneurs (CBOs) arise to transmit citizen opposition. The higher the talkspan, the more opposition there is to the project (higher project opposition conceived as "stated" preferences). But, fewer citizens submit messages as talkspan increases. The total number of messages as a "revealed" preference is slightly lower with higher talkspan as citizens "fend for themselves" and don't have CBOs to increase opposition salience (which motivates the decision to send a message). This phenomena is reflected in observed data where only a small fraction of affected citizens actually participate in institution processes.

As the role of social media on human behavioral interactions is in vogue currently, we cannot help but to examine the implications of talkspan. We see interesting and prima facie, counterintuitive behavior. When talkspan is low, the potential social space for individual citizen political preference exchange is small. Under these conditions, we see many, highly dispersed CBOs form given the decentralized nature of politics. As talkspan is increased and the potential social space for coalition formation is large, we do not see an increased number of CBOs form, but rather the exact opposite. Despite the decline in CBO numbers, we see a marked increase in citizen comments or potential for citizens to impact the siting process. From an organizational behavior market perspective, increasing social space seems to decrease the democratization of CBO autonomy, but might increase CBO efficacy.

Our global sensitivity results on policy lever elasticity shows at best fallacious, and at worst dangerous, the working assumption of policy monotonicity made by so many decision makers. "More is better" whether on money, outreach, or NGO support is definitely not the case to help getting to yes. Utility messaging efforts are a clear example of this in SEMPro. In specific conditions, increasing utility outreach, townhall meetings and neighborhood coffee meetings can have a positive, informative impact that helps bridge community differences in getting to yes. Under other conditions where NGO engagement and the span of the social neighborhood differs, the same utility messaging efforts have the drastically different effect of increasing opposition to the power line.

SEMPro provides multiple benefits for stakeholders across the sitting process. First, it provides sustainable energy policy leaders with strategic guidance on building stakeholder consensus to move from stewardship to sustainability, including negotiation strategies, identification of potential alliances, communication and educational approaches. It also serves as an exploratory platform for ideas about issue framing for successful policy dialogues, scenarios analysis to explore key political, environmental, and regulatory uncertainty and identify which solutions resonate with underserved communities.

California is a world leader in developing renewable electricity and policies to protect the climate. Yet the leader is being hamstrung by the current planning process. Lessons learned in California are generalizable to other regions, and the SEMPro model can be applied wherever siting is delaying the achievement of energy policy goals and can help jurisdictions to prepare for a carbon constrained world as well as existing and expected Renewable Portfolio Standard laws. Approaches like SEMPro can shed light on the most effective pathways to environmental stewardship. By understanding stakeholder preferences, barriers, as well as potential interventions, regulators and electricity providers may be able to predict resistance to new initiatives while building civic participation among underrepresented groups for addressing among the most challenging global problems facing leaders today.

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ODD addendum

SEMPro is part of a new class of techno-social modeling, fusing geophysical and social elements to understand the interactive effects and feedbacks between individual human agency, engineered physical elements and the geophysical environment.

The model description herein follows the ODD (Overview, Design Concepts, and Details) protocol to document the fundamental processes of any agent based models (Grimm et al., 2006, 2010). The ODD framework provides a common ground for model overview, general concepts and detail model design, simulation, results and discussion. This makes any ABM relatively transparent, replicable and process knowledge transferrable to researchers across disparate fields and domains. The model is implemented in NetLogo (Wilensky, 1999) so we use some NetLogo conventions such as for pseudo code.

1. Purpose

The overall goal of our model is to help people better understand the socio-political dynamics of siting energy infrastructure with the goal of improving the siting process. This model simulates how competing political and social interest shape transmission policy and identifies actionable strategies to site new infrastructure. SEMPro is part of a new class of technosocial modeling, fusing geophysical and social elements to understand the interactive effects and feedbacks between individual human agency, engineered physical elements and the geophysical environment. SEMPro can be used to anticipate, shape and decide transmission sitting routes that not only minimize political and social impedance, but maximize positive social externalities for the community.

2. Entities, state variables, and scales

SEMPro has several classes of entities, state variables and scales. Entities span GIS attributes, power lines agents individuals, the utility, citizen based opposition (CBOs) groups, as well as stakeholder and government agencies. State variables include disruption (the height and type of tower), talkspan (the distance within which citizens talk with each other), project need, process of justice, utility message, NGO message, and the political preferences in a local population.

The first entity is the geophysical environment of Southern California, spanning Los Angeles, Orange, San Bernardino and Riverside Counties, using a Robinson GIS projection of block groups from the US Census Bureau (2010). The GIS shape file includes patches characterized by type (block group, or transmission line, land use attribute such as state or municipal parks), areas of land, and areas of water.

Second, human agents are instantiated as individual citizens within block groups based on population from US census data. Individuals are characterized by the following state variables, household income, education, and ideological attitude based on party affiliation from congressional district data. Citizen agents are characterized by two state variables: ideology (liberal-conservative score ranging from 0 to 100), proximity (distance from the nearest transmission line), and power (education * income, then normalized between 0 and 1). An emergent class of entities are community based organizations (CBOs), that form when groups of citizens coalesce for social action around perceived threats to their community.

