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Steen Rasmussen
Diana Mangalagiu
Hans Ziock
Johan Bollen
Gordon Keating

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Collective intelligence for decision support in very large stakeholder networks: The future US energy system.

Steen Rasmussen^{1,2*}, Diana Mangalagiu^{3,4}, Hans Ziock¹, Johan Bollen¹, and Gordon Keating¹

¹Los Alamos National Laboratory, Los Alamos NM 87545, USA; ²Santa Fe Institute, Santa Fe NM 87501, USA; ³Reims Management School, BP302, 51061 Reims, France; ⁴Institute for Scientific Interchange (ISI), Torino, Italy; *Point of contact: +1-505-665-0052, steen@lanl.gov

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Abstract. Pick your favorite complex societal issue. For example, how could the US government, its citizens, and its energy companies reach an acceptable future national US energy plan? How could such a complex problem even be approached in a rational and transparent manner? We discuss a recently developed Internet-based method for clarifying issues, providing insights into understanding causes of conflict in large stakeholder groups facing complex issues, and reaching consent. This method has been tested on a variety of complex social and technical issues that illustrate how the Internet can be used to harness the collective intelligence of large stakeholder groups. This work further shows how to positively influence the capability of large stakeholder networks to make more informed decisions. As our main objective, we outline the key open research questions for applying Internet based collective intelligence methods in very large stakeholder networks. As a case study we examine what it would take to develop “the lay of the land” of possibly millions of stakeholders for the possible future US energy systems. We discuss stakeholder access issues, inherent conflict of interest issues, as well as the necessary machine automation of the collective intelligence method to handle this scale of stakeholder involvement.

1. Introduction

An understanding of the inherent conflicts, as well as a means for facilitating consensus or consent are key when a stakeholder group larger than a typical face-to-face committee of about a dozen people makes decisions that include complex topics and issues. The method presented here expands the capability to make informed decisions about complex issues from small to very large stakeholder groups and it does so more efficiently and more quantitatively than alternative published methods. A vast array of considerations impinges on most decisions. For the

future US energy system these considerations include: economic impact, national security, technical assessments, environmental impact and climate change, the interests of energy companies, public opinion, diverse stakeholder groups and organizations, cost/benefit analysis, public safety considerations, federal regulations, and so on. Given that all possible energy sources and carbon mitigation technologies should be considered in order to meet the growing global energy demands, we are not faced with choosing a single energy source for a nation, but rather we must agree on the best combination of energy and waste disposal solutions that may vary by region. In general it can be assumed that no single individual or organization has sufficient information about or understands the full range of issues associated with a complex set of technical, social, political, or disaster-management problems. Our Web Based Consensus, Consent, and Conflict Clarification process provides a simple recipe for how to harnesses the collective intelligence of the involved stakeholders. A number of other references on collective intelligence activities exist.^[2, 5, 11, 14, 25, 28, 30, 31, 32]

2. Web-based collective intelligence system

The developed system is hosted by an organization that provides a web environment accessible to the stakeholders. The components of the system consist of a stakeholder provided library of background information, an open-response survey, a data processing unit (human or automated), a response database, and visualization tools for interactive analysis (human or automated). In more detail (see Fig. 1) the system would: (1) Provide Internet access to the stakeholder group, which takes an active role in constructing an information repository. (2) Stakeholders individually review available information,

pick, rank, and organize the issues, including adding new issues. (3) Distribute surveys and analyze via human and/or automated means the written texts from the open-response surveys identifying areas of conflict, consent, and consensus via mind-maps, statistics, and other relevant methods. (4) Results of the analyses are posted in graphical form on the web site for feedback to all individual stakeholders. Steps 2, 3, and 4 can be repeated as the stakeholders react to areas of conflict and agreement and individuals modify their positions. (5) The process is finally documented, which is easy as all steps are transparent with identifiable electronic traces.

