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DLgSILENT announces

PowerFactory 2018

DLgSILENT’s simulation software PowerFactory has been continually improved and extended for more than 25 years to meet the increasing demands of its customers.

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Selected Key Features

- New module Probabilistic Analysis incorporating very powerful capabilities for managing stochastic parameters based on distribution curves and their correlations
- New Distance Protection Reach Colouring in diagrams and new Short-circuit sweep plots
- New Remedial Action Schemes (RAS) in Contingency Analysis, for flexible and dynamic analysis of post-fault actions
- New Frequency Response Analysis of dynamic models
- New Plant and Grid Performance Monitor to support real-time data streaming for RMS simulations, based on IEEE C37.118
- Simulation snapshot saving for subsequent analysis
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- Enhanced Cable System Analysis with improved cable layout modelling
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- New Data (Model) Extension concept, opening up new possibilities for customisation with user-defined attributes
- Powerful graphic search option for network elements in diagrams, including geographic search
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- Revised data colouring scheme to provide a better visualisation of parameters with characteristics and distributions
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**THE NOBEL PRIZE COMMITTEE** recently recognized Richard Thaler for his contributions to behavioral economics. His work shows that people do not necessarily make “rational economic decisions,” but rather economists must consider psychological factors.

The focus of engineers needs to expand beyond just solving problems! We should understand the motivations of our customers to fully comprehend the future types and patterns of energy consumption and production. The transition to a smarter, greener grid involves much more than the laws of economics. Customer motivations include their basic values, responsiveness to social pressures, and willingness to utilize new or different ways of consuming and producing electricity. Similarly, the acceptability of proposed siting decisions encompasses much more than a simple quid pro quo of developer payments to local communities in exchange for permission to build electric power facilities.

Many of us have experienced “NIMBY” (not in my backyard), while others have been subjected to “BANANA” (build absolutely nothing anywhere near anyone). These attitudes may be with good reason once we take the time and trouble to understand specific oppositions to projects. People may emotionally adore their current landscape and want it to remain free of industrial development, regardless of lost benefits in the form of payments. The emotional response may be considered irrational, but it is real nonetheless.

Understanding customer motivations and how they respond to industry initiatives remain critical to their success. Too often engineers rationalize and predict outcomes without accounting for emotional and other factors that may be vital to the success of policies and projects. All too often we suffer from the effects of unintended consequences because of misconceptions about the end-use acceptability of policies and projects. (For example, I am often surprised when people in the viewshed of wind farms do not share my aesthetic appreciation of their utilitarian beauty.)

**In This Issue**

This unique issue of *IEEE Power & Energy Magazine* seeks to bridge the gap and encourage dialogue between electric power professionals and social scientists who provide key insights into our customer base. Our guest editors compiled five well-written articles that challenge the usual way most electrical power system professionals think about our industry. As summarized in the “Guest Editorial,” our issue identifies key behavioral factors that must be considered by engineers and ways that we should respond to customer concerns.

The “In My View” column discusses empowering people to facilitate the transition to a more environmentally friendly
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future. The column and overall issue serve to stimulate further discussion among engineers and those in the social sciences and humanities.

**History**
Robert Barnett wrote an outstanding column on arc lighting systems for the “History” column. These remarkably sophisticated systems provided light through a variety of technologies from around 1885 through 1915. The column describes the types, design evolution, and maintenance of arc lights, which gave rise to the earliest distribution systems.

**Society Updates**
A note of appreciation to all IEEE Power & Energy Society (PES) candidates and congratulations to our newly elected leadership:

- President-Elect Frank C. Lambert
- Secretary Jessica Bian
- Treasurer Nouredine Hadjsaid.

In “Leader’s Corner,” Saifur Rahman, incoming PES president, describes the state of the Society and shares his vision of our future. Thanks to the leadership of our outgoing president Damir Novosel, our executive team, and you, our volunteers and membership, the largest global professional society of electric power professionals remains active and strong. The innumerable remarkable achievements, phenomenal growth of membership, and new initiatives provide a sound foundation on which our Society will continue to grow and reach ever-greater heights. The worldwide opportunities for growth of PES activities spans providing technical support to national governments, educational opportunities for our membership through publications available in several languages, attendance at conferences, and other opportunities for academia and industry to learn and grow together. The global focus on the technology, best practices, standards, education, and better customer engagement can only be accomplished through our membership. Please share your thoughts with our incoming leadership team and remain a part of the exciting global activities and initiatives.

This issue features a brief retrospective on the 2017 General Meeting. What a terrific conference! The sessions proved technically stimulating and extraordinarily informative. I truly enjoy seeing close friends and making new ones who share the latest technical innovations and ways of promoting the profession worldwide. It is my hope to see many of you at upcoming events.

**Thanks**
A special note of appreciation to Mel Olken, who continues to provide guidance and tutelage, and to IEEE Publications staff who make this publication possible. Thanks to the many contributors to this issue, especially our guest editors and authors. A particular note of appreciation to Associate Editor Hyde Merrill and Robert C. Henderson, who provide editorial assistance.

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Real-World Engineering

I was fascinated to read the article in the “History” column by Andrew Isaacs, “Simulation Technology,” in the July/August 2017 issue of IEEE Power & Energy Magazine (vol. 15, no. 4, pp. 88–102). One part of the article speaks directly to how engineering works in the “real world” and may deserve expansion and dissemination into the secondary school environment.

The section that caught my eye begins on p. 98, “Can It Simulate HVdc?” In summary, simulation engineers were challenged to analyze a transmission system using an advanced model with the best estimates of the parameters of the physical system. The simulation was unable to replicate an observed failure in the physical system, and so the engineers assembled a task force to find out why. They discovered that one of the input parameters to the model was incorrect, and when it was corrected, they observed that the model successfully replicated the failure. Realizing that this parameter in the physical system might be the cause of the failure, they worked backward from the model and made a change to the physical system that correlated to the model’s faulty input parameter. This resolved the problem in the physical system.

This is an important scenario to communicate to educators because it is an example of several features of real-world engineering.

This series of events “rings true” to my engineering experience. And this real-world example contrasts with the theoretical view of engineering, where somebody provides a clear set of requirements that lead, in linear fashion, to a product. The story here might be a good candidate for the eventual addition to a secondary school STEM or science curriculum as an example of how engineering really happens. It has a bit of an adventurous flavor!

—Douglas Hagerman

Storing Energy

I read with great interest the September/October 2017 issue of IEEE Power & Energy Magazine (vol. 15, no. 5), and congratulations on an issue devoted to electric energy storage.

The article “Grid-Level Application of Electrical Energy Storage” (by Zhang et al. on pp. 51–58) was of significant interest. As an electric power system engineer, working with pumped storage hydro, I would like to comment that, since the mid 1990s, the international fleet of pumped storage plants now includes a growing number of plants with adjustable speed doubly fed induction machines motor/generators, line commutated converter fed synchronous machines, and ternary pumped storage units.

—Peter Donalek

Editor’s Response

Interested readers can avail themselves of additional information about grid-scale, hydro-based storage in the report “Modeling and Analysis of Value of Advanced Pumped Storage Hydropower in the United States,” which is available at the following web site: http://ceeesa.es.anl.gov/projects/psd/ANL-DIS-14-7_Advanced_PSH_Final_Report.pdf.
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Chosen By The Top 40 Electrical Engineering Firms In The World.
As the IEEE Power & Energy Society (PES) president for 2018 and 2019, I would like to share with you where we are and where we plan to go as the largest global professional society of power engineers. Currently, we have over 37,500 members in our society, from 150 countries. This makes PES the second largest Society in the IEEE behind the IEEE Computer Society. However, in Latin America (Region 9), PES has the most members among all IEEE Societies.

We are not only global, we are also local. Our connections at the local level are our Chapters, which provide our grassroots contacts. PES now has 251 Chapters and 298 Student Branch Chapters in almost all the countries in which we operate. The student-run Chapters had phenomenal growth, rising from 134 in 2014 to close to 300 in just three years. Our PES Chapters are a great way to plug in to the Society in most parts of the world and get involved. Our local Chapters can provide networking opportunities to help grow your career, leadership development opportunities, mentoring for our PES Student Branches, tutorials and professional development courses, Distinguished Lecturer presentations, and a host of other benefits.

PES is also focused on public service, working with national governments to contribute technical support for policy development. For example, we worked with the U.S. Department of Energy in 2015 and 2016 and prepared technical support for their Quadrennial Energy Review. PES has also provided support to the U.S. Federal Energy Regulatory Commission and the North American Electric Reliability Corporation. Similar discussions are ongoing with the European Commission. We would be happy to engage with policy makers in South America, Asia, and Africa as well.

With about 70% of our members coming from industry and government, PES has by far the highest percentage of nonacademic members among all IEEE Societies. At the same time, the Society has one of the best participation by academics in our conferences, short courses/tutorials, journal publications, and member outreach activities.

PES publishes six technical journals and two magazines. In addition to hard copies, all of these periodicals are available online. One of the six journals, IEEE Power and Energy Technology and Systems Journal, is open access, and papers are practice oriented. Here industry engineers can publish their case studies, best practices, unique field deployment experiences, and lessons learned for the benefit of working engineers, who can access the material for free.

PES organizes over 30 conferences per year in more than 20 countries. Our flagship conference, the PES General Meeting, routinely attracts over 3,000 attendees who speak and participate in panel meetings, paper sessions, and committee meetings. We are cognizant that the General Meetings are almost always held in North America, which limits participation by our members from other parts of the world. To facilitate participation by such members, we hold our Innovative Smart Grid Technologies Conferences in Latin America, Europe, North America, and the Asia-Pacific regions every year. We also have many regional conferences, such as the PowerTech Conference in Europe, the Asia-Pacific Power & Energy Engineering Conference, and PowerCon in the Asia-Pacific region. We have recently started the annual Power Africa Conference series in Africa.

Under the leadership of 2016–2017 PES President Dr. Damir Novosel, the Society began focusing more heavily on corporate engagements. We have set up executive advisory committees (EACs) comprising industry executives from their respective regions. For example, we now have EACs in place in the United States, Canada, and South America. Similar committees are being formed in Europe/Middle East/Africa and Asia/Oceania. Their mission is to provide strategic support to the PES Governing Board with the goals of helping to provide more benefits to industry members, better communicating those benefits to the membership, and leading efforts to leverage those benefits in their respective organizations and for the overall industry.

PES is deploying significant resources for training and lifelong learning activities for our practicing engineer members. There are numerous short courses, webinars, and tutorials—both
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online and live—available for members throughout the world. We can also offer customized courses at the company level for engineers to be trained in a particular skill. To formalize various training and life-long learning opportunities, PES is in the process of establishing PES University under the IEEE umbrella. This will be a one-stop shop for members or groups of engineers as well as students and faculty to learn new technologies, processes, deployment experiences, and other innovative practices.

We fully understand that, due to time and resource limitations, many of our members cannot attend conferences where important best practices, breakthroughs, and technology deployment issues are presented. Video recordings of high-impact panel presentations, slides presented by experts, and relevant text materials are now being archived in the PES Resource Center for free or at a very low cost for our members.

To reach many of our members in non-English speaking countries, PES has started to offer some publications in other languages. For example, IEEE Power & Energy Magazine is now available in Spanish. Work is underway to provide Chinese content on the PES website. Chinese language publications are also being considered.

With these perspectives in mind, my vision, shared with the Governing Board, is to make PES even more relevant to the global working professional. To me, a working professional could be an engineer working at a power company or a consulting firm, a student studying to be power engineer, an administrator/policy maker trying to improve our daily lives, or a researcher pushing the frontier of the power engineering discipline. This requires focus on the technology, best practices, standards, education, and better customer engagement.

I know we do all of these now to some extent, but we need to be more focused about explaining to our members and others why we do what we do. As your president for 2018–2019, I would like to hear your suggestions, criticism, and advice. But most importantly, please remain engaged with your Society and ask your friends and colleagues to join.
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There are many different disciplines in social sciences and humanities, just as there are many different types of engineers.

Terms used are, among others, people, consumers, citizens, activists, or voters. While acknowledging the importance of the differences among these terms, reflecting different roles of individuals, the authors in this issue use people or consumers as umbrella terms for all sorts of roles of individuals, to avoid overly complicating the message.

This issue of IEEE Power & Energy Magazine contains five articles that all focus on the role of consumer behavior in energy research. The articles give engineers a sense of why it is important to understand consumer perspectives and behavior in energy systems. Common misunderstandings and simplifications are highlighted about why consumers respond or act in the way they do and how this may be changed. Comprehensive approaches to understanding consumer behavior and tools to change their responses and behavior are offered.

The first article by Steg, Shwom, and Dietz, “What Drives Energy Consumers?,” discusses how consumers may be encouraged to actively engage in a sustainable energy transition by targeting important drivers of their behavior and removing significant barriers for change. Drivers and barriers that are discussed include individual characteristics, such as knowledge, awareness, values, identity, and habits. Contextual factors are discussed: spatial, infrastructural, economic, and cultural factors; institutional arrangements; and access to technology, products, services, and information. Strategies to change consumer behavior are presented, including those aimed at changing the context and knowledge and motivation, and the added value of tailored approaches. Finally, the relationship between behavior change and quality of life is given.

In the second article, “Communication Is Key,” authors Abrahame, Darby, and McComas critically discuss three commonly used “fixes” of individuals’ behavior that may lead to environmental and energy problems. Each fix approaches consumer behavior in a different way and has different assumptions. The technological fix aims to modify the physical surroundings, which is assumed to lead to behavioral changes in line with these physical changes. Structural fixes attempt to modify behavior by changing the social context in which decisions are made, e.g., by implementing regulations. Cognitive fixes try to change people’s behavior by targeting cognitive factors that steer those behaviors, such as attitudes, beliefs, and values. The authors argue that none
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of these three fixes on their own are likely to solve energy-conservation challenges because consumer behavior is influenced by all three aspects. A combined approach, however, offers a greater probability of success in the long term, which is referred to as a sociotechnical approach.

The third article, “A Part of the Energy ‘In Crowd’” by Jans, Bouman, and Fielding, reasons that consumers are part of one or more social groups and that these groups influence their decision-making processes, attitudes, and behavior. The authors propose that social identities, i.e., a person’s sense of who they are based on his or her group membership(s), are crucial in this respect. Social identities will particularly affect energy attitudes and behavior when energy issues are an important part of one’s social identity and when individuals strongly identify with the relevant group. The authors contend that community approaches may be very promising in changing people’s energy behavior, followed by approaches focusing on individuals. To that end, the authors conclude that targeting values and norms in groups may be the basis for successful community-based interventions.

The fourth contribution is from van der Werff, Thøgersen, and Bruine de Bruin, “Changing Household Energy Behavior.” In this article, a common strategy to change consumer behavior is critically discussed: monetary incentives. The authors present when monetary incentives are likely to be effective and elaborate on three downsides of such incentives. First, when financial rewards (e.g., subsidies) are employed, the money saved may be spent in such a way (e.g., on energy-inefficient goods) that the system will not benefit, reflecting the so-called rebound effect. Second, incentives may be too small to be worth the effort and thus not motivate people to change their behavior. Third, monetary incentives may lead to crowding out intrinsic motivation, which means that other (intrinsic) motivations to support a reliable sustainable energy system may be undermined.