Both individual citizens and CBOs also have other attributes which are calculated by state variables: attitude (a function of ideology and a random term), preference (a function of proximity and preference), utility (a function of preference and power), type (CBO or not), salience (a function of proximity, preference and type), influence message (a function of preference, power, salience, and a random term), message (a function of influence message), total salience preference (a function of preference and salience), CBO preference (a function of his own preference and power, and other citizens' preference and power), CBO power (a function of his own power and other citizens' power), and CBO utility (a function of his own preference and power, and other citizens' preference and power

As the transmission sitting process involves not just individuals but various regulatory, utility, political, and social groups, a forth class of entities are stakeholder groups and government agencies, that have the potential to influence the sitting process. Specifically, these include regulators, US resource agencies, utilities, power producers, and environmental organizations. Stakeholder agents are characterized by two state variables: preference and power. Similar to citizen agents, stakeholder agents also have preferences, power and utility.

Regulator agents also have three state variables: preference and power as well as utility.

Below we also detail a list of calculated intermediate metrics and final outcome attributes in SEMPro. Utility message, conceptualized as community outreach and pro-development messaging on the particular project. This signal is received according to citizen attitude and a random stochastic component. The more positive the agent's attitude is, the more likely he is to accept utility's message. If the random number component is larger than the citizen's attitude, the citizen becomes more disposed to the utility's position by the same random amount. If utility is sending out more messages than what the citizen wants to accept for a "Needed" power line, the citizen will be turned off by the utility and become more opposed to the power line.

Other metrics included are aggregated opposition as the sum of all citizen preferences. The larger the number, the more negative citizens feel about the powerline. Total salient preference is the sum of salient preferences, which is a function of preference and salience. A large number indicates that citizens hold more salience and they oppose to the power line. Influence message is the number of messages citizens send as comments at each timestep in the model, which is a function of preference, power, salience, and a random term. Total message is the sum of influence messages citizens sent to the utility. Finally, total power is the sum of all citizens' power, which is a function of education and income.

The time step in SEMPRO is one month; simulations are usually run over twenty months coinciding with the EIS process that usually lasts 18-24 months.

3. *Process Overview and Scheduling*

SEMPro model has three different sequential submodels, a citizen/CBO formation module, a stakeholder lobbying module and a regulatory decision making module. Figure 2 depicts the high level process and multi-module architecture. Intuitively, citizens react to transmission siting projects forming opions and shaping those of others, which can result in the formation of Community Based Organizations that either support or oppose such projects. Against this backdrop of political and social opinion formation and transmission processes, organized stakeholders seek to lobby not only citizen opinions and the emergent CBOs that forms as inputs into the siting process, but also other stakeholders to maximize their specific, organizational interests. Finally in given the interplay between citizens, stakeholders and society, the regulatory decision making process models how regulators ultimately approve or deny siting activities given the constantly shifting techno-social landscape. Actionable policy levers for shaping the transmission siting process include the disruption engineering of the project, utility and NGO messaging outreach, as well as perceived project need and procedure surrounding the process.

In this paper, we focus on the citizen preference and CBO formation and stakeholder bargaining aspects of the sitting process. For these modules, after we load GIS data and initialize the model, citizen agents exchange their opinions with each other, decide to form CBOs or not, update CBO preference and power accordingly. Then the stakeholder bargaining module takes the emergent CBO formation into consideration in subsequent regulatory, utility, local and government stakeholders bargaining. The policy levers that can impact the citizen module include utility outreach and messaging, NGO messaging, citizen send out their own messages supporting or opposing the project based on their own attributes and utility and NGO messaging. The pseudo-code for the citizen and stakeholder modules can be written as:

```
Ask citizens create links to all other citizens in talk span
Calculate expected utility of cooperating with another citizen from all links
Choose partner/CBO that they want to join
If else two citizens can both provide the other with a higher expected utility
    [set members' preference to CBO preference, calculate CBO power, turn on their CBO attribute]
    [ask link between the two citizens to die, citizens' preference and power remain unchanged]
Ask CBOs and stakeholders create links to each other
Calculate optimal expected utility of cooperating with each other
Choose partner/coalition that they want to join
If else two stakeholders can both provide the other with a higher expected utility
    [set all members' preference to coalition
```

```
preference, calculate coalition power]
    [ask link between the two citizens to die,
citizens' preference and power remain unchanged]
Citizens in CBOs update preference according to
stakeholder coalition preference
```