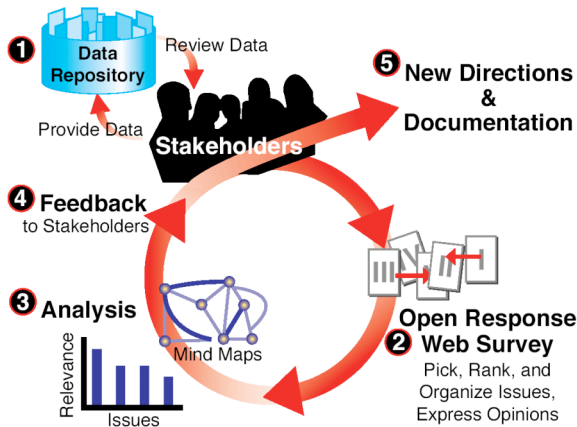


Figure 1. Collective intelligence process summary.

We present and discuss the method in the context of a number of earlier studies^[17, 18, 23, 24] we have conducted and provide guidelines for how to expand the method to include millions of stakeholders for a proposed case study of the US energy future.

3. How simply can web-based collective intelligence function in practice?

Because a group of many people know more than any single individual in the group, collective intelligence can easily transcend failures of traditional communications in the case of disaster evacuations^[23]. On May 4, 2000, a prescribed burn ignited in the Bandelier National Monument in Northern New Mexico, USA, blew out of control. More than 47,000 acres were burned in the Santa Fe National Forest, the Santa Clara Pueblo, the County of Los Alamos and parts of the Los Alamos National Laboratory. The impact included hundreds of millions of dollars of damage in infrastructure, houses, relocation costs, lost income, and incalculable damages in human suffering and loss. During the fire, about 25,000 people were forced to evacuate their homes, temporarily moving to shelters, hotels, or the homes of friends and

relatives. This massive rural displacement was further aggravated by the lack of a system for the evacuees to communicate with their family members and friends, to locate them, and to identify their condition, because the phone systems broke down due to overload, and Internet access was limited due to the geographic displacement.

Within days of the start of the fire, a grassroots, ad-hoc organization launched a Disaster Information Network, consisting of a multiple-site, Internet-based network of important disaster information. The website contained housing lists and message boards, as well as a database of evacuees' contact information. These people-finder databases turned out to be critical for locating the 25,000 evacuees, for no single person or organization had information about the location or condition of the vast majority of the evacuated people. This self-organizing location process reached its maximum effect within five days after the launch of the people finder database, alleviating the overloaded phone systems (Fig. 2).

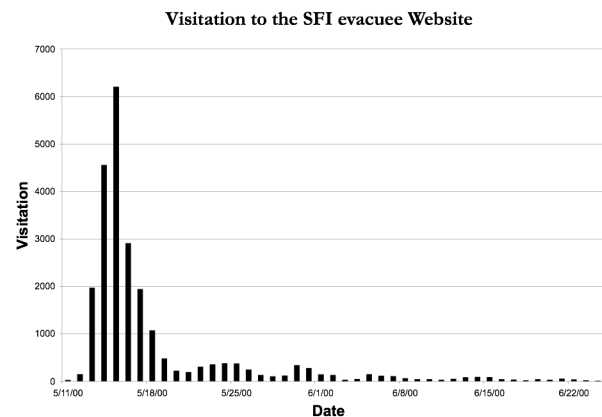


Figure 2. Visitor web log for the Santa Fe Institute's evacuee database usage. Note the two day incubation time before the usage of the disaster web became significant, followed by a week of heavy daily traffic. After the peak (about 6000 hits/day) the community reconnects quickly, which is seen in the rapid decline in the use of the databases^[23].