The articles give engineers a sense of why it is important to understand consumer perspectives and behavior in energy systems. The articles give engineers a sense of why it is important to understand consumer perspectives and behavior in energy systems.

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and, as a result, such incentives may not be effective and may even be counterproductive. The authors then present alternative strategies to change the behavior of energy consumers and discuss how and when monetary incentives may strengthen or undermine these strategies.

In the final article, “At the Heart of a Sustainable Energy Transition” by Perlaviciute, Schuitema, Devine-Wright, and Ram, the authors contend that public engagement and acceptance are crucial for realizing sustainable-energy projects. They argue that misguided, inaccurate, and simplified assumptions about public acceptability often lead to ineffective policies that lack public support. Various misperceptions of policy makers and engineers are discussed, such as interpreting all public resistance to energy projects as a not-in-my-backyard response and assuming that financial incentives or information provision will always enhance public acceptance. The belief that initial resistance to change will automatically be overcome when changes are made is debated. Finally, the idea of a one-size-fits-all approach is critically discussed. The authors state that public acceptance depends on the characteristics of energy projects, the qualities and meanings of places where projects are sited, and general psychological and social factors. Taking such different factors into account, they outline concrete steps for progress, alternative approaches that take public acceptability as a necessary and valuable building block for the development of energy projects.

The issue concludes with an “In My View” column by Gerd Schönwälder from the European Commission, who makes the case for empowering people and putting them at the center of the new, greener energy system of the future. He discusses why empowering people is needed, which knowledge gaps and research challenges are out there, and why they need to be addressed. In his role in the European Commission, Schönwälder works on embedding socioeconomic aspects of the transition to a decarbonized energy system in EU policy directions.

We hope that this issue of IEEE Power & Energy Magazine will broaden your horizon and, most of all, stimulates debate among engineers, social scientists, and humanists.

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What Drives Energy Consumers?

By Linda Steg, Rachael Shwom, and Thomas Dietz
Providing clean, safe, reliable, and affordable energy for people everywhere will require converting to an energy system in which the use of fossil fuels is minimal. A sustainable energy transition means substantial changes in technology and the engagement of the engineering community. But it will also mean changes in behavior and policies and, thus, will require the engagement of the social science community. The choices, preferences, and behaviors of individuals and households are major direct influences on energy demand, and they also shape the acceptability and effectiveness of technologies, strategies, and policies to bring about a sustainable energy transition. A successful transition to a more sustainable energy system will require a wide range of sustainable actions by diverse people across the globe.

In this article, we discuss how to promote the active engagement of people in a sustainable energy transition. We propose that efforts to encourage sustainable energy behavior change will be more effective when they target important drivers of relevant behaviors and remove significant barriers to behavioral change. In addition, it is essential to examine how behavior and lifestyle changes impact individuals’ quality of life. We first discuss different types of behavior that can promote a
Behaviors That Contribute to a Sustainable Energy Transition

A sustainable energy transition is characterized by a system that uses less energy overall and is made up of an increasing proportion of renewable energy. This is a technological problem, but it is also a behavioral problem since it requires the adoption of a wide range of sustainable energy behaviors. Such behaviors include the adoption of renewable resources, e.g., solar power (Figure 1); the implementation of resource-efficiency measures in buildings, such as insulation; the use of more sustainable technologies both large (electric vehicles, as in Figure 2) and small (energy-efficient domestic appliances or low-flow shower heads); technology maintenance, such as changing heating, ventilation, and air-conditioning (HVAC) air filters; and energy-saving behaviors, such as reducing room and water temperatures and line-drying laundry (Figure 3) and walking, cycling, or using public transportation rather than driving (Figure 4). To have maximum impact, policies and programs could first target those behaviors with a substantial potential for reducing fossil energy use. Identifying such high potential targets requires considering both the elasticity of the change (i.e., how much reduction in emissions will occur if the change happens) and the plasticity of the behavior (i.e., likelihood that the targeted behavior will be adopted). As Table 1 demonstrates, sometimes behaviors that could have large impacts if adopted may not be the best starting points for policy because they are hard to change. Even as the low-hanging fruit of behaviors with high plasticity and elasticity are targeted, policies and institutions can be developed that promote and facilitate further changes in behavior required to enhance the sustainability of energy systems.

The adoption of sustainable and resource-efficient technology typically results in higher reductions in energy use and greenhouse gas emissions than changes in daily user behavior, even though daily behaviors may seem easier to change. Moves toward more efficient technology have the

![figure 1. The adoption of renewable energy sources: solar panels [By Pujanak (own work, in the public domain), from Wikimedia Commons.]]

![figure 2. The adoption of sustainable technologies: electric vehicles (Pixabay.)]

![figure 3. Energy-saving behavior: drying clothes outdoors on the line. (Pixabay.)]

![figure 4. Energy-saving behavior: taking the train instead of driving. (MaxPixel.)]
added advantage of demonstrating to consumers that their efforts are rather effective, at least when savings are visible to the adopter. Although initial financial investments may be needed, technology adoption requires little additional effort or inconvenience once put in place. This is in contrast to changing daily user behavior, such as lowering the thermostat or taking shorter showers, that have to be undertaken repetitively and can be perceived as inconvenient. The general point is that different types of behaviors, such as adopting new equipment, maintenance, and changes in daily actions, can have different drivers and obstacles.

The timescales of behavior changes matter. Some changes may be implemented immediately, such as taking shorter showers, unplugging appliances, and cycling or walking short distances. Other changes require more time. Replacing technology or household retrofits require planning and substantial investment in time and money and may be most readily accomplished at certain critical transition periods, such as when a building is sold. Decisions on household energy retrofits are more likely made when people buy a house because, at that time, other work is usually being done, the costs of energy investments seem relatively small compared to other expenses, and there is often a period when the dwelling is unoccupied, making it easier to do intrusive work.

In addition to timescales, it is also important to consider whose behavior is most influential in making particular decisions that affect fossil energy use. For example, water heaters are typically replaced when the old one begins leaking, and, generally, the replacement is what the plumber brings. So it is the decisions of plumbers and plumbing wholesalers that have the most effect on water heater efficiency as consumers tend to rely on their expertise. Real estate agents can also provide information and shape expectations around efficient and green energy technologies in the housing market.

In addition to being consumers, individuals can also take actions in their role as citizens and as members of organizations. In both of these roles, individual behaviors can have a substantial impact on fossil energy use. Political behaviors can influence the adoption of specific policies. In addition, the public can have strong reactions to both technologies and the siting of energy facilities, which may inhibit their implementation (Figure 5; see also Perlaviciute et al., this issue, for a discussion on public acceptability). Sustainable energy behaviors in organizations, including businesses, governments, and nonprofits, can have a long-lasting and significant impact on reductions in fossil energy use as well, not only by affecting direct fossil energy use within the organization but also via the energy efficiency of products and services offered to their customers and clients.

A sustainable energy system will require the wide-scale adoption of many kinds of behaviors, including resource-efficient technology. Therefore, it is important to consider how changes in different types of sustainable energy behaviors influence one another. It is possible to have positive spillover effects, in which a few initial steps lead to a further commitment to sustainable behaviors. Positive spillover effects may come from learning that such actions are easy, feeling efficacious, feeling satisfied with having taken the initial steps, or developing an identity as someone who engages in such behaviors. It is also possible to have negative spillover effects, in which undertaking a few sustainable behaviors discourages further actions. Negative spillover may happen when people feel licensed to not act sustainably because they already did their bit or when they use financial savings realized in ways that are fossil fuel intensive; the latter is known as the “rebound effect” (see van der Werff et al., this issue).

Table 1. Examples of elasticity and plasticity of sustainable energy behavior changes.

<table>
<thead>
<tr>
<th>Sustainable Energy Behavior</th>
<th>Elasticity (Potential Emissions Reductions with 100% Adoption, in MtC)</th>
<th>Plasticity (Estimated Adoption Percentage from Effective Programs, in MtC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car pooling and trip chaining</td>
<td>36.1</td>
<td>15</td>
</tr>
<tr>
<td>Weatherization</td>
<td>25.2</td>
<td>90</td>
</tr>
<tr>
<td>Changing HVAC air filters</td>
<td>8.7</td>
<td>30</td>
</tr>
<tr>
<td>Low-rolling resistance tires</td>
<td>7.4</td>
<td>80</td>
</tr>
<tr>
<td>Water heater temperature</td>
<td>2.9</td>
<td>35</td>
</tr>
<tr>
<td>Low-flow shower heads</td>
<td>1.4</td>
<td>80</td>
</tr>
</tbody>
</table>

Note: 1 Metric tons of carbon. Data from Dietz et al. (2009), for U.S. households. More detailed information can be found in Dietz et al. (2009).

Figure 5. The public can have strong reactions to the siting of energy facilities. (By Mark Dixon from Pittsburgh, PA (CleanEnergyMarch-5-1470215) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons.)
A successful transition to a more sustainable energy system will require a wide range of sustainable actions by diverse people across the globe.

Factors Influencing Sustainable Energy Behavior
Efforts to encourage sustainable energy behaviors will be more successful when they target important drivers of such behaviors. These include both individual factors, such as values, identity, beliefs, and norms, and features of the contexts in which individuals act, such as access to information, financial circumstances, and social network connections. Understanding these influences on behavior is essential to designing successful sustainable energy programs and policies.

Individual Factors
A first step for any change toward more sustainable energy behavior is that individuals must be aware of how they use energy and what changes may lead toward greater sustainability. Energy use is rather invisible, and people have only a limited understanding of the impact of their actions. Most people underestimate the effect of changes that have large impacts and overestimate the effect of changes that have small impacts because of a well-understood phenomena: judgments are made relative to a reference point (say the energy used by an incandescent light bulb), and people tend to underestimate the difference between the reference and other energy uses. This is one of many simple heuristics used to assess energy use, and such heuristics are not always accurate. So people may lack the information to behave effectively.

Yet while knowledge is important, it is seldom sufficient. Motivational factors play a key role. Of particular interest are general motivational factors that can affect a wide range of behaviors, making them an important target for promoting consistent sustainable energy behavior. Values are among the most important general motivational factors influencing energy behaviors. Values are defined as the general goals that people strive for in their lives, and there are four types most relevant to understanding sustainable energy behavior. Hedonic values make people focus on what makes them feel good and on ways to reduce effort, while egoistic values make them focus on how to increase their resources (e.g., money or status). People focus on ways to benefit others in altruistic values, while biospheric values make them focus on consequences for nature and the environment. People around the world endorse all four types of values to some extent. Yet people prioritize these values differently, resulting in different perceptions, preferences, and actions. In general, strong hedonic and egoistic values inhibit sustainable energy behaviors that are often perceived to be somewhat personally costly, inconvenient, or burdensome. In contrast, strong altruistic and particularly biospheric values generally encourage sustainable energy behaviors. While values are a powerful force motivating sustainability behavior, they are hard to change. The extent to which different values are activated in a particular context may change more readily, which affects the extent to which the relevant values influence choices. We come back to this issue later on.

Personal identity, another general motivational factor, may be especially important in promoting consistent engagement in sustainable energy behaviors because of the positive spillover effects referred to previously. When people realize that they engaged in sustainable energy behavior, they are more likely to see themselves as a person who acts pro-environmentally (i.e., to have a strong environmental self-identity), which motivates them to act sustainably again since people are motivated to be consistent and act in line with how they see themselves. Such a positive feedback process is likely to be very important in the transition to a sustainable energy system.

There are many factors in addition to values and identity that influence sustainable energy behaviors. Of course, prices affect energy behaviors. For example, the low price of fossil energy and the market’s inadequate integration of environmental costs is one reason people do not conserve energy or switch to renewables, while relatively high prices of sustainable energy innovations can inhibit their adoption.

However, prices are not always as influential as many assume. Many factors motivate people to reduce the use of fossil energy that often predict sustainable energy behavior more strongly than the perceived financial costs and benefits of actions. These include environmental and moral considerations: people may act sustainably because they are motivated to protect the environment and the quality of life of current and future generations. They may engage in sustainable energy behaviors because doing so makes them feel good, either because it is pleasurable or they feel good by being virtuous when engaging in behavior that benefits others and the environment. They may engage in sustainable energy behavior for symbolic reasons: doing so may enhance their social status or fit with how they would like to see themselves. Furthermore, they may act sustainably because of social norms: they think others expect them to do so, or they think most others would do so as well.
It is particularly important to enhance intrinsic motivation so that people voluntarily engage in sustainable energy behavior over and again, without external pressure.

It is useful to differentiate intrinsic from extrinsic motivation. Intrinsic motivation comes from within the individual (e.g., rooted in values and identity) and is driven by internal rewards, satisfaction, or fulfillment. Intrinsically motivated people behave without being coerced and without receiving external rewards because acting morally and doing good makes them feel good and thus yields intrinsic rewards. Intrinsic motivation can be long lasting and self-sustaining. Alternatively, motivation can be extrinsic, done for the sake of some external outcome, such as social pressure or financial consequences. Generally, extrinsic motivation is not a stable source of sustainable energy behavior.

When behavior is motivated by social norms or rules, people may only engage in the relevant behavior when there is a high chance of being socially rewarded or sanctioned. Highly visible behaviors like driving an electric vehicle or installing residential solar can be socially rewarding, but less visible behaviors like installing an efficient air-conditioner or curbing its use would be less visible and less likely to be socially rewarded. Therefore, it is particularly important to enhance intrinsic motivation so that people voluntarily engage in sustainable energy behavior over and again, without external pressure. It may be possible to design programs and policies that engage both intrinsic and extrinsic motivation, for example, by clearly linking an extrinsic incentive to an environmental goal, but care must be taken that the latter does not drive out the former.

Research shows that people do not always carefully consider the costs and benefits of their actions. People can act habitually, without making a conscious decision. They can follow quick cognitive shortcuts in making decisions rather than thinking through the implications of their actions. Habits and decision-making shortcuts are functional, as individuals cannot possibly consider all the costs and benefits of every action. Furthermore, individuals face the same choices repeatedly, so it would not be efficient to reconsider every time they must act. Once habits are formed, change requires making people aware of the consequences of their habits and undeliberated choices by employing strategies that create the opportunity for reflection and encourage an active decision.

**Contextual Factors**

Contextual factors include spatial and infrastructural, economic, and cultural factors; institutional arrangements; and access to technology, products, services, and information. On the one hand, such contextual factors may affect behavior directly by influencing the opportunities and constraints people face and defining the cost and benefits of different actions. For example, solar panels are easy to install on some houses but may not be very feasible for others. Contextual factors also define the financial costs, time and effort, convenience, and the social approval and disapproval of behaviors. These factors can vary across social groups and affect the equity effects of sustainability policies. For example, income tax rebates for energy efficiency may provide little benefit to low-income households that do not have sufficient funds to make the initial investments and then wait for rebates. Renters can change immediate consumption by adjusting thermostats and water temperatures, but they are not in a position to buy a more energy-efficient furnace or water heater.