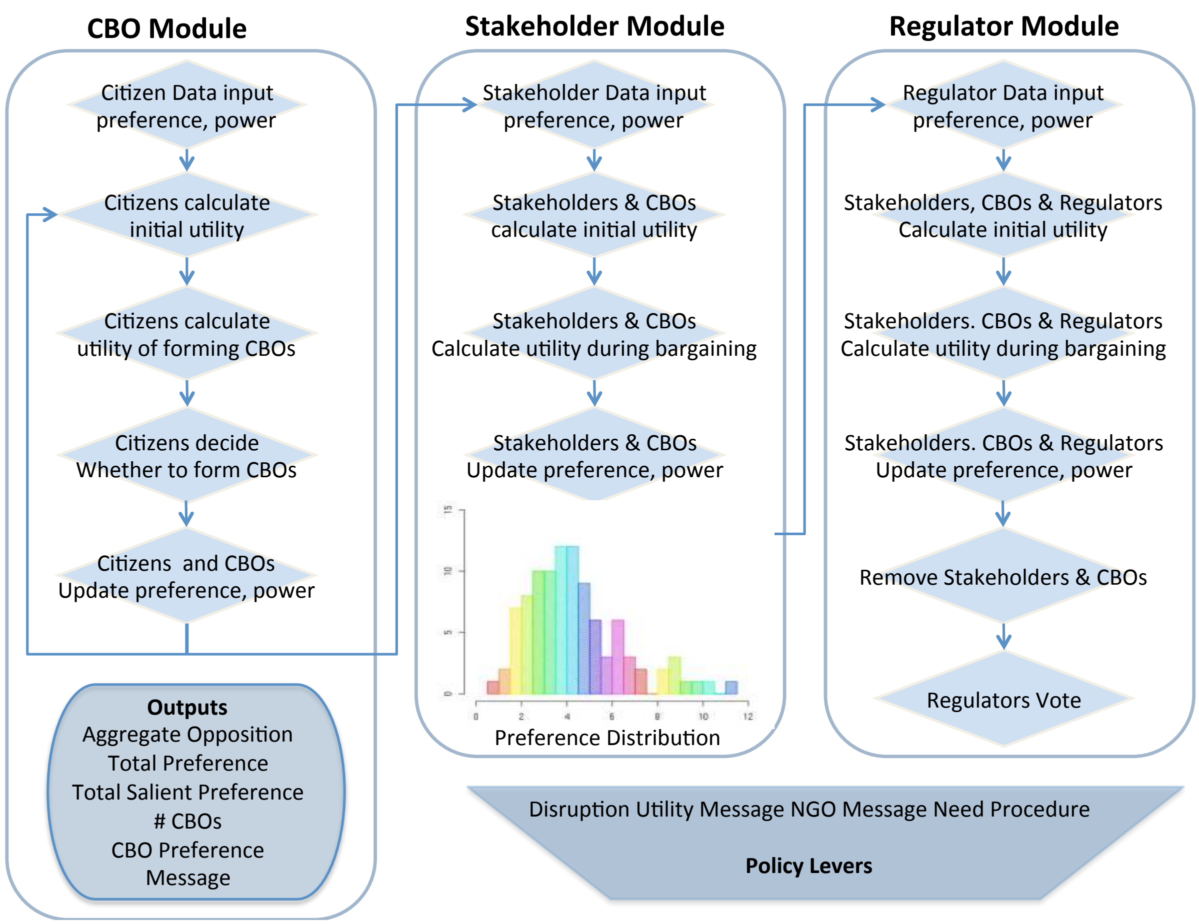
Citizens are queued and processed according to their patch or grid location in fixed order, using synchronous updating for preference communication and CBO formation in one tick time steps. Given CBO formation, then stakeholders bargain over support or opposition to the project within the same tick. Given new non-cooperative bargaining outcomes, stakeholder and CBO coalition formation changes CBO weighted preferences that are fed back into the CBO module for tick 2 processing. This parallel, linked module processing sequence then iterates. Policy lever inputs condition relevant data and processes at each time step.

4. *Design concepts*

Emergence. Individual citizen preferences, reactions to proposed transmission sitting routes, CBOs and the spatial distribution of both entity attributes interact in the citizen module. Here we see dynamic changes in individual preferences as well as the formation of CBOs given key geophysical and engineering attributes of the siting project. Given these emergent behaviors, citizens can send influence messages to the stakeholders and regulators in subsequent sub modules 2 and 3. This also impacts the number, strength and preferences of CBO's that become stakeholders in the stakeholder bargaining module as well as the resulting policy outcomes.

Sensing. Individual citizens sense the geophysical and engineering attributes of their local environment and process such information through their individual political preferences and neighborhood social interactions with other individual citizens. Citizens sense the distance to nearest power line, as well as other citizens' preference and power within talkspan.

Figure 1 - SEMPro Modules



Adaptation. The formation of CBO is based on the calculation of citizens' expected utility. Each agent has initial preference and power, and their utility is calculated as the power multiplied by the distance between actual preference and their preference. CBOs can also adapt in the stakeholder bargaining module.

Objectives. If joining a CBO provides the citizen with a higher utility than what the citizen originally has, she will have the incentive to become part of the CBO. Each agent will sort the expected utility that she can get by joining different CBOs and chooses the one that provides her with the highest utility. In the stakeholder bargaining module, stakeholders and emergent CBOs also sort their expected utility to form coalitions that support or oppose the project, this time based on non-cooperative game theoretic processes.