4. Collective consensus and conflicts

A few examples from the Artificial Life (AL) community, shown in figure 3, illustrate the kind of information a web-based system can provide. In connection with the year 2000 AL workshop, the community was asked among other things: "How can artificial life solve its most significant scientific issues?" The analysis of the open (free text) responses provides a clear picture of what the community thinks.^[24]

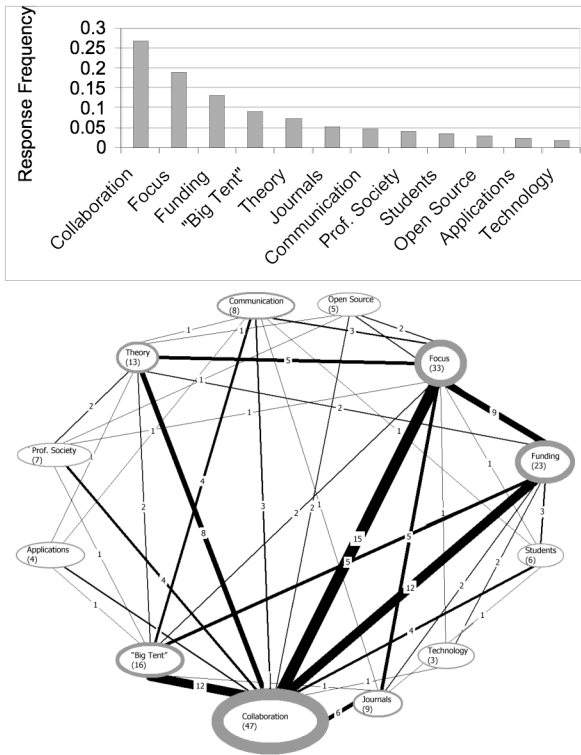


Figure 3. “How can artificial life solve its most significant scientific issues?” Collaboration, Focus, and Funding are the most important issues (top), which are also connected in the triangle in the mind-map (bottom).^[24]

The most significant issues for the artificial life community are: “to enhance collaboration”, “to focus on main issues”, and “to ensure funding to this new community”. The fourth most important issue is “to maintain ‘the big tent’ culture” for the artificial life community, which ensures that different disciplines can freely interact. Given the current disciplinary structuring of available funding, issues three and four are not easy to pursue simultaneously. Since the edge weight between two issues is increased every time an individual picks both issues, the mind-map shows a triplet of issues: “collaboration”, “funding” and “focus” are closely coupled.

Important (anonymous) information about the different artificial life subpopulations can be gleaned from this system. In figure 4 we see a comparison of how biologists and computer scientists respond to the same question as addressed in figure 3. Not surprisingly computer scientists find collaboration much more important than biologists, as the latter have more domain knowledge. Biologists more frequently mention “focus” than computer scientists although enhanced focus in the community is equally important for the latter group.

This collective feedback from the artificial life community has inspired the community to

collectively take a number of actions to address the identified issues. Today, more than six years later, the community is characterized by a higher degree of focus, e.g. as seen in the stricter acceptance criteria of papers for the Artificial Life journal (MIT Press), as well as a higher degree of computational and experimental integration, e.g. as indicated by two major recent integrated artificial life projects, one in Europe^[20] and one in the US^[21].

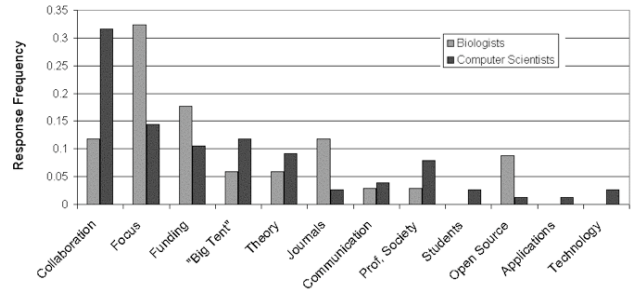


Figure 4. Comparison of how biologists and computer scientists responded to the question: “How can artificial life solve its most significant scientific issues?” Note how Collaboration and Focus is switched as most important.^[24]

5. Proposed case study: The future US energy system

In this section we outline some of the fundamental issues associated with the US energy system as policies and economic, environment, energy businesses, and societal issues, as well as the fundamental questions this information could raise for the stakeholders. Information of this kind will form the foundation of the knowledge repository of our proposed web-environment. The technical collective intelligence issues associated with this environment are discussed in the following subsections.