In addition to making behaviors harder or easier to carry out, context can encourage individuals to focus on particular consequences of choices. Advertising and product labeling help frame decisions by reminding people of their values and the relationship between those values and particular behaviors. For example, environmental symbols on products may remind people of their biospheric values, making these values more influential in decision making than they might otherwise be. Similarly, materialistic symbols (e.g., price) may remind people of their egoistic values.

**Strategies to Promote Sustainable Energy Behavior**

Policy to encourage sustainable energy behaviors will be more effective when important drivers of the relevant behavior are targeted and significant barriers to change are removed. As outlined earlier, there are many forms of sustainable energy behaviors, many individual factors that influence them, and a variety of both broad contextual factors and context-specific framings all at play in shaping energy choices. Accordingly, many different strategies can be followed to encourage sustainable behaviors of different groups, targeting relevant individual and contextual factors. We will discuss key strategies later. Policy can be aimed at rewarding or facilitating sustainable energy behavior (pull measures or carrots) or punishing or inhibiting undesired behavior (push measures or sticks), and the related behavior change can be more or less voluntary or imposed. Push measures that impose behavior change can be effective but generally meet more public resistance than pull measures and policy motivating voluntary change.
Efforts to encourage sustainable energy behavior change will be more effective when they target important drivers of relevant behaviors and remove significant barriers to behavioral change.

**Changing the Context**
A key first step in policy design is identifying what constraints people face and how behavior change can be facilitated. Often designers of a policy or new technology are not aware of the constraints and concerns of people. So careful evidence-based diagnosis is necessary since intuition about barriers to behavioral change may not be correct. This suggests that those designing programs and policies and developing new technologies should directly engage with interested and affected parties and understand which factors influence the relevant behavior. Such direct engagement can help build mutual understanding and trust and lead to more effective policies. As part of this effort, governments and organizations need to be transparent and accountable when implementing energy policy.

External incentives can be useful to motivate and enable people to engage in sustainable energy behavior by lowering the barriers to action. For example, infrastructure changes such as dedicated bicycle lanes, better public transport infrastructure, or closing off areas to private car traffic may promote sustainable transportation. Likewise, the production and sale of energy-saving products can be regulated (e.g., a legally mandated phase out of incandescent lightbulbs or fleet fuel-efficiency standards).

Another common external incentive is pricing policy, including subsidies, rebates, and taxes. The common understanding is that such pricing policies are rather effective to promote sustainable energy behavior because people are strongly motivated to save money. Well-designed financial incentive programs can be effective when they help overcome financial barriers, such as initial costs of investments in energy-efficient technology or retrofits, which is especially important for programs and policies to have a positive impact on the less affluent. Yet responses to pricing policies are often not as great as might be assumed, suggesting care must be used in using prices as a policy instrument. Notably, as indicated earlier, many other motivations affect behavior besides financial costs and benefits. Moreover, in many cases, financial incentives to promote sustainable energy behavior yield small financial gains, partly because energy is rather cheap, making behavior change seem not worth the effort.

The effects of financial incentives strongly depend on nonfinancial factors, such as the ease of participating in a program or marketing efforts. Besides, financial incentives, an extrinsic motivation can crowd out intrinsic motivation to engage in sustainable energy behavior. It may even give the impression that one can buy the right to pollute; people no longer feel guilty when acting in environmentally unfriendly ways as they have paid for doing so. As a result, financial incentives may even increase the behavior that was intended to be minimized because people think they have “paid for it.” Of course, it is possible to buy “carbon offsets” to compensate for emissions. The concern is that the psychological effects of monetization might increase emissions even when no offsets are actually in place.

Extrinsic incentives, such as prices and regulations, are often only effective while they are in place. When the incentive is removed or the chance of being caught and sanctioned is seen as low, people may revert to previous behaviors. In some cases, however, extrinsic incentives can result in long-term behavior changes, even after the incentive is removed. Such effects are particularly likely when incentives motivate people to try out the behavior, and they find that the behavior appears to have more beneficial and fewer negative consequences than anticipated, or when new habits have been formed. There is some evidence that incentivizing a behavior for a moderate time period can lead to more positive evaluations and long-term increases in the behavior.

**Changing Knowledge and Motivations**
Since many people remain unaware of the links between their energy behavior and critical sustainability issues, it is often useful to provide information about the need for and urgency of a sustainable energy transition and the significance of their actions for sustainability. Such information would enable people to act upon their intrinsic motivation to protect the environment. Information on the environmental impact of different behavior options can often be provided in simple ways, such as via “green” product labeling. Information on costs and benefits of different behaviors will be particularly effective when people start with inaccurate perceptions of such costs and benefits, when such information is from a trusted source and offered at a time and place close to decisions. While information provision is important, it is seldom sufficient since decisions inevitably are based on more than just knowledge. So effective approaches to changing behavior have to avoid the “information deficit” fallacy, assuming that if members of the public had the same information as professionals, their behavior would change.
Many factors in addition to price and economic self-interest motivate people to engage in sustainable energy behavior.

Yet providing feedback on one’s behavior or environmental performance has proven to be effective in encouraging sustainable energy behavior, particularly if it is provided frequently and immediately after or even while the behavior occurs. Comparative feedback, where one’s behavior is compared to the behavior of others, also can be effective at encouraging sustainable energy behaviors, especially when people learn that others act more sustainably than they do (as people are motivated to act in line with the norm) and when the comparison group is similar to the receiver (as this provides a more credible reference point).

Strategies can take advantage of the human desire to be consistent, and acting in line with previous statements or actions will strengthen their intrinsic motivation to act sustainably. For example, people are more likely to engage in sustainable energy behavior when they explicitly set the goal to do so, particularly when combined with feedback so that they learn to what extent their goals have been achieved. Commitment strategies, where people make a private or public statement to engage in particular sustainable energy behavior, and implementation intentions, where people additionally indicate how and when they will engage in the relevant behavior and how they will deal with possible barriers, have resulted in long-term behavior changes. Alternatively, people can be made aware of their previous sustainable actions, which will make them realize that they are a person who acts sustainably, thereby strengthening their environmental self-identity. This can provide intrinsic motivation to act in line with this identity in subsequent situations. This also suggests that emphasizing that a person is not yet doing the right thing might weaken his/her environmental self-identity and inhibit consistent sustainable energy behavior.

Behavior modeling, that is, having peers demonstrate sustainable behavior, can also be effective. It both invokes social norms and shows how to carry out a behavior. This suggests that network effects will matter—knowing people similar to you are carrying out a behavior builds on norms and provides information about how to proceed. Community or block-leader approaches, where local volunteers initiate and deliver an intervention program in their neighborhood, build on this logic. Such strategies seem most effective when people have strong ties with their community; people tend to have higher trust in and are more easily persuaded by people who are perceived to be similar to them, such as their neighbors, rather than outsiders.

Tailored Approaches
It is important to remember that one size does not fit all. Different individual and contextual factors may affect the sustainable energy behaviors of different groups. Thus, tailored approaches are called for, taking into account individual and sociocultural differences and targeting key factors motivating or inhibiting the behavior of the relevant people. As noted, a program targeted toward homeowners may have no impact on renters, and a program based on tax rebates may not be effective for those who cannot bear up-front costs. Information that takes into account the opportunities faced by and the motivations of different individuals appears to be more effective than generic information. For example, information about sustainable energy decisions can be framed in a way that is congruent with values, making it more likely that those who strongly endorse the relevant values will act accordingly.

There is considerable evidence that people are more likely to take up new information that is compatible rather than in conflict with their core values and existing beliefs. So for those who give priority to biospheric values, climate change messages may be effective, while for those who give priority to self-interest, information about financial savings may be more influential. While in mass marketing one would have to include both messages, marketing via social media and other social networks can target specific value implications to specific audiences. Information also can be tailored to the circumstances faced by an individual, so that people only receive information on the most effective options for them, thus insuring salience and reducing information overload. It is crucial to remember that constraints are typically not equitably distributed. Hence, policies have to be attentive to the needs of those who are struggling and empower them to engage in sustainable energy behavior.

It is important to carefully evaluate the effects of strategies to promote sustainable energy behavior. Evaluation programs should not only examine the effects of interventions on energy behavior in the short as well as the long term but also consider why interventions were effective (or not) by studying changes in drivers of behavior. Such insights are important to enhance our understanding of the successes and failures of intervention programs. Furthermore, it is important to compare those who receive an intervention program with a control group who did not participate in the program to be confident that any changes observed were caused by the intervention rather than other factors that may have changed at the same time.
Sustainable Energy Behavior and Quality of Life

The motivation for moving to a sustainable energy system is driven largely by two concerns. One is to protect the environment and the biosphere. The other is to enhance human well-being. There are inherent ethical reasons for protecting the biosphere, but it is also clear that reducing environmental problems such as anthropogenic climate change is of benefit to humans. However, many perceive that the current fossil-fuel energy system enhances quality of life for the majority of the world’s population and presume that behavior changes needed to achieve a sustainable energy transition will threaten rather than enhance human quality of life as such behavior is seen as requiring greater financial expenditures, more time, more hassle, and less comfort. For example, traveling by public transport is seen as less pleasurable than traveling by car, and turning down the heat or air-conditioning can make a home less comfortable. Some of these perceptions are influenced by how society defines social ideals such as “home.” If a good home is normatively defined as a roomy stand-alone house in the suburbs, moves toward sustainability, such as living in a smaller attached home closer to the city, will be perceived to entail a lower quality of life.

Various sustainable energy behaviors may enhance an individual’s quality of life. For example, most shifts toward higher energy efficiency have substantial economic benefits both to households and nations. Moreover, sustainable technologies, such as light-emitting diode lights or mass transit, can be designed to match hedonic expectations.

More importantly, these examples reflect a limited view of what constitutes a good life. Sustainable behaviors may not only be pleasurable as reflected in the examples above (enhancing hedonic well-being) but also meaningful (enhancing eudaimonic well-being, that is, meaning in life and self-realization). Sustainable energy behaviors are a potent source of eudaimonic well-being; such behavior benefits nature, the environment, and the well-being of others, including future generations. Indeed, acting sustainably is perceived as virtuous behavior, leading to a positive self-image, which yields positive feelings and enhances quality of life. The relationship between energy sustainability and hedonic and eudaimonic well-being deserves more research, especially around ways to design a sustainable energy system that enhances well-being.

Summary

The current fossil energy system is in transformation. This is not only a technical problem that will challenge engineers but also a problem of human behavior that will challenge social scientists. Interdisciplinary collaborations are required: the technologies that will be most effective at driving the energy system toward sustainability are likely to be those that use knowledge from both engineering and the social sciences. Key elements of design criteria could take into account factors facilitating the adoption and effective use of the new, more sustainable technology. Such design would take into account not only the elasticity of the technology—the reduced use of fossil fuels that will come with it—but also its plasticity—the features that will assure its support and rapid uptake by the public. Such designs will require new forms of collaboration between engineers and social scientists.

Significant and wide-scale changes in behavior are needed to achieve a sustainable energy transition. People acting as consumers affect the uptake of efficient and renewable energies, technologies, and overall energy use. As citizens, they play an important role in supporting the implementation of policies that aim to encourage sustainable energy behaviors. Efforts to encourage behavior change for a sustainable energy transition will be more effective when they target important individual and contextual factors of relevant behaviors and remove significant barriers to new ones.

We can enable sustainable behaviors by changing the context for actions so that the costs and barriers for action are lowered. At the same time, we can encourage behaviors by targeting individual factors influencing behavior, including knowledge and motivations. Many factors, in addition to price and economic self-interest, motivate people to engage in sustainable energy behavior, including environmental considerations, affect, status and identity considerations, and social norms. The approaches used will be more effective when they are tailored to the motivations and constraints of those being asked to change. Sustainable behavior and lifestyle changes, particularly when such changes are mandated, should enhance rather than degrade individuals’ quality of life. Acting sustainably can enhance quality of life as people feel meaningful when engaging in behavior that benefits others and the environment.

For Further Reading


Biographies

**Linda Steg** is with University of Groningen, The Netherlands.

**Rachael Shwom** is with Rutgers University, New Brunswick, New Jersey.

**Thomas Dietz** is with Michigan State University, East Lansing, Michigan.
SCIENTISTS ARE NOW MORE CERTAIN THAN EVER that humans are responsible for climate change through the combustion of fossil fuels. A recent Global Energy Assessment report, compiled by the International Institute for Applied Systems Analysis, indicates that, globally, domestic energy consumption accounts for about a quarter of global greenhouse gas emissions. A fundamental shift in energy consumption is needed, moving away from the use of fossil fuels to meet emission reduction targets.

Energy consumers can make important contributions to reducing emissions by adopting efficiency and curtailment behaviors. Efficiency behaviors are actions or measures that result in less energy being used for a given level of energy service (e.g., insulating a building and installing light-emitting diode bulbs). Curtailment behaviors are actions that result in less energy service (e.g., lowering thermostat settings and switching off lights). Efficiency behaviors typically involve the one-off purchase and installation of an appliance or device and imply a financial cost (e.g., home retrofits and energy-efficient appliances), whereas energy curtailment behaviors tend to be low or no cost but need to be done frequently to achieve energy savings (e.g., the previously

By Wokje Abrahamse, Sarah Darby, and Katherine McComas

Communication Is Key

How to Discuss Energy and Environmental Issues with Consumers
mentioned activities of lowering thermostat settings and switching off lights) and can involve the loss of associated amenities (e.g., less heating and lower lighting).

Research has shown that behavioral changes are a key element in reducing greenhouse gas emissions through energy conservation. Research also indicates that it is difficult to encourage the adoption of energy-conservation behaviors. Commonly used policy instruments such as the provision of information, technological innovations, and financial incentives have had mixed success and uptake. For example, the demand response by end-use consumers in response to electricity price increases is not always in line with what economic models would predict.

The social sciences have much to offer in terms of providing insights about how to communicate with energy consumers to reduce energy demand, and recent decades have seen increasing recognition of the fundamental role that social sciences play. This article briefly outlines key areas where social science research provides such contributions, including interventions and policy instruments that are often used to encourage consumers to change their behavior: the role of technological innovations, the use of incentives, and the provision of information and feedback. We then describe how a sociotechnical approach can better communicate with energy consumers to reduce energy demand.

**Three Fixes for Environmental Problems**

Environmental sociologist Thomas Heberlein writes about “three fixes” that can address environmental problems: technological, cognitive, and structural. Each of these fixes has a different way of approaching human behavior change. Technological fixes, such as motion-sensor lighting in the case of energy use, try to bypass the human element by modifying the surroundings instead of changing people’s behaviors or changing social structures. Structural fixes, such as fuel-efficiency regulations or reduced pricing for solar panels, try to modify human action by regulating the social setting or “structures” in which these actions occur. By changing the context in which people make decisions, people’s choices are assumed to change (e.g., a higher uptake of solar panels due to a lower up-front cost). Cognitive fixes, such as information campaigns geared toward connecting an individual’s energy use with greenhouse gas emissions, directly attempt to modify human behavior by targeting the attitudes, beliefs, and values that affect those behaviors. Figure 1 provides an illustration of these fixes, and next, we reflect on some of the thinking behind them and explain why none of them, alone, sufficiently addresses energy conservation needs.