Learning. Citizens change their preference regarding the siting project, enter and exit CBOs, and alter the number of messages he sends out over time. Elite stakeholders also perform similar updating.

Prediction. Each citizen predicts his expected utility that they can get from joining a CBO based on his own preference and power, and other citizen's preference and power. They make their decision based on their original utility and expected utility that they can get from forming a CBO. Stakeholders also bargain non-cooperatively and deterime the distribution of political power for or against the project.

Interaction. SEMPro captures multi-level entity interactions between the techno-social environment and agents. At the individual level, citizens communicate within their neighborhoods limited by talkspan, exchange information, form opinions. Each interaction can result in no change in citizen preference, or a coalition of 2 or more citizens forming a CBO, in which an aggregate average preference is created. Stakeholders and CBOs then interact given these processes to simulate the evolution of the policy decision making process.

Stochasticity. Attitude is calculated based on congressional voting data plus a random term, and subsequent political preference regarding the siting project is calculated accordingly. This is done to capture data variability which block group level information might miss.

Collectives. Citizens form CBOs that are affected by their preference and power, and also affect their level of salience and number of messages they send out. Stakeholder coalition formation also exhibits collective behavior.

Observation. We generate output on number citizens in the population belonging to CBOs, the number of CBOs, the preferences (position) of CBOs, the distribution of CBO preferences around the mean value. We also track stakeholder plus CBO bargaining at each step, displaying the total distribution of weighted preferences for or against the project, total salient preferences, as well as the number of messages sent to the regulator module.

5. *Initialization*

SEMPro is initialized with 2010 US Census geophysical and citizen block group data for the Chino Hills area. including population density, household income and education. The transmission siting project is also overlaid in the geophysical space according to the shape files for Southern California Edison's Tehachapi Renewable Transmission Project approved by the California Public Utilities Commission in 2009 .

Figure 2 shows the NetLogo interface. In the center we represent the technosocial output space with the geo-physical environment—citizen agents at block groups with transmission line, which is taken from Census Data 2010. White lines separate block groups of LA county Riverside county. The black line indicates the transmission line. Parks are represented in green and yellow. Citizen and CBO agents are sized by the number of influence messages that they send. Citizen and CBO preference is differentiated by color gradations where red indicates opposition and blue indicates support for the project.

The dots arranged in a circle is a simple static depiction of the 16 stakeholders that comprise the bargaining process. Stakeholders are labeled and the size of these stakeholders is constant; the color is set by five preference ranges where blue indicates support and red indicates opposition to the siting project. Data is from citizen response surveys. However, the lines connecting stakeholders to other stakeholders, individual citizens and CBOs show the network of interactive messaging and utility comparison effects at any tick.

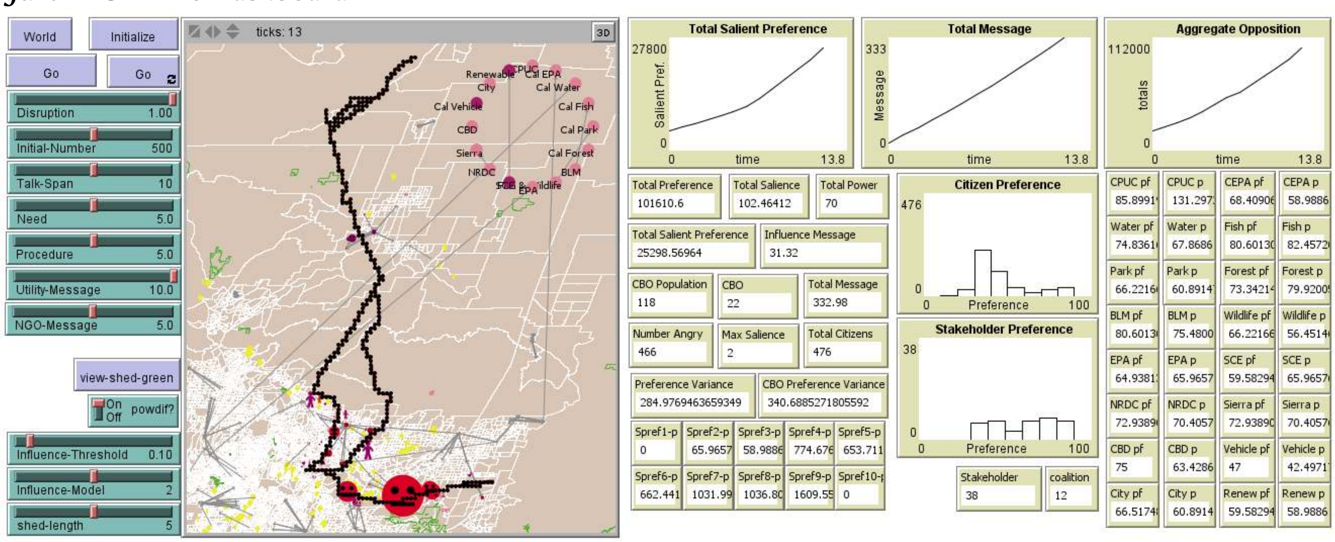
On the left side, are ten sliders to control model parameter settings and input data. *Disruption* indicates the level of physical disruption the proposed siting project causes, which is measured as the height/type of tower, with 0 indicating an underground routing while 1 indicates maximum aboveground disruption of a 200 ft tall 500 kilovolt high voltage transmission line. *Initial-Number* is the sample number of citizen agents we run in the model randomly selected from the census block group data. *Talk-Span* is the neighborhood grid distance in which citizen agents talk with each other and make decisions on whether to form CBOs. *Need* is the perceived project need. The highest value is when the project has been approved by the state transmission operator and provides reliability for the communities affected by the power line. Need is lower when the power line carries power to other regions without significant local benefits (reliability). *Process* is an indicator for procedural justice, or how the citizens think their preferences will be included in regulatory decision-making. *Utility-Message* indicates the number of utility, pro-development outreach messages the utility sends to citizens to shape public attitudes. *NGO-Message* is the number of anti-development outreach messages the NGO sends to citizens to help inform and shape public opinion.