5.1. US energy policy challenges

To be viable, the US energy system will need to produce cheap, clean, and abundant energy. With ever growing energy demand and usage, what had been sufficient in the past is no longer adequate for the future. A paradigm shift is necessary to make the energy infrastructure both secure and sustainable. This requires an integrated perspective that takes into account the energy system as a whole together with the rest of society and natural systems.

Energy generation and delivery is the largest US industry in terms of investment and revenues. In 2005, US energy sales amounted to ~ one trillion dollars (~10% of GNP). Energy use and generation is also responsible for much of the nation’s CO₂ and sulfur and nitrogen oxide emissions. The US

accounts for nearly 25% of the world's ~25 billion tons of yearly anthropogenic CO₂ emissions, which is ~7% of the natural annual C-cycle.

Historically, the United States' energy policy making has been ineffective. Government and industry decision making on energy questions tends to be event- or crisis-driven. However, the US is not alone in its inability to adequately address these issues.

5.1.1. Technological issues: increase energy supply and upgrade distribution system

In parts of the country, the energy supply has failed to keep pace with growing demand and this imbalance is projected to persist into the future. The results of this trend are a lack of reliable supply, high prices, and damage to the nation's economy.

Coal: Contributes predominantly to US electricity generation (~49% in 2005)^[9] and remains considerably cheaper than other energy resources. However, for the past several decades most new electricity-generating capacity has been natural gas fueled, as coal plants have been difficult to locate due to air pollution, aesthetic concerns, and large upfront investment costs.

Oil: Oil is the nation's largest source of primary energy, serving almost 40% of U.S. energy needs. Transportation fuels account for about two-thirds of the oil consumption while the industrial sector accounts for 25%. Residential and commercial uses (heating) account for most of the rest. Since the mid 1950s, domestic usage of oil has exceeded the domestic production levels.

Natural gas: Electric generation from natural gas had until recently come down in price due to improved generation efficiency, "low" capital costs, and scalability. However, very high operating costs, largely due to recent steep increases in fuel costs, have led to the idling of many natural gas plants. This is in spite of the other advantages that such plants offer, including less than half of the CO₂ emissions for the same power production when compared to coal plants, quick startup time to meet peak demand, and a high capacity factor (~95%).

Nuclear energy: Nuclear energy is the second-largest source (20%) of U.S. electricity generation. While nuclear power has been the most prominent alternative source to fossil fuel generation in the United States, it has fallen far short of early expectations.^[6] No new nuclear power plants have been built for decades due to past accidents, public perception, problems of acceptable waste disposal, nuclear weapons proliferation, and high initial costs.

Nonetheless, with capital investments paid off and major improvements in operational reliability, today nuclear power plants produce power at low cost and with no direct CO₂ emissions.

Renewable energy: Following the 1973 Arab Oil Embargo the U.S. became the early leader with modern renewable energy development. The 1978 Federal Public Utility Regulatory Policies Act was largely responsible for this development.^[12] Despite this early development, the US is a particularly challenging marketplace for renewable energy due to the low costs of conventional electricity and fossil fuels and the seeming lack of concern about the issues of energy, environment, and sustainability among the US population. Renewable energy is typically more costly than fossil fuel-derived generation, especially solar power. However, with rising fossil fuel costs and falling wind installation costs, wind in particular is becoming competitive.^[4] Cost estimates however do not include the fact that wind and solar generation rely on conventional power plants to compensate for their highly variable output. A further issue is their large environmental impact due to the very diffuse nature of their energy source. The development of the renewable energy industry needs government intervention (regulations, mandates, subsidies, incentives, tax credits, etc.) as it continues to grow. Prices for solar- and wind-derived electricity have nonetheless declined more than tenfold during the past decade thanks to technology advances.^[13]

5.1.2. Economic and regulatory issues

Federal vs. state vs. local level policies: The federal institutional structure for energy decision-making is weak. None of the numerous energy laws are truly inclusive. Energy decisions are made through a complex mix of market factors and federal and state regulations. As a result they are ineffective in accomplishing clear and consistent goals. The states have become innovators in energy policy, taking the lead in further deregulation of the electric utility industry. For example, due to a lack of stable federal support, the US state-based programs are becoming the major stimulators of growth of renewable energy. Renewable energy funds and portfolio standards, green pricing programs, tax incentives, and government renewable energy purchases are presently being pursued at the state level.^[13] At the same time, the net cost impact, the environmental consequences, and effectiveness of these different programs are largely unknown.