**Can a Technological Fix Save the Day?**

The prospect of technological fixes to solve energy problems is certainly enticing, and there are plenty to choose from. While the most striking examples of technological fix thinking may be associated with nuclear fusion or carbon capture and storage, we can also see it in the energy-efficiency literature when technical advances are seen to offer the main hope of a sustainable energy future and in much of the smart grid, building automation, and autonomous vehicle literature.

But it is striking how rarely (if ever) technical “solutions” work as planned. For example, households with programmable thermostats can use more heat energy than those without, and there is evidence that only a minority of householders with central heating fully understand their controls, let alone use them in the way intended by the designers. One response to this situation is to try to edit out human misunderstandings/shortcomings through automation and ever-purer technical fixes. Yet automated energy management raises concerns about the additional energy and materials required for the sensors and associated hardware and also about what happens when a system fails or is hacked. In technology, as elsewhere, one solution is likely to generate another problem, and any dream of a big technical fix for complex energy and climate dilemmas is not realistic; any technical fix is likely to have unpredictable emergent effects.

For this reason, a more promising alternative to the technical fix is a “technical and…” approach that recognizes and embraces complexity and pays attention to communicating how and why technology works. As sociologist Elizabeth Shove notes, “Technical change is an unremittingly social… process” and one that takes place in particular times and places. It is in these times and places that (to return to our theme of communication) technology has to be communicated or to communicate itself. A simple piece of energy technology like an open hearth and chimney tells its own story and needs only basic skills to operate successfully. A modern wood-burning stove or a heat pump will be more efficient but more complex, and a heat pump will need a reliable electrical infrastructure.

Examples of the communication we often take for granted in modern energy systems are the electricity flows themselves between switches, billing systems, monitoring and alarm systems, traffic signals, and appliance efficiency labels that send “messages” we can read in the design of buildings and transport systems. You can work by daylight here but not there, or charge your vehicle faster if you pay a higher price in this place; here is a cool room for food storage, and there is an outdoor space for drying laundry.

Often a building gives away little about what is going on inside it in terms of energy flows. Pipes, wires, and radiators are painted over or hidden. The small lights and digital clocks

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**figure 1.** A visual display of approaches to communicate with energy consumers (modeled after Heberlein, 2012).
Energy consumers can make important contributions to reducing emissions by adopting efficiency and curtailment behaviors.

that indicate standby consumption are easily disregarded. Radiant heaters, gas fires, and lights may provide visible and tangible services but are fed from invisible sources. So it is all too easy for occupants of most modern buildings to have only a slight understanding of how gas and electricity are used in their home or workplace. Only consumers who rely on solid or liquid fuels, those who are not on an electricity grid, or those on prepayment meters have finite sources of energy services; only those in passive houses are able to do without fuel (though probably not without electricity). The rest rely on supplies of gas, district heat, and electricity that are purchased on credit and pour invisibly through pipes and wires. Problems with overconsumption are partly due to people depending on technologies that do not communicate well how much energy they are using and that do not give the sort of feedback that can guide them toward using less. A useful comparison can be made with the fuel gauges in automobiles, especially those in hybrid vehicles that show consumption and battery status in near real time.

One more communicative factor worth considering in relation to "technical and..." approaches is the communication needed to train the people who design, regulate, and operate buildings, vehicles, machinery, appliances, and infrastructure. If there is a serious mismatch between expert designers and inexpert users, we cannot expect good environmental outcomes, no matter how environmentally sound the intentions of either or both of these groups. Any new technological development has a social dimension, and the outcomes will depend on how the technology is conceived (such as were the users involved in the design), communicated, and understood. A combination of intuitive design, information, expertise, and informal learning through experience can address the social dimension effectively. The role of "middle actors" in energy systems, people who act as bridges or guides between producers and consumers, experts and nonexperts, technicians and lay people, owners and tenants, is attracting increasing attention. Effective communication with consumers may involve several channels: technology design itself, direct communication through messaging, and indirect communication via middle actors and informal networks.

Structural Influences on Human Behavior

The good news, as indicated previously, is that there are possibilities for bringing about lower-impact energy outcomes, once we stop expecting technology to do all or most of the work of addressing complex problems. This includes addressing individual attitudes, i.e., the aforementioned cognitive fix, and the social, political, and cultural structures surrounding individuals, i.e., the structural fix. A critique of technical and technical-economic models is offered by sociologist Loren Lutzenhiser as a springboard for proposing that research be expanded to include (among others) institutions, networks of actors in energy systems, and social practices. An analysis that includes more social and organizational understandings of energy systems can help us understand how smart grid development may have very different impacts on carbon emissions in different countries, depending on factors such as patterns of demand, efficiency programs, tariffs, and arrangements for demand-side response. Behavioral, organizational, and technical dimensions of change occur together and can be addressed together.

Price Signals

One example of a structural fix in the domain of energy conservation is price signals, which aim to make energy-efficient choices more financially attractive or, conversely, make energy inefficient choices more expensive. The use of price signals can take various forms, for example, via a subsidy on energy-efficient appliances at the point of sale or by providing a rebate after purchase or a subsidy on home-retrofit products. These are intended to encourage energy conservation through rewarding energy-efficient consumer choices. Taxation or price hikes, on the other hand (e.g., a carbon tax or peak versus off-peak price tariffs), make energy-inefficient choices less attractive. In this sense, pricing policies change the relative costs and benefits, which is assumed to guide behavioral choices of energy consumers.

Pricing is generally an effective way to change behavior. But the effectiveness is not always as strong as sometimes assumed, and often the effect is short-lived. When energy prices rise, energy consumers can respond to this hike by reducing electricity demand; but energy consumption levels tend to revert to previous levels when prices fall (see also van der Werff et al., in this issue). Research findings also suggest that when higher tariffs are introduced for electricity consumption during peak hours, energy consumption can then simply shift toward off-peak hours, while overall energy consumption levels do not necessarily change. Consumer education, feedback, and enabling technology can improve the situation: it is the nature of a program, rather than a simple pricing fix, that determines the outcomes.

Energy consumers are likely to differ in the extent to which their choices are determined by pricing. Price signals may work better for consumers who are mostly driven by extrinsic motivations (e.g., rewards and incentives). But consumers who are more strongly intrinsically motivated (e.g., by environmental concerns) may be less persuaded by price signals to change
energy-consumption choices. For example, when a group of employees in a Dutch environmental organization were given a financial incentive to start saving energy (e.g., by switching off their computer screen during a lunch break), they ended up saving less energy in comparison to a group of employees who had been given a social reward (e.g., social recognition of their efforts to save energy). What might explain this finding? One possibility is that the financial incentive may not have been high enough (and perceived to not be worth the effort). Another possibility is that the reward did not align with employees’ main reasons for saving energy. Giving a financial reward may have reframed the situation: saving energy was no longer a moral choice (i.e., because of environmental benefits), but it became a financial choice, which may not have aligned with their (intrinsic) motivations for saving energy. It is important to acknowledge that while financial incentives are effective in many cases, they may not be a blanket approach that works for everybody all the time.

**Governance**

The importance of providing consumers the right to participate in energy decisions that affect them is also germane to this issue. Research on energy policy ranging from the large-scale adoption of renewables to the more individual use of smart metering has demonstrated the importance of having a transparent decision-making process. Of particular importance is attention to procedural justice and shared governance in individuals’ acceptance of outcomes and belief in the legitimacy of decisions (see also Perlaviciute et al. in this issue). When trust is lacking among key stakeholders, which is not uncommon given the potential for competing stakes in the outcome, the ability to depend on a decision-making process viewed as fair cannot be understated. For example, customer resistance to the first attempt at (mandatory) smart meter roll-out in The Netherlands not only meant that the Dutch program had to be substantially modified, it also influenced the U.K. rollout, which is voluntary and backed by a substantial public relations and customer education program.

**The Cognitive Fix: Information Provision**

Largely absent from research on technical or structural fixes are formative questions asking about individuals’ fundamental motivations—beliefs, attitudes, and values—that guide their behaviors. Understanding and incorporating these motivations is integral in the design of effective communication messages and campaigns. These types of questions can be seen as aligning with the third or cognitive fix, which involves a belief that the provision of information can effectively modify or change individuals’ attitudes and resulting behaviors, thereby solving the problem. The provision of information is a commonly used approach to encourage consumers to implement energy efficiency or curtailment behaviors. The underlying idea is that by providing consumers with information, they will acquire “better” knowledge about what they can do to save energy, and this will result in behavioral changes. This is also known as the knowledge-deficit approach.

But the research to date is clear: information provision results in an increase in knowledge and awareness but does not necessarily lead to a change in behavior. For example, consumers who say they know that leaving one’s television in stand-by mode uses electricity will still leave their television in that mode. People who believe in climate change do not always adopt measures to reduce their contribution to greenhouse gas emissions. The research largely indicates that information provision leads to an increase in knowledge, but it does not result in the adoption of energy-conservation behaviors. Information is, however, a relatively inexpensive and easy way to reach a large audience, and research from the social sciences examines the ways in which the effectiveness of information provision can be enhanced.

There are some stories of success. For example, some interesting work is being undertaken on the use of visualization tools, with the aim of making information about energy conservation more situation specific. For example, drawing on theories and methods from the physical sciences and psychology, a U.K.-based study examined the effectiveness of thermal imaging as an intervention to encourage home retrofitting. Thermal imaging is a technique that uses infrared radiation to show the heat loss of an object. The study examined the effectiveness of thermal imaging in reducing heating-related energy consumption through homeowners’ implementation of efficiency measures such as draft proofing and insulation. Compared to a no-intervention control group, households were more likely to install draft-proofing measures and reduce energy consumption after seeing the thermal images of heat escaping their homes.

It is also important to tailor the information toward the specific audience. Tailoring is a process that helps create personalized communications. Information can be collected about individual households (e.g., income, household size, and attitudes toward energy conservation), and an intervention can then be developed that meets this household’s needs. In an application of tailoring, a group of Dutch researchers conveyed tailored energy-saving advice via a website. First, they collected information from households (through an online survey) about ownership and the use of various household appliances. Then, households were provided with tailored (i.e., relevant to their specific context) information about energy-saving measures and the relative impact these measures would have on their energy bills (this was communicated to households in terms of monetary savings as well as carbon dioxide emission reductions). Compared to a no-information control group, households who had received tailored information significantly reduced their energy consumption.

Studies have also found modest changes in energy-consumption levels after the provision of feedback on energy use. Interventions with real-time energy information seem to be more effective in yielding savings as are feedback interventions that provide households with detailed energy-use information, such as feedback on the amount of energy used by appliances.
Comparative feedback, which highlights one’s own energy use in relation to important others, has also shown success in reducing energy consumption. Comparison feedback can have different effects for relatively high- and low-energy consumers. Households with higher energy consumption levels tend to reduce their consumption following comparative feedback. However, households with relatively low energy consumption that receive comparison feedback have been found to increase energy consumption. This is presumably because the social comparison made it clear they had some room to move in comparison to other households. This suggests that it is important to carefully implement such interventions, as they may have different effects for different energy consumers.

These and other findings suggest some paths forward. One of the ways to enhance the effectiveness of information (and feedback) provision is through emphasizing social norms about energy conservation. Social norms refer to what society expects of us, and when social norms are made salient, they guide our behavior. A series of studies by Robert Cialdini and colleagues found that people litter more in littered environments and that people litter more when they see somebody else littering. Both situations signal that littering is the norm.

If social norms guide our behavior, then social norms can also be employed to encourage behavior change. There is now a wealth of research on the use of social norms as part of both information and feedback provision in the energy-consumption domain. The assumption is that households will be motivated to make changes to energy consumption patterns when they know that other people are also doing this. In one of these studies, households in California received a message that either emphasized monetary savings, social responsibility, environmental considerations, or social norms (“77% of San Marcos residents often use fans instead of air conditioning to keep cool in summer”). Compared to the other messages and a control group, households that had received social norm information reduced electricity usage the most.

In other studies, social norms are made salient through a process called social comparison. Social comparison refers to our tendency to compare our own performance with that of other people. The effect of social comparison has been tested in field experimental settings: households receive information or feedback about their own energy-consumption levels compared to other households (e.g., in the same neighborhood or the “most efficient” neighbors), and energy consumption is compared to a no-intervention control group. A number of large-scale randomized control trials (run by the company OPower) in different parts of the United States have observed energy savings of around 2%, compared to a no-intervention control group.

**Combining These Fixes: Communicating About Energy Conservation Using a Sociotechnical Approach**

This brief overview suggests that no one fix is likely to succeed in solving energy-conservation challenges, yet a combined approach offers a greater probability of success in the long term. What we refer to as sociotechnical approaches can be very helpful when thinking about energy conservation interventions, including how to communicate about energy. For a start, they take into account the communication that already goes on between the equipment and infrastructures that make up an energy system; the people who derive energy services from the system (everyone); and the people who contribute to its operation, maintenance, and development. Communication, in this sense, is not just some optional extra in an energy system: it happens all the time between things and things (automated sensing and control), things and people (controls and interfaces), and people and people at different scales. It is a necessary part of the systems of technologies, habits, meanings, and knowledge that lead to energy (and climate) outcomes. An appreciation of this approach requires consideration of two main elements: who is communicating and what is being communicated.

**Who Communicates?**

Figure 2 illustrates some of the actors who communicate within a system for providing electricity to homes. It is a flat diagram, giving no indication of the relative power and influence of different actors, but it offers an indication of just how many individual, organizational, human, and non-human elements it can take to make a system work, powered by traditional grid

![figure 2](image-url) Communications between some actors in an electricity system.
electricity along with some distributed generation such as rooftop solar photovoltaics.

Note that there are no one-directional arrows between the elements in Figure 2: communication occurs with, not to. In the rush by marketers and policy makers to tell consumers what they need to do, often with the best of intentions, there can be surprisingly little effort to understand who they are, how they live, and how they think. Note, too, the “middle actors,” who can be essential in making technology work for the people who need the energy service and for the system that provides it; markets are unable to do this in the pure, frictionless way that is sometimes assumed. Examples of such actors include architects, designers, builders, vehicle fleet managers, heating engineers, energy advisers, and local authority personnel, such as housing officers, building inspectors, and planners. All of these are potential communicators with consumers but may not have the training, resources, or inclination to make the most of that role.

What Is the Communication About?

Figure 2 also gives some idea of where lines of communication can run. This is important when thinking about potential areas where communication is needed, such as the following:

- Where improved design and investment are needed for buildings, mobility, appliances, and infrastructure (climate-appropriate design, effective construction, retrofit, maintenance, and repair). Colleges, universities, and other sources of professional and trade development have a role to play as well as the people who develop and apply technical and operational standards.