The three sliders at the bottom are model processing control switches: for *Influence-Model*, when set a 1, attitude is pent up and then released; at 2, agents convey their attitude every iteration; at 3, agents convey their attitude every iteration only after reaching a certain threshold, which is set by *Influence-Threshold* slider. In this paper, we set model processing at 2 using agent's conveying attitudes at each time step. *Shed-length* can be adjusted to show the viewshed or area of disturbance where citizens can see the siting tower given it's particular height or disruption. *View-shed-green* toggles displaying the viewshed, while turning on *powdif?* calculates citizens' power by education and income census data, instead of assigning a equal constant weight across, such as one-person, one-vote schema. This is useful to explore the socioeconomic impact of political power and social formation compared to an explicitly egalitarian population.

On the right side of the dashboard, we display several intermediate variable monitors and plot windows.

Aggregated Opposition the same as total preference, and is the sum of preference of all citizens. The larger the number is, the more negative citizens feel about the transmission line. *View-shed-green* toggles displaying the viewshed, while turning on *powdif* calculates citizens' power by education and income census data, instead of assigning a equal constant weight across, such as one-person, one-vote schema. This is useful to explore the socioeconomic impact of political power and social formation compared to an explicitly egalitarian population.

Figure 2 – SEMPro Dashboard



Preference shows the sum of salient preference, which is a function of not only preference attitudes, but weighted by salience to indicate the actual strength of support or opposition. *Preference Histogram* shows the number and distribution of citizen pro/anti preferences. *Total Message* sums the number of comment messages citizens send regarding the siting project. *Total Salience* is the sum of citizens' salience. *Total Power* is the sum of citizens' power, which is a function of the distribution of education and income in the project area. *Influence message* sums the total number of comments sent by all citizens, which is a function of preference, power, salience, and a random stochastic component. *CBO Population* is the number of citizens that participate in CBOs, and *CBO* is the number of CBOs. *Number Angry* is a quick sum of the number of citizens with opposition preference over 80. *Max Salience* indicates the maximum level of salience citizens' hold. *Preference Variance* and *CBO Preference Variance* lists the variance of citizens' preference and CBOs' preference and is a good metric on the volatility of results.

Citizen Preference shows the preference distribution of all individuals given their own political proclivities and CBO participation, if any. This allows us to see a quick sample of public opinion distributions for or against the project by deciles. *Stakeholder Preference* is a similar graphic, but includes both elite stakeholders as well as emergent CBOs. We also monitor by tick, the individual stakeholder and CBO preference and power.

6. *Input data*

We load US Census block group GIS data on Los Angeles, Kern, and San Bernardino counties including population, density, income, and education. Areas of water, land, and parks are also included. We also have geocoded citizen comments from the project EIS to help validate our model. Stakeholder data on preferences comes from a web based survey of stakeholders involved in transmission siting administered between Nov, 2011 and July 2012. Approximately 23 of 44 stakeholders (51%) responded to the survey invitations which included a $20 incentive (Starbucks gift card) for completing the survey. All parameters are set at values consistent with either the above empirical data or set to match our baseline characteristics based on expert opinion.