Deregulation of the energy market: The deregulation of the U.S. energy industry started relatively late, in the mid 1990s, following passage of the 1992 Federal Energy Policy Act. Many questioned the extension of market reform to energy as only the wholesale generation of power and the retail function were deregulated, while wholesale transmission (under federal control) and retail distribution (under state control) remained natural monopolies in order to avoid competing infrastructure.^[7]

The energy market restructuring and liberalization failed to deliver anticipated benefits. By 2002 deregulation had hit major roadblocks following California's energy crisis and the collapse of Enron, the largest independent energy trader at the time. California's electricity restructuring plan posed structural problems in wholesale power supply.

Energy industry: Exxon, Chevron and Conoco-Phillips, the main US-based energy companies, account together for \$700 billion in revenue in 2005. Traditionally involved largely in the petroleum refining, all the companies diversified into the gas and electricity supply chains, some more vigorously and successfully than others. However, nearly all companies sought to diversify into other energy sources than oil and gas, but also disposed of their assets in coal mining activities. All the companies but Exxon invested in renewable energy, although they focused on different renewables with varying enthusiasm and success. The companies differed quite substantially with respect to the geographical orientation of their investment strategies. In the 1990s, diversification (vertical and horizontal) in the companies followed several distinct paths, but none of the companies fundamentally revised their investment policies. These corporations could now be characterized as 'vertically integrated oil and gas companies', as most of their new investments had been made in downstream natural gas activities and electricity generation based on natural gas. Moreover, by the late 1990s, virtually all of the energy companies had in place some code of conduct and had revamped their approaches to environmental responsibility.

5.1.3. Environmental issues

Climate change and control of CO₂ emissions: The growing concern over global warming led to the establishment of ambitious targets for emission reductions in the late 1980s and early 1990s at the domestic and international level. Some 15 years later, emission levels are still increasing in most countries, and projections are that energy related

emissions of CO₂ will increase by more than 60% from current levels by the year 2030.^[15]

Conservation and energy efficiency

Conservation and energy efficiency are crucial components of a national energy plan. Energy efficiency refers to the production of the same amount of useful work or services while using less energy. Conservation is closely related and means simply using less energy. Improved efficiency and conservation reduces consumption, costs, air and water pollution, land disruption from mining and drilling, solid and hazardous waste generation, and greenhouse gas emissions, while maintaining equivalent services, but typically at increased short term and possibly long term cost. The cost issue is however often difficult to quantify as it depends on where the boundary is drawn and made difficult due to often times substantial upfront costs.

5.1.4. Social issues

In the absence of strong federal leadership, there is today no broad public discussion in the US about a sustainable and secure energy future. Neither is there much awareness about climate change.^[19] However, as citizens have begun to realize the link between energy use and environmental degradation caused by greenhouse gas emissions, state governments have responded by rewarding companies that address environmental concerns. The public is viewing environment friendly products more favorably.^[1]

Although surveys suggest that more than half of Americans claim they are willing to pay a premium for "green power," it remains unclear how consumers perceive renewable energy and if they are actually willing to pay a premium or not. When given the opportunity, only 1 percent of the nation's households have chosen to do so among the 40 million that have access to a green market plan.^[35]

Therefore, the extent and effects of customer pressure on utilities' portfolio decisions are unclear. It is naive to believe that independent residential consumers on their own will altruistically pay more to be green when the benefits from such actions accrue to the greater public good. The free market cannot generate the desired energy solutions alone.