- Options for distributed generation and storage, where network operators, vehicle fleet operators, energy service companies, and tariff designers all need to communicate with each other and with their customers.

- Person-to-person communication, in the form of energy labels and marketing materials, on-site advice programs, audits, advertising campaigns, or online material.

- Technology-to-person communications such as controls and feedback on energy use and generation.

- Technology-to-technology communications including rounded appraisal of the possibilities, risks, and uncertainties in highly connected systems.

All of these involve diverse variables and actors, and some entail administrative, legislative, and political activity as standards are negotiated and arrangements made for implementation. But all involve communication about matters related to everyday living and particular pieces of equipment, and, to be effective, they need to take careful account of who communicates what to whom. For example, the early experience of smart meter rollout in Great Britain (along with the research literature on energy feedback and technology adoption) pointed to the value of a combined approach in which 1) customers are offered a smart meter designed to meet particular functional requirements including two-way customer-utility communication, along with 2) an in-home display to communicate energy use to customers, 3) installers are trained in communication skills, and 4) suppliers are obliged to make provision for customer information and advice before, during, and after installation.

Conclusions

Climate change, environmental degradation, and the provision of energy services are all complex processes that have to be addressed with many resources—material, cognitive, moral, social, and political. Research on energy consumption benefits from a greater involvement of the social sciences. This article has highlighted that too much emphasis on either a technological, structural, or cognitive fix will not be sufficient to achieve the fundamental shifts in energy consumption needed to meet emission reduction targets.

The research literature on consumer energy demand confirms the extent to which energy systems are sociotechnical in nature, so that purely technical fixes to reduce demand are rare or nonexistent. Communication with consumers needs to reflect this, using technology as part of the message and involving technicians in the process of designing technology. Drawing on social science research about individuals’ motivations, attitudes, and behaviors, technologies can be developed and implemented that “communicate well” with their end users. Technicians can take an active part in implementing such technologies by explaining and developing them with end users.

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For Further Reading


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One of the most critical and pressing solutions needed to address global climate change is the transition to secure, affordable, and sustainable-energy systems. This transition is usually considered a technological challenge because it involves the integration of renewable energy, a trend toward decentralizing energy generation, and more demand-side participation. However, involving consumers in the transition is crucial for its success. For example, sustainable-energy transitions may require consumers to adopt sustainable-energy sources, technologies, and energy-efficiency measures as well as change their direct and indirect energy use behaviors to the limited and fluctuating supply of (renewable) energy. However, such behaviors may not always be easy for consumers to adopt, as they can entail personal sacrifice and discomfort or require them to change habits or infrastructure, which can be cognitively and financially demanding. To guarantee a sustainable future for all, it is critical that we understand what motivates consumers’ energy behaviors and how we can promote consumers’

By Lise Jans, Thijs Bouman, and Kelly Fielding
motivation to engage in sustainable-energy behaviors and act beyond immediate personal interests.

Most approaches to promote sustainable-energy behaviors conceptualize people as individuals motivated by self-interest. Yet, the social context—and in particular the groups people are part of—play an important role in how people think and behave, even though they often don’t realize this. We do not live in a social vacuum. Rather, we are members of various groups—friendship, professional, and community—that have the potential to influence our energy attitudes and behaviors. For instance, when you buy an electric vehicle, you may feel that this was your decision, yet the fact that most people in your neighborhood have an electric vehicle may have (consciously or unconsciously) motivated you to buy one too. In this sense, the adoption of an electric vehicle is not merely an individual decision; it may be motivated by the fact that you belong to a particular neighborhood. Your membership of that neighborhood group can guide your actions, in this case whether or not to buy an electric vehicle. In addition, the adoption of an electric vehicle could also signal to others that you belong to a particular group, namely, the group of people who care about sustainable energy (assuming electrical vehicles are good for sustainability). This example illustrates that people’s sustainable actions and attitudes can be guided by the groups to which they belong (see Figure 1).

In this article, we will discuss how groups and group-based approaches can be used to promote more sustainable-energy behaviors among group members. We will first outline the key theoretical lens within social psychology—the social identity approach—that provides an understanding of why groups influence attitudes and behaviors. We will then discuss how this theoretical lens enables a better understanding of energy-related attitudes and behaviors. We will use these insights to discuss different group-based approaches to encourage sustainable-energy attitudes and behaviors. We hope these insights enable readers to better assess the important role of groups in promoting a sustainable society and help them to better take into account the human dimension of the sustainable-energy transition in their professional practice.

**How Can Groups Influence Energy-Related Attitudes and Behaviors?**

A central proposition of the social identity approach is that our self-concept is made up of both personal and social identities. Our personal identity is comprised of the distinctive and idiosyncratic aspects of ourselves that makes us different from others. Social identities, on the other hand, are the identities that arise from membership in specific social groups. For example, a reader of this article may have a self-concept that is made up of the social identities of being a woman, an electrical engineer, and a member of the IEEE Power & Energy Society. Our social identities can relate to large social categories like gender, profession, or nationality, to small groups such as friendships or work group, and to medium-sized groups such as a neighborhood or a school. The social identity approach contends that our membership in any of these groups can influence how we think and behave.

The social identity approach outlines the conditions under which our membership in a specific group (i.e., our social identity) will influence our attitudes and actions. When the situation makes our personal identity come to the fore, we define ourselves in terms of our distinctive attributes, and our behavior is driven by individual motives. As an example, a conversation with another electrical engineer that highlights that you are someone who cares strongly about the environment, whereas he/she does not, may activate this personal identity (“I”) and influence your decision about whether to invest in sustainable-energy technology (see Figure 2 for an illustration of salient personal identity).

In contrast, when a particular social identity becomes salient, our personal identity is pushed to the background and we define ourselves in terms of this group membership; we internalize the content of that group identity (i.e., its needs, goals, norms, and values), and our attitudes and behaviors are driven by the group’s motivations. Group members are also more likely to communicate with and influence each other as well as cooperate and act collectively to pursue their group’s interests. Group members’ relations with other groups can also change. Members aim to see themselves as positively distinct from

**figure 1.** Engaging in sustainable-energy behaviors, such as the adoption of an electric vehicle, may well be influenced by the group(s) of which you are a member. (© Marlies Bouman, used with permission.)
The social context—and in particular the groups people are part of—play an important role in how people think and behave, even though they often don’t realize this.

other groups (i.e., different and better than other groups) and may, under certain conditions, compete with or come into conflict with other relevant groups. As an example, imagine you and your colleague have been invited to an interdisciplinary climate change conference, and you are debating with social scientists about the best solutions to address the issue. In this situation, your social identity as an electrical engineer (“we”) will likely come to the fore, and the arguments you make will be consistent with your electrical engineering identity. You might even find yourself thinking that electrical engineers are more concrete and rational than social scientists, hampering the likelihood that you and the social scientists will reach an agreement (see Figure 2 for an illustration of this social identity salience).

The extent to which a social identity influences our sustainable-energy-related attitudes and behavior will depend on the extent to which the issue is relevant to the identity. The take away message from the social identity approach is that, to the extent that sustainability is relevant to it, social identity can strongly influence our sustainable attitudes and behaviors as well as who we collaborate or come into conflict with over energy-related issues. Which social identity becomes self-defining and influential depends on the person as well as the particular situation he or she is in.

With regard to the person, certain social identities (i.e., group memberships) may be more accessible to a person than other social identities, depending on the person’s prior experiences with the group and his/her motivations. For example, the strength of identification that a person has with a group is important. Individuals who identify strongly with a particular group are more likely to define themselves in terms of this membership and be influenced by it than individuals who identify more weakly with the group. In the context of sustainable energy, research suggests, for example, that the more one identifies with a community energy group, the more willing he or she is to engage in sustainable-energy behaviors, independent of one’s personal motivation to engage in these behaviors.

With regard to the social context, specific social contexts can make certain group memberships stand out. People are more likely to be seen as a group when they are perceived as similar to each other and different from other people. This is why in the debates around climate change and climate change believers and sceptics are increasingly seen as two clearly distinct and opposing groups, in which members of each group are seen as increasingly alike and as increasingly different from members of the opposing group.

The social context can also influence the perceived content of the group’s identity. Depending on the characteristics of other group(s) in a particular social context, the group’s distinctive features can be fluid. For example, when the British compare themselves to Americans (whom they perceive to be less pro-environmental than they are), they are more likely to see themselves as pro-environmental and engage in behaviors aligned with this normative position than when they compare themselves with, for example, Scandinavians.

Furthermore, processes within the group can foster the experience of shared membership. Through interactions among members, individuals actively contribute to what the group is about and develop a consensus about important aspects of their group’s identity. Particularly in new groups, interactions among group members are needed to establish what a membership entails and enable people to identify with the group. For example, interactions among community members may facilitate setting up or becoming engaged

**Figure 2.** Whether people define themselves in terms of their personal identity, (a) “I” (or social identity) or (b) “we,” is dependent on the social context they are in. (© Marlies Bouman, used with permission, inspired by S.A. Haslam, S.D. Reicher, M.J. Platow, 2011. *The New Psychology of Leadership: Identity, Influence and Power.* New York: Psychology Press, 2001. ISBN 978-1-84169-610-2.)
in community sustainable-energy groups and thereby developing a new social identity that can motivate sustainable-energy behaviors.

In summary, our group memberships (i.e., social identities) and the processes that relate to these groups can strongly influence our attitudes and behaviors related to sustainable energy. When a particular group membership becomes self-defining, personal interests are pushed to the background, and people’s sustainable-energy attitudes and behaviors are motivated by the content of their group’s identity (when sustainability is relevant to that group identity). This can promote cooperation among group members in the service of sustainability but also conflict between groups over energy-related issues. The influence of membership is particularly strong for people who highly identify with their group and when the social context makes them stand out as a group. These insights highlight the important role of group processes in the context of sustainability.

**Group-Based Approaches to Change Consumers’ Energy Behavior**

The insights offered by the social identity approach provide suggestions for group-based approaches to encourage sustainable-energy attitudes and behaviors. To date, most interventions to promote sustainable-energy attitudes and behaviors target people as individuals, aiming to change their individual motivations (e.g., save energy to save money). Yet, the transition toward sustainable energy is inherently social and particularly suitable to be addressed by group-based approaches.

Evidence for this position comes first from the fact that the unsustainable usage of limited energy sources fostering climate change has often been defined as a collective problem. Collective actions of individuals and groups have caused the unsustainable usage of limited energy sources, and cooperation among individuals and groups is needed to transition toward a more sustainable-energy system. One example of the potential for cooperation can be found in Denmark, where the community on Samsø has made their island the first fully renewable energy-powered island in the world.

Second, evidence for the social nature of the sustainable-energy transition lies in the fact that different groups in society have contributed to and will be affected by this collective problem to different degrees. For example, whereas groups of higher socioeconomic status (e.g., large, often western, industrialized nations) are contributing to climate change significantly more than groups of lower economic status, it is particularly members of economically disadvantaged groups (e.g., small island developing states) who will experience the harmful impacts of climate change the most. This enhances the likelihood that group memberships become salient in the context of sustainable energy and that group memberships influence one’s position on sustainable energy.

The important role of groups and group processes in the context of sustainable energy makes evident why group-based approaches are particularly well suited for changing attitudes and behaviors in the context of sustainability. Addressing people as a group, rather than as individuals, can help them to overcome their differences and to act in accordance with their shared group membership in the energy domain. As we will discuss later, groups can either support or discourage sustainable energy, depending on their social identity content.

**Social Identity Content: Supporting or Discouraging Sustainable Energy**

Groups influence how we see ourselves, with whom we connect, and what kind of beliefs and behaviors we think are appropriate in a situation. Clearly, these influences depend on our shared understanding of what the group is about (its content), which is in part based on the group’s values (i.e., general principles that are important for the group) and group norms (i.e., what is considered appropriate to do and think within a group). Sustainable attitudes and behaviors are most likely when group memberships are made salient in which sustainable values are focal and norms promote sustainable-energy behaviors. We will explain these two factors in more detail.

**The Importance of Group Values**

Group values indicate what a group stands for. For example, green political parties have protecting the environment as a central value whereas conservative political parties usually privilege economic growth. Group values are strongly intertwined with the group’s identity, believed to be relatively stable over time, and are seen as underlying factors that consistently affect members’ behaviors and beliefs. According to Schwartz’s universal value theory, there is a set of values that can be found across individuals and groups worldwide. Individuals and groups endorse most of these values to a certain extent but differ in the way they prioritize them.

Two value clusters—self-enhancement and self-transcendence values—are generally considered to relate to
environmental behaviors and beliefs. Values are relevant for groups as well as for individuals (for a discussion of individual values, see Steg et al. in this issue). Self-enhancement group values focus on benefits for the group and its members (e.g., pleasure, gratification of desires, power, and resources), whereas self-transcendence group values focus on the welfare of others and nature (e.g., social justice, being helpful, and respecting and protecting the environment). Generally speaking, the stronger a group endorses self-transcendence values, the more likely the members will act sustainably; whereas the stronger a group endorses self-enhancement values, the less likely that members will act sustainably. Self-transcendence and self-enhancement group values are often believed to be in opposition but can coexist. The relative strength of both value clusters determines which value is more influential for behavior.

Group values can be operationalized in two ways. First, and most commonly, group values can be operationalized as the aggregate of group members’ personal values. That is, the group’s value system equals the sum (or mean) of all the group members’ personal value systems. Assuming that members actively contribute to what the group values through interactions, this appears to be a relatively objective way of measuring group values. This operationalization can be useful in characterizing groups and comparing them with each other, to identify what members, on average, value. By knowing that, arguments for sustainable-energy behaviors can be made more persuasively by tapping into these values. For instance, members of a community who, on average, endorse self-transcendence values more than self-enhancement ones may be more persuaded to invest in photovoltaic panels by arguments that fit with their group values (e.g., focusing on environmental benefits rather than on financial profits).

Second, group values can be assessed by asking members how strongly they think a typical group member endorses each value. This more subjective approach assesses how members perceive the values of the group. According to the social identity approach, this would be particularly likely to influence group members’ behaviors as it is these values that people internalize when a particular social identity is salient. These subjective group values could also be more easily changed by the context or an intervention. For instance, making a community member aware that typical members place strong value on the environment and nature can strengthen the perceived self-transcendence values of this group, which in turn can increase the willingness of this community member to invest in energy-efficiency measures.

The Importance of Group Norms
Often linked to the groups’ core values, groups can have stronger or weaker norms, indicating whether sustainable-energy behaviors and beliefs are appropriate or inappropriate within a group (e.g., use energy efficiently or install energy-efficient technology). Group norms are more concrete than values and often focus on specific actions or behaviors. Whereas group values are believed to be relatively stable over time, group norms are more flexible, which makes them more suitable for interventions.