7. *Submodels*

7.1 *Citizen Participation and CBO Formation Submodel*

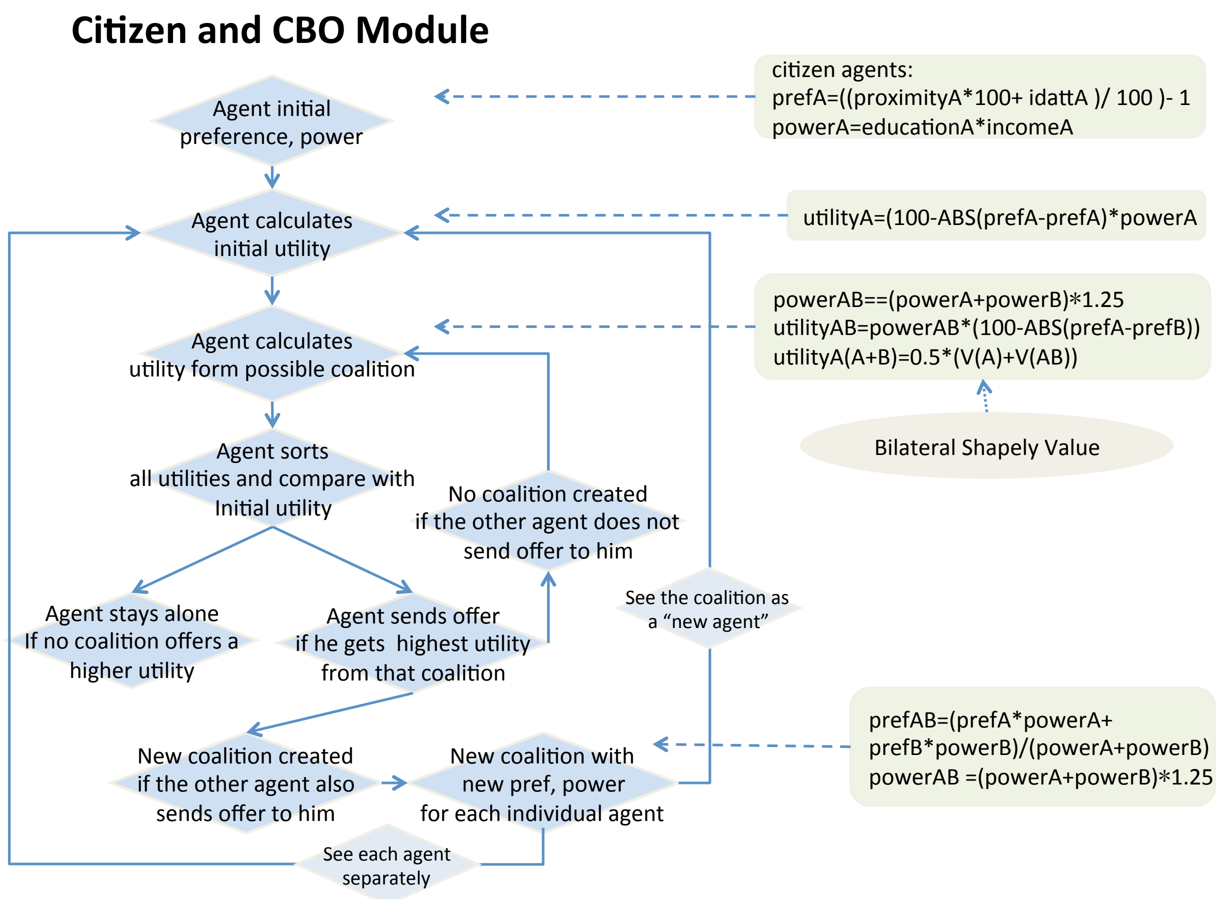
The citizen participation module focuses on the micro-foundations of political and social attitude formation surrounding transmission siting and the resulting behavioral impacts. Figure 4 details the citizen module processor. Conceptually, the citizen and CBO formation module proceeds in four phases; local information derivation, communication, calculation, and bilateral agreement stages (Yeung et al., 1999).

For local information, agents first receive their initial preference and power (income * education), from two sources. The first is the GIS shape file of US census block data already described above. The second are individual citizen preferences and utility, derived: ideology (liberal-conservative score ranging from 0 to 100), proximity (distance from the nearest powerline), and power (education * income, then normalized between 0 and 1). A key property of the citizen module is modeling CBO emergence based upon individual political preferences and local social interactions. Thus CBO formation from the citizen module is one key to driving or dropping new organizations in the stakeholder lobbying and bargaining module and impacting outcomes.

The following phases are based on calculation of Bilateral Shapely Value (BSV) of all citizen agents. BSV is a concept in cooperative game theory for explaining coalition formation, and thus a natural modeling strategy to use in CBO formation (Ketchpel, 1995). Each citizen agent is assumed to be autonomous, with bounded rationality, maximizing it's own utility subject to the geophysical, engineering and social constraints of its environment (Yeung et al., 1999). BSV looks at the combination of all possible coalitions that N citizens can join, that maximizes citizen utility and then compares all possible coalitions utilities in deciding whether or not to join or form a CBO. BSV dynamics focus on the permutations of individuals in different coalitions based on the marginal utility gained from formation.

To define agent characteristic functions, each agent A has initial preference and power, and their utility V(A) is calculated as the power multiply by the

Figure 3 - Citizen Participation and CBO Formation Decision Process



distance between actual preference and their preference where V(A) = (100-ABS (prefA-prefA) * powerA. We assume that when keeping power constant, agents maximize their utility when the actual preference is the same as their own preference. When two agents form a coalition V(AB), the coalition utility is calculated by the distance between their preference and the sum of their power where V(AB) = (powerA+powerB) * 1.5 * (100-ABS (prefA-prefB)). For the individual citizen agent in this coalition, his utility is calculated as V-A(A+B)= 0.5 * (V(A)+V(AB)). This equation takes into account the original utility and the contribution from possible new coalition.