5.2. Proposed US energy issues web system

Energy policy design poses an exceedingly difficult collective decision making problem which could be supported by the implementation of a collective decision making environment as described in sections 3 and 4. Such a web-based system should provide both overview and in-depth information about all technical issues associated with energy

resources, production, distribution, storage, environmental impact, and climate issues. Further, it must from the outset factor in the key non-technical socio-political issues associated with any technical energy systems solution, which the government has failed to address in the past. The handling of nuclear waste issues is a case in point. Government institutions for decades only focused on the strictly technical issues associated with nuclear waste, and did not factor in the socio-political issues. When DOE and its Labs finally were forced to realize the importance of these non-technical issues, they had already developed a bad public reputation among many stakeholders. Thus from the outset, any such web-based system must take into account the many complex conflict of interest issues the nation faces. In fact, the technical issues associated with the many grand energy challenges the US faces are truly global problems and should be addressed as such.

The size and composition of the stakeholder groups may be variable. Because the best mix of energy sources and waste disposal technologies may vary on a regional basis, the most effective consensus-building and conflict clarification technique may be based on regional stakeholder groups who will consider the economic, socio-political, and environmental impacts of various energy policies^[22]. These groups may be comprised of subject matter experts from utilities, universities, and national laboratories as well as activists, interested citizens, and government representatives.

The proposed web-based energy information-clearing house must also include the socio-political perspectives for the different possible energy futures. The feedback tool at the center of this web system must be able to objectively map “the lay of the land” in terms of issues of great contention (key conflicts), issues with a high degree of consensus, as well as clarifying for the nation what the key drivers for the different technical solutions are and why they are the key drivers. See figure 5.

Obviously, this tool should also provide links to all the technical issues and possibilities associated with the grand energy challenges including simplified (sandbox) energy systems simulations, cost analysis (and scenarios) that on-line users can play with interactively to create their optimal or most frightening energy future. Such a web-tool could within a few years become the (inter)national Wikipedia-web^[34] for global grand energy challenges.

Last but not least, the organization that hosts this web environment must be transparent and under

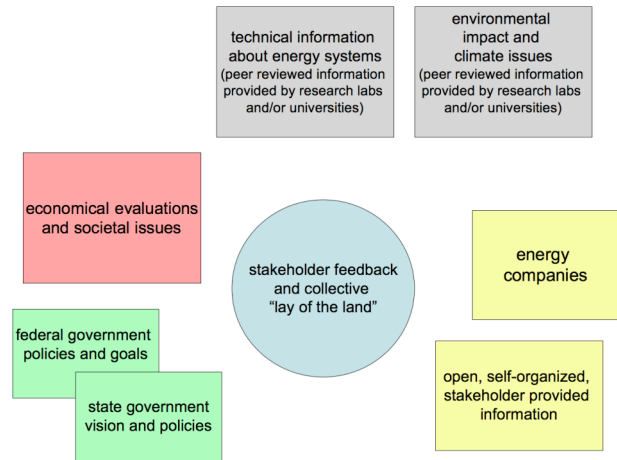


Figure 5. Basic structure of the proposed web-based energy information-clearing house.

constant stakeholder review, similar to democratic voting processes, to minimize the possibilities for information manipulation. Further anonymity needs to be guaranteed for demographic data. Accountability and documentation of the collective process is obtained easily as all steps are transparent with identifiable electronic traces. Such an energy issues web-based system could be hosted by a government institution, but it could also be hosted by specifically tasked non-profit organizations.

5.3. Technical issues in harnessing the collective intelligence of millions of stakeholders

The collective intelligence web decision support systems we have implemented can currently digest only a relatively modest size stakeholder input (in practice less than a few hundred people) because the analysis of the short open responses is currently done manually. Automated text parsing and categorization techniques^[16] may to some extent alleviate these shortcomings, in particular because the open questions can be asked in a well-defined context so that the text analysis is restricted and no longer free format. However, these methods are presently not at a stage where one could expect entirely autonomous, reliable operation. However, a range of social network-based knowledge integration techniques, developed and commercialized as part of the Web 2.0 movement^[33], can be leveraged in this context.