There are two main types of group norms: injunctive and descriptive. Injunctive norms describe which actions are approved of or desired by a group. For instance, an organization can state that employees should switch off their lights when leaving the office. For an injunctive norm to be influential, it should be clearly and strongly communicated and focal when the required action is desired. To be effective, injunctive norms should fit with the values of the group. If this is not the case, it could be seen as illegitimate, “greenwashing” (i.e., presenting the group as more sustainable than it actually is) and might exacerbate tensions between subgroups (e.g., they, the management, versus us, the employees).

Descriptive norms focus on what group members do in general. For instance, an employee observes that most colleagues switch off their lights when leaving the office. When the desired behavior is clearly (made) visible, a positive descriptive norm could be very powerful in promoting this behavior. For instance, when all of your colleagues commute by public transportation to a meeting, you’ll be more likely to also use it instead of your car. Descriptive norms might be particularly effective for group members who slightly underperform on the norm, since these individuals see others performing better. When someone already outperforms most other group members, confronting this individual with the behaviors of others (e.g., that you are saving more energy than others) could backfire if that person defines him or herself in terms of personal identity (“I’m doing better than others, so I don’t need to try so hard”). However, when one accentuates that these behaviors are strongly valued by the group, well-performing group members are likely to feel good about their own performance, as it signals that they are exemplary group members. This
A central proposition of the social identity approach is that our self-concept is made up of both personal identities and social identities.

could increase the motivation to keep on performing well and motivate other members to change their behavior to align with the group’s descriptive norm.

Note that the use of descriptive norms to change behavior needs to be approached with caution. Normative feedback must always be authentic; that is, accurate feedback must be provided. There is often a temptation to highlight that there is a problem by communicating a negative descriptive norm (e.g., people aren’t saving energy); the problem with this is that it may send the wrong message to group members (e.g., “no one else is saving energy, so why should I?”). If it really is the case that people aren’t saving energy, then it would be better to focus on communicating a strong positive injunctive norm.

Bringing Supportive Social Identity Content to the Fore
Groups can promote sustainable attitudes and behaviors among its members when the content of its social identity is supportive of sustainable energy. Therefore, for a group-based approach to change energy behaviors in a more sustainable direction, it is key that the group is clearly perceived to have sustainable group values (i.e., self-transcendence values) and norms (i.e., norms promoting sustainable-energy behaviors). This raises the question of how sustainable values and norms be brought to the fore.

One way to accentuate or even change the perceived values and injunctive or descriptive norms of a group is by introducing a particular comparison group (an out group). If a lack of environmental concern is a central characteristic of an out group, in-group members might come to see sustainable-energy behaviors as more normative and central to their group, as a way to positively distinguish themselves from the out group. For instance, after the United States withdrew from the Paris Climate Agreement, sustainable norms were emphasized in many other countries all over the world, such as Germany, China, and India (to name a few), potentially as a way to reinforce in-group values and differentiate from out-group ones. This also signals the importance of choosing the right comparison group; telling group members that other groups are behaving more sustainably than they are might not motivate group members to do “better.” Rather it may lead members to assume that their group does not really care about sustainability, thereby decreasing, rather than increasing, the motivation to behave in a sustainable manner.

When aiming to accentuate or even change perceived values and injunctive or descriptive norms, group leaders can play a vital role. Such exemplar members can be very powerful in setting group norms and communicating group values. Leaders can advocate for sustainability, and their actions can provide a clear indication of what is normative and valued in relation to sustainable energy, thereby motivating members’ sustainable-energy behaviors. However, the influence of leaders depends on the extent to which they are seen as prototypical members of their group, that is, typical and representative of the group as a whole. Hence, to promote sustainable behaviors, leaders should not only advocate for sustainability, but they should also make sure that they are seen as representatives of their group. They can do this, for example, by emphasizing the group membership they share with their followers, by using words such as “we” and “us,” rather than “I” and “me.”

In summary, the content of a group’s identity, as reflected by its values and norms, can influence sustainable attitudes and behaviors. The “right” values and norms can be brought to the fore by changing the comparative context or having representative in-group members advocate for sustainability. Yet, in certain cases, the group may not value sustainability at all and may even endorse unsustainable behaviors. In these instances, it may be better to have people redefine themselves in terms of another identity, by making another group membership salient.

Bringing Supportive Groups to the Fore
As discussed earlier, groups can have a strong influence on members’ behaviors, but only when the group identity is salient. Accordingly, a promising strategy to promote sustainable-energy behaviors is to make social identities that are supportive of sustainable-energy behaviors salient, fostering identification with these groups, and shifting the focus away from groups that do not support sustainable energy. This can be done as described previously, by reminding people of the similarities between groups that engage in sustainable behaviors and highlighting their differences from ones that do not. Other approaches to make these memberships salient and strengthen identification with these groups can be to stimulate positive interactions among members and have them focus on their common outcomes, rather than their individual ones. For example, feedback systems on energy usage often give assessments on an individual level; however, providing group-level feedback, say for the organization
as a whole or a particular neighborhood, can accentuate shared group membership and may foster the willingness to cooperate on problems of sustainable energy.

In addition to highlighting or focusing on existing group memberships, new groups can also be formed to further sustainable-energy actions. People can form groups with others holding similar sustainable-energy attitudes to advocate for sustainable-energy transitions. Groups focused on sustainable energy can attract new members, who can then be motivated toward sustainable-energy use. Thus, by creating or emphasizing shared group memberships, groups can influence the attitudes and behaviors of its members and foster cooperation among people in the context of sustainability. Neighborhood groups that form to facilitate the installation of solar panels or meet to discuss ways to make their neighborhood more sustainable are examples of this approach in action (see Figure 3 for a picture of such a neighborhood initiative).

Although making particular group memberships salient can enhance cooperation among group members, it can at the same time make it more difficult for groups to cooperate on sustainability issues. Indeed, strong national identities are an important reason why negotiations between members of the United Nations to mitigate climate change are so difficult. In these negotiations, the focus seems to be on the subgroup identities of these different nations, and what is in the interest of these (national) subgroups, rather than on what is in the interest of the United Nations as a whole. Highlighting shared group membership at a superordinate level can be a way to overcome such frictions and to foster cooperation for the greater good.

**Summary**

In this article, we have discussed the important role that groups play in the context of sustainable-energy issues and the important influence they have on people’s attitudes and behaviors regarding energy. We have outlined the key theoretical approach within the field of social psychology to understand the influence of groups on people’s attitudes and behaviors in general as well as specifically in the context of sustainability. Based on these insights, we have discussed different group-based approaches to encourage sustainable-energy attitudes and behaviors and foster cooperation around sustainable-energy issues. We hope these insights enable the readers, and in particular our colleagues in electrical engineering, to better assess the importance of group memberships in the transition to a more sustainable society and help them to better take into account the social dimension of the sustainable-energy transition when designing sustainable interventions.

**For Further Reading**


**Biographies**

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TO COMBAT CLIMATE CHANGE, THE INTERGOVERNMENTAL PANEL FOR CLIMATE CHANGE (IPCC) calculated that greenhouse gas emissions in the energy domain should be reduced by 90%, compared to 2010 emissions, between the years 2040 and 2070. In Europe, residential households consume about a quarter of total energy used (excluding the energy that is embodied in products). To contribute to the carbon emission reduction targets set by the IPCC, households need to reduce their fossil-energy use.

Household fossil-energy use can be reduced through efficiency and curtailment behaviors. Efficiency behaviors refer to one-off investments that reduce the fossil energy needed to maintain household activities. For example, a household may adopt solar panels, insulate the home, or replace an old fridge with a more energy-efficient one. Curtailment behaviors involve repeated behaviors that reduce household fossil-energy use. For example, appliances such as the TV may be switched off after each use, instead of being left on standby. Curtailment behaviors may also include switching energy use to times when
renewable energy is available, thereby reducing household fossil-energy use. For example, a consumer could choose to use solar panel energy when the sun is shining. Efficiency behaviors usually produce a long-term effect after one focused effort, while curtailment behaviors require consistent commitment and vigilance. Efficiency behaviors often lead to larger energy savings than curtailment behaviors. Monetary incentives to change household fossil-energy use have mostly targeted curtailment behaviors. However, both types of behaviors may be required to meet IPCC emission targets.

Monetary Incentives to Reduce Household Fossil-Energy Use

Practitioners and policy makers often use monetary incentives to promote reductions in household fossil-energy use. For example, subsidies have been offered for the installation of heat pumps, solar panels, or energy-efficient appliances, and differentiated tariffs and monetary rewards have been implemented in an effort to encourage households to reduce energy use.

Although there are limitations to the effectiveness of monetary incentives, some studies have suggested that they may sometimes be an effective tool to reduce fossil-energy consumption in the home. One study reported that, in 2011, of the nearly 5,000 Southern California households with solar panels, approximately 1,500 participated in third-party ownership programs, where solar panels and related equipment are offered to households through commercial companies. Such third-party ownership provides a monetary incentive because it reduces up-front adoption costs, in addition to removing the technical challenges of initial installment. This monetary incentive especially promoted solar panels among younger, less affluent, and less educated consumers.

Additionally, monetary incentives may sometimes promote curtailment behaviors to reduce household energy usage, such as those results shown in Figure 1 from a Japanese study. Participants were randomly assigned to three groups. The first group was offered approximately €1.70 for each 1% reduction in energy use. Members of the second group received the same offer combined with social comparison feedback that compared their energy use with that of their neighbors. The third group served as a control and received no information. These groups reduced their energy use by 5.9, 8.2, and 1.7%, respectively. In this case, monetary incentives did seem to motivate consumers to curtail their home energy use, especially when combined with social comparison feedback.

These studies suggest that monetary incentives can sometimes effectively reduce fossil-energy use. However, when interventions provide monetary incentives, they usually do so as part of a package of supplementary strategies. In the first example, monetary incentives were provided in combination
Three Downsides of Monetary Incentives

Monetary Benefits May Lead to Rebound Effects
One limitation of providing monetary rewards for energy savings is that the saved money may be spent on other energy-consuming behaviors. For example, when purchasing new energy-efficient equipment (e.g., energy-efficient lightbulbs or a fuel-efficient car) leads to saving money (i.e., on electricity or fuel), households may use that extra money to pay for increased use of their new equipment (e.g., turn on more lights or drive more) or other goods or services (e.g., holiday air travel). Effective curtailment behaviors may also lead to monetary savings that can be spent elsewhere. If so, this will lead to an increase in energy consumption, a rebound effect, that may swallow up some of the initial reduction in energy consumption—and related carbon dioxide ($CO_2$) emissions (see Figure 2).

For example, providing free home insulation and energy-efficient air-conditioning did not reduce energy use. A Florida Power and Light study of the effectiveness of providing free home insulation and energy-efficient air-conditioning found no differences in energy savings among three treatment groups receiving various combinations of free conservation technology and a control group. Households that used electric heating and cooling were randomly assigned to one of these four groups. Energy savings for home cooling in the treatment groups in nonsummer months were 13% below the potential savings estimate. In summer months, energy savings were 1–2% lower than the potential savings estimate. For home heating, the savings were 8–12% lower than the estimate. Savings were lower because participants increased the temperature in their home during winter months and decreased the temperature in their home in summer months following the installation of energy-efficient technologies. The energy-efficient technologies saved participants money, which they then spent on greater comfort by increasing their use of heating and cooling equipment.

Although the rebound effect has not been studied for all energy-saving behaviors, energy savings do inherently lead to monetary savings, and any reward or monetary subsidy adds to the means that households have available for additional consumption, including additional energy consumption. Therefore, monetary incentives likely produce a bigger rebound effect than nonmonetary measures with the same behavioral effect.

The Incentive Is Not Worth the Effort
Monetary incentives for energy savings may activate a cost-benefit mind-set, which makes consumers focus more on the private costs and benefits. That is, they weigh the investment it takes in terms of money, effort, and discomfort against the money that can be saved. When the monetary savings are small, they may not outweigh the private costs. If people focus exclusively on the private costs versus benefits, they may not be likely to engage in the behavior.

Many behaviors that reduce household fossil-energy consumption may seem to have higher costs than benefits. Efficiency behaviors often take large investments, which are recouped from energy savings after a relatively long period of time. For example, the pay-back period for solar panels may be eight years or more. Research shows that most people have a strong preference for receiving money now,
Monetary incentives for energy savings may activate a cost-benefit mind-set, which makes consumers focus more on the private costs and benefits.

compared to receiving the same amount in the future. As a result of such temporal discounting, the monetary savings obtained from efficiency behaviors can be perceived as not worth the effort. The private benefits of curtailment behaviors, such as lowering the heater or taking shorter showers, may be perceived as rather small, too small to justify the increased discomfort. Thus, curtailment behaviors may also be perceived as too costly compared to the benefits.

Hence, when deciding to use monetary incentives and thus promoting cost-benefit thinking among consumers, it is important to carefully consider the private costs and benefits of the promoted behavior. When the private costs in terms of down payment, effort, and/or comfort are relatively high, the private benefits need to be high as well. In general, monetary incentives need to be large enough to justify and overcome these costs but usually are not.

Incentives May Crowd Out Intrinsic Motivation
A third downside of providing monetary incentives for reducing household fossil-energy use is that doing so may undermine people’s intrinsic motivation to engage in behaviors they would have engaged in anyway (for a discussion on intrinsic versus extrinsic motivation, see Steg et al. in this issue). Indeed, many people engage in sustainable energy behavior without receiving monetary incentives for doing so. For example, they may sign up for residential energy-saving programs, switch to a green energy provider, or buy energy-efficient appliances because they are motivated to save the environment. When individuals engage in behaviors without receiving money or other extrinsic rewards, they display so-called intrinsic motivation. Research has found that offering an extrinsic reward in the form of a monetary incentive tends to reduce or “crowd out” intrinsic motivation for that behavior. Even highlighting the monetary rewards inherent to energy savings may undermine consumers’ intrinsic motivation to change their behavior. For example, a study using three different advertisements for residential energy-saving programs, which highlighted monetary benefits, environmental benefits, or both benefits, found that those who received the advertisement highlighting environmental benefits were the most willing to enroll (see Figure 3). When highlighting monetary benefits, either alone or in combination with environmental ones, consumers’ environmental motivations and willingness to enroll were reduced. These effects were especially pronounced among consumers who care about the environment, that is, who are intrinsically motivated to enroll in the program.

Monetary incentives may also influence the likelihood of obtaining so-called spillover effects (see Steg et al. this issue), where making people act to protect the environment in one area makes them more likely to act environmentally friendly in other areas as well, that were not targeted by the intervention. If people engage in an energy-saving behavior for the money, this does not increase their motivation to also engage in other pro-environmental behaviors that are not incentivized. For example, in one study, clients of a German energy provider were randomly allocated to three groups. The first group received electricity saving tips combined with a monetary framing (savings in euros), the second group received the same tips with an environmental framing (savings in CO₂), and the third group received no information and served as the control group. The first two groups showed higher intentions for saving electricity than the control group. The framing was combined with the provision of electricity savings tips; therefore, it is unclear if the tips or the framing influenced the intentions to save electricity. However, positive spillover on climate-friendly intentions beyond saving electricity at home (e.g., reducing energy use at work or reducing beef consumption) was found in the environmental framing condition only. Monetary incentives for specific energy-saving actions may
therefore lead to less energy savings overall than other types of interventions having the same direct effect on behavior.