At the decision phase, agents A compares this value with his original utility V(A) and make a decision—if V-A(A+B)>V(A) then formation the coalition with B; if not then he remains as an individual. As to agent B, if V-B(A+B)>V(B), he also decides to join coalition AB. Each agent does the same calculation with all other individual citizen agents N within a local neighborhood, then sorts the value and chooses the coalition that provides him a value then his own utility. Only when both agents agree to go together with the other one can the coalition be created. This is to satisfy the super-additivity requirement that all players in a grand coalition is collectively rational. For agent who has multiple choices, he will choose to join the coalition that has the shortest distance between coalition preference and his own preference. After a citizen agent joins a CBO, his preference changes to CBO preference, and his own power becomes 1.5 times his previous power. But when he leaves the CBO, his power changes back to original power.

One critical element of the BSV calculation is talkspan, which determines the extent of each individual citizen's local social interaction with other citizens when calculating it's BSV. The BSV algorithm originally looks at all permutations of possible agent parings in coalition formation and thus is exponential. However, we know from the communications literature that neighborhood distance and communication methods impact the potential social-spatial feasibility set (McPherson et al., 2001). Thus we incorporate talkspan to limit each individual agent's characteristic function to only evaluate local partners. Talkspan ranges from 1 to 20, defining grid size radius for the local neighborhood. At talkspan of 1, citizens only interact and evaluate BSV coalition formation with their direct neighbor patches, while at 20, citizens can potentially interact with over 1200 neighbors, however this is limited in our model by population density block group data where patches can be empty.

7.2 Stakeholder Bargaining Submodel

For the stakeholder module, we incorporate a non-cooperative bargaining model to reflect competing interests during the process. CBOs formed in the first module participate in the bargaining with other stakeholders including CPUC, Cal EPA, utility, etc.. Similar to what we have in the first module, agents in this module also have initial preference and power. Individual utility is calculated with the equation utility = (100-ABS (prefA-prefA) * powerA)), which means the power multiply by the distance between actual preference and their preference. The smaller the distance is, the higher their utility they have. When two agents decide to form a coalition, the coalition preference is calculated by the weighted individual preference: prefAB=(prefA*powerA+prefB*powerB)/(powerA+ powerB); while the coalition power is calculated as the sum of individual power: powerAB = powerA + powerB. For each individual stakeholder, their utility from the coalition is calculated as the distance of preference multiply by power: utility (AB) = (100-ABS (prefA-prefAB)) * (powerA + (powerAB - powerA) * (powerA / powerAB)). The first half of the equation represents the distance between the coalition preference and his own preference; the latter half of the equation shows that power is calculated as his own power plus the weighted gaining power from the coalition. After the calculation, each agent compares the value of individual utility and utility form all possible coalitions, sort the value and decides to send an offer to form the coalition if that coalition gives him the highest utility. But if A send an offer to B but B does not send offer to A, then A and B will stay separately. Only when both agents send offers to each other can the coalition be created.

Like the CBO module, after each stakeholder agent calculates his utility and makes the decision in the first round, coalitions form with new level of preference weighted by power, and new power calculated as the sum of the coalition members. Then each individual stakeholder as well as each citizen agent in CBOs that participate in stakeholder module updates his preference according to the coalition preference. In the second round, each coalition will calculate their utility based on new preference to decide if it is better to form a new coalition with other coalitions or individual stakeholders. At the same time, each individual in the coalition also calculates their utility of separating from the current coalition and forming a new coalition with someone else. All coalitions and individual stakeholder agents do the same thing in each round, until no coalition can provide higher utilities for all joining agents.

A benefit of our approach is to identify actionable policy levers to beneficially impact the sitting process. Table 1 identifies and maps our 5 policy levers effects onto various state variables and agent attributes.

Disruption is the engineering characteristics of the transmission line, where zero is the status quo land use and a value of 1 is calibrated to simulate a giant, 200ft 500Kv high voltage transmission tower. Disruption has dramatic impacts across several agent attributes, including salience, salient preference, influence message and the resulting citizen comments