A “lay of the land” overview of social opinions and perspectives can be derived from the structure of tags collectively assigned to a set of resources by the users of a “folksonomy” system.^[10] Folksonomy systems allow users to freely assign metadata tags to any number and range of resources they have visited. These tags are then overlaid and integrated

into a tag cloud.^[29] The resulting tag cloud can then be exploited in recommender systems and visualizations of the perspectives of the user community with respect to a particular resource. For example, a US Energy Systems web decision support system could initially make available a range of resources deemed relevant to the US Energy Systems, e.g. reports, pictures, graphs, and video. Each resource when displayed could be accompanied by a set of existing tags and a small text field where individual users could freely add their own tags. Users could in addition submit their own resources, by means of e.g. Wiki systems for the collective generation of documentation and open-source content management platforms such as Drupal.^[8] These user-provided resources could then be further tagged by other users and as such related to existing resources. The resulting network of tags and resources would gradually converge to a representation of the collective perspectives of that particular user community on the subject of the US Energy Systems.

The use of folksonomies may combine many of the desirable features of both manual and automated text categorization. Technically, they would furthermore be relatively easy to integrate in the existing interfaces of any online information system.

The resulting lay of the land needs to be fed back to the user community. We therefore need to provide automated, real-time, user controlled, graphical feedback for the stakeholders, as they need to be able to display (graph) the analyzed input interactively to see different representations of the lay of the land.^[3] Given the large number of commercial services to implement both folksonomies and their subsequent visualization, this task can largely be executed with off-the-shelf software.

Several existing Web 2.0 frameworks^[33] can be leveraged here as well. We refer to the innovative work on collective decision-making techniques by Smartocracy^[27] and the work by Rodriguez^[26] where social network frameworks have been proposed to aggregate the individual perspective of millions of participants into a single collective decision. These social networking systems are related to online prediction market systems, e.g. <http://us.news-futures.com/>, that can be leveraged to further aggregate the perspectives of expert participants.

It is furthermore possible to move the proposed system to the next level by providing formal algorithms that process the grouped input categories and provide computationally suggested energy scenarios with specific energy production systems, cost

structure, environmental impacts, citizen preferences, etc. The reason why this is possible is because the citizen preferences are quantified in the above process and can therefore be integrated (exploited) in a formal utility function.

A key socio-political challenge lies in implementing partial consensus views developed in a web-exercise such as defining the best US energy future. Given that the consensus view is likely to be complex, based on many energy technologies and regional considerations, the implementation will consist of choreographing these complex, interrelated ideas and concerns. An important aspect of the design of the system will be building structural connections to legislation; in essence, defining a contract to formally engage lawmakers in the outcomes. Further, the identified and clarified conflicts in this process could naturally be the topic for further political negotiations.

6. Conclusions

The Web Based Consent Development, Consensus Building, and Conflict Clarification system has an important potential pay-off, as it will support any organization, private or public, for-profit or non-profit, that has a large stakeholder group. This method (and the associated web-based tools) facilitates and documents this complex self-organizing consent/consensus building processes as well as clarifies conflicts, which otherwise would be unwieldy. Furthermore it does so in a transparent and easily documentable manner. Please note that this method cannot (and should not) replace face-to-face meetings and other proven survey and other qualitative methods. However, it can reduce operating costs by alleviating the need for expensive meetings and more effectively gathering input from a far larger group of interested parties. In addition, this web-based approach may be the only reliable and inexpensive manner to extract vast amounts of coherent information from the public at large regarding their points of view and what action they might take.

The proposed web-based energy issues clearing house, will map out the interactions of technical, economical, environmental, and societal energy issues. It will do so on the basis of its proposed ability to quantify, integrate, and synthesize stakeholder perspectives and feed them back to the community. In addition it can be expected that such a system would accelerate the basic awareness about energy related issues by connecting and processing dispersed information.

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