Hence, highlighting monetary benefits when promoting energy savings may backfire, especially among pro-environmental consumers. Monetary incentives lack the spillover effect on other energy-saving behaviors that other interventions may have. Therefore, monetary incentives need to be large enough to overcome this reduced intrinsic motivation.

In summary, although monetary incentives can be an effective means to reduce carbon emissions by reducing household fossil-energy use, they are often not cost-effective. To have any effect at all, the incentive needs to be large enough to justify the effort and other costs of engaging in the behavior. As energy costs are currently too low to significantly deter consumption, substantial monetary incentives need to be added to make cost-benefit analyses lead to fossil-energy savings. Also, the incentive needs to be large enough to more than compensate for any reduction in intrinsic motivation, which may be crowded out by the incentive. Further, incentives need to be provided for all behaviors one aims to encourage, as incentivized behaviors are not likely to lead to spillover effects. Finally, if the monetary incentive leads to more money in the hands of consumers, some of the energy savings may be eaten up by rebound effects created by the spending of this money.

**Incentives to Reduce Household Fossil-Energy Use**

In the light of the possible downsides of using monetary incentives, a crucial question is if and how interventions can be designed to more effectively reduce household fossil-energy use. We will discuss three possible routes. First, we consider other strategies that may be more effective than monetary incentives to reduce household fossil-energy use. Second, we discuss ways to implement monetary incentives that may increase, rather than decrease, the receiver’s intrinsic motivation to engage in sustainable energy behaviors. Third, we discuss research on the use of temporary monetary incentives as a means to change people’s habits, thereby promoting a change in behavior in the long run.

**Other Strategies**

Monetary incentives are only one among several proven strategies to promote sustainable energy behaviors. Although there is clearly no “silver bullet,” there are other strategies that may effectively reduce emissions by reducing household fossil-energy use under some circumstances. One such strategy is energy audits, which have proven effective at promoting energy saving, provided people accept the offer. Energy audits involve giving people tailored information regarding which changes in energy behaviors are relevant for the specific household, in person. The Achilles’ heel of such strategies is to get people to accept the offer of an energy audit; when they do, energy audits are effective both because the conveyed energy-saving tips are personally relevant and because of the personal contact. In particular, research shows that people are more likely to act on information when it comes from someone they know or like.

As noted previously, environmental motives are often the reason that people perform both efficiency and curtailment behaviors. In contrast to small monetary motives, small environmental savings have been found to be perceived as worth the effort. Highlighting environmental benefits of reducing fossil-energy use tends to reinforce rather than decrease intrinsic motivation. Therefore, providing environmental arguments, for example by stressing CO₂ reductions, can sometimes effectively reduce fossil-energy use without the need for monetary incentives.

Social rewards have been found to sometimes motivate the reduction of fossil-energy use. Social rewards can, for example, involve recognition or praise by others for a consumer’s reduced usage. The effectiveness of social rewards can be illustrated by a quasi-experimental study, which assigned employees to receive weekly monetary or social rewards for saving energy at work. The weekly monetary reward was between €0 and €5, and the weekly social reward was a grade between five and ten, depending on the energy saved. Half of the participants learned about their weekly reward in a private announcement, while the other half received it in a public announcement. The participants receiving (public or private) social rewards reduced their energy use, while the participants receiving (public or private) monetary rewards did not reduce their energy use compared to a control group (see Figure 4).

Social norm communication has also been used to reduce household fossil-energy use (see also Jans et al. this issue). Social norm communication provides information about the energy behavior of neighbors or other people. Social norm communication can be effective because people tend to be
Although monetary incentives can be an effective means to reduce carbon emissions by reducing household fossil-energy use, they are often not cost-effective.

Monetary Incentives May Sometimes Strengthen Intrinsic Motivation

Monetary incentives may not always crowd out intrinsic motivation. In some cases, monetary incentives may make people aware of their intrinsic motivation to reduce household fossil-energy use or increase the salience of this motivation. For example, a study in the United States found that offering a monetary incentive effectively promoted switching energy consumption to off-peak periods. However, switching was independent of the size of the monetary incentive. Instead, switching depended on the extent to which people felt morally obliged to shift their energy use to off-peak periods. The extent to which people felt morally obliged to switch energy use also did not depend on the size of the monetary incentive. In this case, it may be that the monetary incentive increased the salience of the morality of energy consumption and thereby activated people’s intrinsic motivation for the behavior. Possibly, when the government employs what is perceived to be a strong regulation, this communicates that the targeted problem is indeed serious and something a responsible citizen should be concerned about. It has been suggested that such implicit communication from the government can reinforce internalized motivation in the form of a moral norm.

Hence, it seems that monetary incentives do not always crowd out intrinsic motivation to engage in sustainable energy behavior, but the reasons for this are not yet fully understood. More
research is needed into the conditions under which crowding out intrinsic motivation is more or less likely to occur and then if and how incentives can be designed to at least avoid crowding out intrinsic motivation for sustainable energy behaviors.

**Temporary Incentives to Change Energy Habits**

Like other interventions, monetary incentives may lead to durable fossil-energy savings if they produce a change in behavior and the new behavior becomes habitual. Habits are behaviors that people engage in automatically under specific conditions, without considering their motivation or the costs and benefits of the behavior. For example, in one study, people who were randomly assigned to pay extra for energy consumption during peak hours significantly reduced their peak energy consumption as compared to a control group. In this case, a monetary incentive indeed changed energy behavior. The monetary incentive may have been strong enough to compensate for the effort needed to switch energy use to off-peak hours, at least for a while. Alternatively, the monetary incentive may have focused people on their intrinsic motivation to reduce fossil-energy use. The study showed that the group that received the monetary incentive also used less energy than the control group during off-peak times, when there was no incentive, and they continued using less energy after the incentive was removed. Possibly, the monetary incentive increased attention to energy consumption, reinforcing people’s behavioral motivation to consume energy responsibly, and facilitated the formation of a sustained habit to reduce consumption. However, more research is needed on the conditions under which monetary incentives may lead to the establishment of new habits for sustainable energy behaviors.

In sum, engineers and economists who are designing energy markets and efficiency schemes should be aware that there are downsides to using monetary incentives but there are also indications that at least some of these may be overcome. Monetary incentives can sometimes remind people of or strengthen their intrinsic motivation to reduce household fossil-energy use, perhaps because regulations using monetary incentives may be perceived as a sign of the seriousness of the targeted problem. Furthermore, a temporary monetary incentive can be a means to break unsustainable energy habits and instill new, more sustainable habits. However, when developing cost-effective interventions to reduce household fossil-energy use, it may often be more cost-effective to use other strategies, for example relying on social influence.

**Summary**

We still need a better understanding of which incentives and other strategies influence which types of energy behavior, how, and under which circumstances. To achieve this, care needs to be taken to control for possible confounding factors that might influence behavioral and energy outcomes, which is most effectively done by randomly assigning participants to different treatment groups and a control group. When testing the effectiveness of monetary incentives and other strategies, it is important to focus on those behaviors that reduce emissions the most. A disproportionate number of studies thus far have tested the influence of interventions on curtailment behaviors, while efficiency behaviors often lead to larger energy and emissions savings. To fully assess the energy savings following an intervention, it is important to take possible indirect effects (i.e., spillover effects) on other energy behaviors into account that are not directly targeted by the intervention. Finally, to improve the effectiveness of interventions, we need to understand why they may be effective, which can be done using surveys and other methods to measure these underlying processes. This will help policymakers develop cost-effective interventions to reduce emissions by reducing household fossil-energy use without automatically relying on costly and ineffective monetary incentives.

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**For Further Reading**


**Biographies**

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Public acceptability is at the heart of changing the energy system toward a more sustainable way of energy production and use. Without public acceptability and support for changes, a sustainable energy transition is unlikely to be viable. We argue that public acceptability is often addressed too late and should be incorporated into the planning process from the start. Moreover, engineers, policy makers, and project developers tend to misjudge the complexity and causes of public resistance, trying to find the magic bullet to “solve” the lack of public acceptability. Such attempts are likely to be ineffective, or even counterproductive, if they fail to address people’s key concerns surrounding energy projects. There is not a one-size-fits-all solution; public acceptability is a dynamic process that depends on the context, the specific project at stake, and the parties involved.

By Goda Perlaviciute, Geertje Schuitema, Patrick Devine-Wright, and Bonnie Ram
The United Nations-led regulatory framework for environmental projects established by the Aarhus Convention emphasizes that citizens have a right to be informed about and comment on environmental decisions and that their comments will be taken into account in decision making. Public engagement and support are crucial for realizing sustainable energy projects that are necessary steps toward the Paris Agreement’s goal of keeping the increase in global average temperature to well below 2 °C and aim to limit the increase to 1.5 °C. Reducing air pollution, enhancing public health, and conserving water and food are also central motivations for a cleaner energy system. Energy projects will not be viable unless people adopt and adequately use the related infrastructure and technology, change their behavior to adjust to the (renewable) energy supply, reduce overall energy demand, and accept policies surrounding a sustainable energy transition. Yet many proposed sustainable energy projects are met with fierce public opposition, especially from communities where these projects are to be deployed (Figure 1). To secure democratic decision making and promote wide public support for a sustainable energy transition, it is essential to understand what drives public acceptability of energy projects and how this knowledge can be integrated into project development from the start and during implementation phases.

Public acceptability is a broad concept that refers to people’s general evaluation of energy projects, i.e., the extent to which they favor or disfavor a particular energy project. It manifests itself in people’s opinions as well as their (intended) actions toward energy projects and can be accompanied by emotional responses to these projects. Possible public responses include active resistance, apathy, uncertainty, passive acceptance, support, and embracement. However, public acceptability typically receives attention from project developers and decision makers only when it challenges a specific project (e.g., because people protest) or when there is a strong fear that this may happen. This reflects a somewhat narrow instrumental approach to acceptability, usually aimed at legitimizing already developed energy projects. Instead, we advocate an alternative approach that views public acceptability as a necessary and valuable building block for the quality of the project, informing whether and how these projects should be changed or if new projects need to be developed differently.

Misguided, inaccurate, and simplified assumptions about public acceptability often lead to ineffective policies that fail to enhance public support but, rather, inflame conflict between authorities and developers, on the one side, and the public, on the other side. We elaborate four such common simplifications and misunderstandings: 1) public acceptability is merely a not-in-my-back-yard (NIMBY) response and can be affected positively by 2) financial incentives, 3) providing information to people, and 4) the lapse of time. Ad hoc and counter-effective solutions are often implemented based on these misunderstandings. These are often one-size-fits-all solutions failing to take into account that similar energy projects may be evaluated differently by different communities and individuals. To remedy this, we propose to analyze projects from the very beginning of their development in terms of key factors and processes that underlie public acceptability. We discuss alternative, often more promising, ways to address public acceptability that take these factors and processes into account. Finally, we end with some concluding remarks on how to better incorporate public acceptability in practice and research.

**Common Misunderstandings About Public Acceptability**

**Public Acceptability Is Merely a NIMBY Response**

People who object to energy projects are commonly labeled as NIMBYs by the media, policy makers, and industry. NIMBY is an easily used and widely understood concept, but it is rich in problems as well. It presumes that those who object have certain negative characteristics, such as being selfish and motivated only by personal gain, irrational and overly emotional, ignorant about the scientific or engineering aspects of energy projects, and parochial (i.e., more interested in local impacts than national or global benefits). The labeling as simply NIMBYs influences the way project developers and authorities tend to interact with the public about energy projects and how they attempt to tackle each of these pejorative assumptions: addressing selfishness by offering incentives (often labeled benefits packages), addressing ignorance by public awareness campaigns that focus on “the facts” (as experts understand them), and dealing with what they view as irrationality by avoiding public meetings with angry protesters. However, it is likely that these strategies will fail to increase public acceptability unless they address people’s genuine concerns, as we will discuss.

Figure 1. A protest against the building of a wind park in The Netherlands. The protesters say “no” to wind turbines but “yes” to solar panels. (©Dagblad van het Noorden/Maaike Wind, used with permission.)
Public acceptability is a broad concept that refers to people’s general evaluation of energy projects, i.e., the extent to which they favor or disfavor a particular energy project.

Financial Incentives Will Increase Public Acceptability

It is commonly assumed that if people are compensated financially for the possible risks and costs of energy projects, they will accept these projects. This idea is supported by the fact that if you ask people directly what motivates them most, they often mention finances, such as the price of energy technology or their energy bill. Financial incentives can indeed have positive effects on public acceptability, especially when large investments are needed. For example, high up-front costs for energy technology (e.g., solar panels and heat pumps) may reduce the likelihood that the technology will be adopted, while tax rebates, subsidies, and feed-in tariffs that reduce the initial up-front costs and/or the subsequent costs for the energy use can increase public acceptance of such technologies. However, financial incentives do not always have the expected effect on public acceptability, particularly when the amount is small and it is uncertain whether people will benefit at all. Even more importantly, issues other than financial costs and benefits may drive public acceptability. Interestingly, when measured indirectly, financial incentives are not always the main motivation (see also van der Werff et al. in this issue).

Effects on Personal Comfort, Well-Being, and Health

People may be concerned about, for example, noise from wind turbines, the visual impact of high-voltage power lines, or noise and local pollution from bioenergy power plants. Regardless of whether or not such risks are factually true, or even if the chances of any of these risks occurring are very small, such concerns should be taken seriously as they can vividly influence public acceptability.

Renewable Value

Renewable energy projects and energy-efficient technologies such as electric vehicles tend to be more acceptable when people perceive them as signaling something positive about themselves, for example, if they have a positive symbolic function (see also Jans et al. in this issue). People may be proud to be part of renewable initiatives and enjoy making a public commitment to sustainability. For example, in Japan, the names of community members who contributed to a wind park are placed on the wind turbines. Providing financial incentives could potentially impede the signaling value as, if there is money to be earned, it may reduce the opportunity for people to see themselves, and to be seen, as doing the right thing.

Environmental and Societal Consequences

The more people believe that certain energy projects provide benefits to society and the environment, such as public safety and a reliable and sustainable energy supply, the more they may support these projects. There is empirical evidence suggesting that, in comparison with financial arguments, public health and environmental arguments more strongly influence public acceptability. Collective benefits for society at large, as well as for the local community where an energy project is to be sited, can influence acceptability. Research has shown that individuals who strongly self-identify with their country are more supportive of energy infrastructure projects that are labeled as nationally significant and are more trusting of national energy institutions such as grid companies. Providing financial incentives can crowd out intrinsic motivation driven by societal and environmental concerns, and people will cease to act sustainably when the incentives are no longer large enough or when they are taken away.