Figure 4 – Stakeholder Bargaining Policy Process

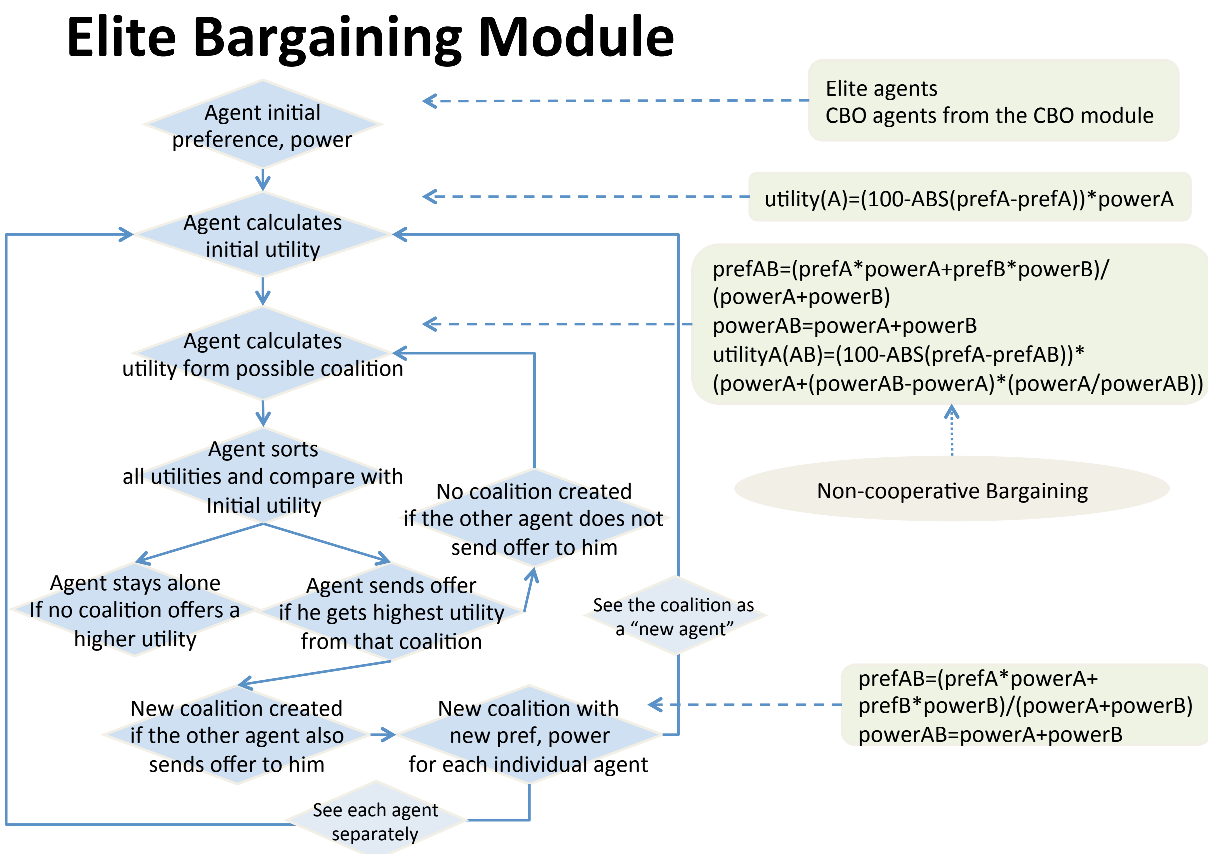


Table 1 – Policy Lever Impact

	VARIABLES				
LEVER	**Salience**	**Salient Preference**	**Influence Message**	**Comment**	**Attitude**
Disruption	= disruption *proximity*turcbo	= preference*disruption *proximity *turcbo	= preference*power* disruption*proximity* turcbo	Via Sum of influence message at every tick	
Utility Message					If Utility-Message > Need, citizens change their attitude closer to utility's; otherwise change their attitude further from the utility's. idatt = idatt (1 + random-float 0.15) * (idatt + Utility-Message * 10 / abs (own-pref - utilitypref))
Need					
NGO Message					If NGO-Message > Procedure, citizens change their attitude closer to NGO's; otherwise change their attitude further from the NGO's. idatt = idatt (1 + random-float 0.15) * (idatt + NGO-Message * 10 / abs (own-pref - ngopref))
Procedure					

One key question is how do utility outreach messages influence citizen attitudes and actions on siting projects (Bray, 2011). The utility influences the citizen agents through the utility-info procedure. The utility sends out a message to all citizen agents. This message can take the form of flyers, public hearings, phone calls, town halls, neighborhood coffee meetings.

If utility message values are smaller than project need, citizens can change their attitude closer to the utility's preference. The stronger the utility message the more citizens can move closer, while the shorter the preference distance between citizens and the utility, the more citizens will be receptive to utility messages. However, if utility message values are greater than project need, citizens have an adverse reaction to high messaging, and can react similarly away from utility preferences.

NGO messages also influence citizens in a similar manner. The idea is that there are NGOs, such as the Sierra Club or Wildlands Conservancy or others, that try to influence people against siting transmission projects. If NGO message is smaller than procedure, citizen change their attitude closer to NGO's according to the strength of NGO message and the distance between their preferences. However, if NGO message is too strong, citizens' attitude moves in the opposite direction.

The number of utility messages impacts citizens' preference. This value is calibrated between 1 and 10. The number of NGO messages also impacts the level of attitude as it makes citizens either more supportive or more opposed to the transmission line. This parameter is set at a range between 1 and 10.

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