Fair Distribution of Costs and Benefits

Besides the different types of costs and benefits per se, how the positive and negative consequences are distributed among people, either broadly speaking or within a community, is important for the public acceptability of energy projects. Financial incentives could potentially be a good strategy to compensate the groups that are most disadvantaged by energy projects (e.g., those living in the vicinity of a power plant). At the same time, care should be taken so that such compensations are not perceived as bribes, for example, when people think that developers should address the potential societal and environmental risks and benefits of energy projects rather than providing compensation aimed at only increasing support for these projects. In sum, financial incentives can be effective in influencing public acceptability of energy projects, particularly when large investment costs are at stake. However, financial incentives should be used with care, considering other possible concerns that may drive public acceptability.

Education and Information Can Enhance Public Acceptability

One-way communication from project developers and politicians to the public is usually based on the assumption that people are ignorant or unaware of the benefits of energy projects. Hence, it is assumed that information on the (financial) benefits of the projects will increase people’s knowledge...
Energy projects have implications for four types of values: biospheric, altruistic, egoistic, and hedonic.

and subsequently increase public acceptability. This reasoning is rooted in the classical economic argument that there is a knowledge gap, which should be overcome by providing people with more information. Information is indeed important when people have (yet) little knowledge or hold misperceptions about energy projects, but this is not always the case. Many objectors are not ignorant at all and may emphasize concerns and uncertainties not shared by the experts. Furthermore, knowing about a project or understanding its aims and benefits does not necessarily mean that people will accept it. The communicated benefits may not address people’s key concerns; people may disagree that the benefits outweigh the related costs and risks; they may oppose the way the costs, risks, and benefits are distributed; or they may not be convinced by the information provided. It is important that they trust the responsible parties, the decision-making process, or the technology involved.

One-way communication often occurs and can represent low public engagement in energy projects, making it likely that people will feel that their concerns are not sufficiently considered. This impedes public acceptability. If people have an opportunity to express their opinion, for example, in public hearings, but their voices eventually have little-to-no impact on decision making, their attitudes toward a project will not become more positive and may even become more negative. This is most likely when the rationale for engaging the public is purely instrumental, namely, trying to increase the public acceptance and legitimacy of a proposed project without having to change the project. Public engagement will much more likely lead to better and more acceptable projects when the rationale behind it is normative and substantive, striving for democratic decision making and willingness to integrate lay knowledge and diverse societal values and interests in project development and implementation. To this end, the highest level of public engagement, public participation—which involves a two-way exchange of information, with the possibility of transforming opinions on both sides—is the most recommended form. It implies that developers and the public together discuss the development and implementation of energy projects, reaching for solutions that adequately account for the multiple values and interests of different stakeholders. By definition, public participation requires that people are engaged from the early stages of project development and implementation, when they can still exert influence on decision making rather than being faced with already fine-tuned energy projects. Public participation is the cornerstone of the Aarhus Convention and emphasized in national environmental policies. For example, in The Netherlands, in an ongoing reform of environmental law, the importance of public participation for the quality of environmental projects and their acceptability by civil society is increasingly stressed. Yet many questions remain about how such participation should be organized: when to engage the public (e.g., when sketching sustainability visions or planning specific projects); whom to invite and who will actually participate; which form of participation to choose and how much time, effort, and knowledge should it require from participants; and how to reach an effective and socially acceptable consensus.

**Public Acceptability Will Increase with Time**

There is a general notion that, by nature, people often resist change, which can result in public resistance to any type of change. An intuitive approach to overcome this general resistance to change is to simply go ahead with a project, despite public resistance. Such a "decide-announce-defend" approach relies on the assumption that once all changes are made and energy projects are up and running, the public will automatically get used to them and eventually accept them. Indeed, there are examples where public acceptability increased after energy projects or policies were implemented, particularly when people experienced the benefits. However, in other cases, energy projects had to be reversed or changed because public resistance remained persistent. Examples include carbon capture and storage in The Netherlands and the building of hydropower dams in Patagonia, Chile; in both cases, the authorities initially approved the projects but eventually had to stop them because of the lack of public support. In Chile, this took eight years of persistent opposition from citizens, community groups, and national and international nongovernmental organizations.

One possible reason changes do not get accepted is that people do not feel sufficiently engaged and represented in decision making, for example, when only one-way communication takes place and public input has little to no impact on decision making, as discussed previously. Public participation and engagement early in the siting process can help prevent cancellation or changes later in the process, when substantial investments have already been made.
Caution should be taken in how public acceptability is assessed, for example, whether it refers to people merely not resisting the project that is already there (e.g., because the damage is done and resisting is pointless) or actively supporting the project and thinking positively about it (see the broad definition of public acceptability previously mentioned). In a study in the United Kingdom, 97 participants reported that they accept high-voltage power lines but that they do not support them (Figure 2). A sustainable energy transition can only realize its full potential when people accept and properly use the related energy sources, infrastructure, and technology; make the necessary behavioral changes (e.g., match their energy use to the supply of renewable energy, reduce energy use, etc.); and accept the related policies. Such a broad spectrum of changes is more likely when people strongly support energy projects, rather than when they only passively tolerate them.

One Size Fits All
Misperceptions about the public acceptability of energy projects can lead to thinking that there are one-size-fits-all solutions that can “fix” the lack of public support in many projects and among different people. However, localities where energy projects are to be sited can have distinct settlements, community structures, and meanings associated with them. Consequently, the same energy project can be seen as a disturbing development in one place and as enhancing the community in another. For example, placing large-scale energy infrastructure in rural or coastal areas without such facilities typically leads to social conflict, as communities attempt to protect local landscapes from unwanted “industrialization.” Siting such infrastructure in already-developed locations may be the solution but can bring other difficulties by overburdening certain communities with multiple forms of infrastructure (e.g., transportation and waste). It is essential to take the unique characteristics of local places and their meanings to local people into account in the development and implementation of energy projects. Next, there is no one-size-fits-all solution because people often differ in how they perceive and evaluate energy projects and what they find acceptable, as we discuss next.

People Don’t Agree on What Is Acceptable and What Is Not
Looking only at the energy projects themselves does not fully explain public acceptability, as there are often disagreements among people on whether, and how, certain energy projects should be implemented. Moreover, there is usually no consensus among the public about what is acceptable and what is not. It is, therefore, crucial to take individual factors into account as well to better understand public acceptability of energy projects.

Values define what people find important in their lives in general (see also Steg et al. in this issue). Energy projects have implications for four types of values: biospheric (protecting nature and the environment), altruistic (safeguarding the well-being of others), egoistic (safeguarding personal resources such as wealth and status), and hedonic (seeking pleasure and comfort). People differ in how they prioritize these values and how acceptable they find different energy projects. People accept energy projects that, they think, support their core values, whereas they do not accept energy projects that, they think, threaten their core values. For example, research shows that the stronger their biospheric values, the more acceptable people find renewable energy sources and the less acceptable they find nuclear energy. By contrast, the stronger their egoistic values, the more acceptable they find nuclear energy and the less acceptable they find renewable energy sources. This is probably because people with strong biospheric values are concerned about possible environmental risks of nuclear energy (e.g., nuclear accidents and radioactive waste), while people with strong egoistic values are concerned about possible individual costs of renewable energy sources (e.g., financial costs and intermittency of energy supply).

People pay particular attention to information about energy projects most important for their core values. This could explain why information strategies may not always have the desired effects. For example, information about certain benefits of energy projects will most likely be attended to by people who value these benefits and already support the project (i.e., preaching to the converted). Conversely, people who do not value these benefits as much and/or are primarily concerned about other project consequences may disregard this information. Furthermore, people tend to evaluate many different characteristics of energy projects overly positively or negatively, depending on whether these projects support or threaten their values, respectively. As a result, people may give multiple arguments against (or in favor of) a project that supports their initial value-based position but, at the same time, are not very important to them in light of their values. Addressing such post-hoc arguments by providing information or even by changing the project will probably have little impact on public acceptability. To develop effective strategies that target the root causes of

<table>
<thead>
<tr>
<th></th>
<th>Not Support</th>
<th>Support</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Accept</td>
<td>97</td>
<td>337</td>
<td>434</td>
</tr>
<tr>
<td>Not Accept</td>
<td>151</td>
<td>1</td>
<td>152</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>248</strong></td>
<td><strong>338</strong></td>
<td><strong>586</strong></td>
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**Figure 2.** The frequency of participants accepting and/or supporting high-voltage power lines at a general level in the United Kingdom. (Adapted from S. Batel, P. Devine-Wright, and T. Tangeland, “Social acceptance of low carbon energy and associated infrastructures: A critical discussion,” Energy Policy, vol. 58, 1–5, 2013.)

Public participation and engagement early in the siting process can help prevent cancellation or changes later in the process, when substantial investments have already been made.

Public acceptability of energy projects, it is important to look at which values underlie people’s acceptability judgements as well as their evaluations of the costs and benefits of energy projects. There is initial evidence to suggest that emphasizing the benefits of sustainable solutions for people’s core values reduces their scepticism and increases their support for these solutions. At the same time, it is not possible to reframe any type of energy project as supporting any type of values. For example, research suggests that people with strong biospheric values are not readily convinced by the argument from industry and/or governments that nuclear energy and natural gas are relatively environmentally friendly.

Place Attachment
Energy projects that are large in scale bring fundamental changes to the character, including the visual appearance, of the localities where they are sited. As mentioned earlier, projects may be objected to if they are interpreted as industrializing the character of a place that is considered to be natural, such as a rural landscape or coastal view. Place attachment refers to the ways that certain valued places come to be associated with positive emotional bonds and become important aspects of people’s identities. Research has shown that individuals with strong place attachments, particularly those with “active” place bonds who like to keep up with changes in the neighborhood, may view proposals to site energy projects as a threat to their identity, associated with negative emotions such as anxiety, fear, anger, shock, and frustration, leading to attempts to protect or defend their place from unwanted change. Analyzing the relationships between people’s place attachment and how acceptable they find energy projects can help developers and policy makers better identify how these projects affect a specific locality.

Trust
Energy projects are very complex, and people need to rely on responsible parties for the development and implementation of these projects. The extent to which people trust these parties can deeply influence the public’s acceptance of them. People can be critical about the role of the government and large energy companies in the development and implementation of energy projects, which makes them reluctant to accept them. For example, people may not trust that responsible parties will sufficiently mitigate and adequately cope with the risks posed by energy projects. Trust is a useful heuristic for people to evaluate the project and its implications; generally, the more people trust the regulators, the more acceptable they find the project. Trust in responsible parties can also influence how people respond to provided information to evaluate the costs and benefits of energy projects and whether they think that these costs and benefits are distributed fairly. Importantly, trust can influence and be influenced by how people perceive the decision-making process in an energy project.

Summary and Practical Implications
Public acceptability and its causes are often misunderstood and oversimplified by those responsible for the development and implementation of energy projects. Common misunderstandings about public acceptability can lead to post hoc one-size-fits-all solutions that are ineffective in increasing acceptability and may frustrate people by making them think they are not being taken seriously. Moreover, ill-designed solutions may unwittingly foster greater social conflict instead of reducing it. We argue that public acceptability is a complex construct that depends on the characteristics of energy projects, the qualities and meanings of places where projects are sited, and general psychological and social factors. Furthermore, public acceptability is dynamic and develops over time and can manifest itself in many different forms. Taking these complexities into account, we outline concrete steps for progress toward a sustainable energy transition.

✔ There is not a one-size-fits-all solution. Public acceptability is more than merely toleration or a lack of conflict or controversy. It is a complex construct with multidimensional layers of values that need to be considered over time. We defined four types of values that relate to energy decision making: biospheric, altruistic, egoistic, and hedonic. There are also many different communities and stakeholders in energy decision making that create a mosaic of many different concerns and perceptions of risks and benefits. For example, sense of place drives some concerns about changes to the landscape and seascape that reflect important aspects of people’s identity. Equity is an issue that needs careful attention, so (financial) incentives need to be creative and take people’s key concerns into account.
✔ Sustainable energy transition is a long-term process. Engagement strategies with interested and affected communities are vital.
People accept energy projects that, they think, support their core values, whereas they do not accept energy projects that, they think, threaten their core values.

communities are needed early on and throughout the life cycle phases of project development, implementation, and operations. Also, it is important to continue analyzing and monitoring public acceptability after the projects have been in place for insights into the dynamics and the achieved levels of public acceptability (e.g., tolerance and active support). These analyses become important lessons for future projects. Though commitments to public engagement do not guarantee rapid success, failure is virtually assured without an investment in the process.

✔ Two-way communication with opportunities for the public to influence decision making (i.e., public participation) is often rare but can be critical for success. Public participation should be organized in a way that ensures information exchange between developers and authorities, on the one side, and the public, on the other side, and that diverse societal values and interests are represented in decision making. This requires the consideration of public acceptability and its underlying factors and processes from the very beginning of project development and not only when the project faces strong public resistance. The required public hearing processes linked to environmental assessments are often not sufficient to understand the diversity of public concerns. There is extensive, evidenced analysis on how to facilitate public participation, but these approaches are not widely known or applied.

✔ Trust is a very critical factor in planning and siting processes. Efforts should be made to build trust, although this is not easy to do. Third parties or intermediaries can play a role in ensuring that the process incorporates local concerns beyond what can be discovered at public hearings. People need to recognize that their values and interests are taken seriously.

✔ A diverse project team is needed for developing and implementing energy projects, particularly people with relevant professional backgrounds who can engage with the public and assess its concerns. It is important that project developers, engineers, and policy makers come up with a more robust approach about key factors and processes that drive public acceptability. A more effective team approach may address these factors in information strategies and interventions aimed at changing projects or developing projects differently to increase public support. To develop this approach and incorporate aspects of public acceptability from the beginning, interdisciplinary collaborations among engineers, project developers, environmentalists, and a wide range of social scientists are needed.

For Further Reading


Biographies

**Goda Perlaviciute** is with the University of Groningen, The Netherlands.

**Geertje Schuitema** is with University College Dublin, Republic of Ireland.

**Patrick Devine-Wright** is with the University of Exeter, United Kingdom.

**Bonnie Ram** is with the University of Delaware, United States.
FROM ABOUT 1885 TO 1915, THE most common means of lighting streets was the use of arc lamps. These lamps and the systems by which they were supplied were very technologically sophisticated. These were the first electrical distribution systems. The manufacturing companies that made the equipment for arc lighting went on to be the companies that launched the so-called electrical age.

To appreciate how sophisticated these devices actually were, we need to understand how they functioned. We’ll begin by classifying arc lighting systems as dc, also known as continuous current at that time (not the same as constant current), ac, series-connected constant current, parallel-connected constant potential, and open arc or enclosed arc. Table 1 shows the types of arc lamp systems that were available at the beginning of the 1890s.

A constant potential system is what is now used in almost every case for lighting and power. The voltage is held constant, and the current changes as load is added or removed. This was not always the case. Beginning in the mid-1880s, the series, dc, constant current system came into widespread use to provide arc lamps for street lighting. This system was supplied from special dc generators that were controlled to keep the current flowing to the lamps as close to a constant amperage as possible. We’ll concentrate on these types of lamps and mention the other systems only as they differ from this type.

**Arc Lamps**

First, let’s begin by examining the source of the light—the arc itself. We’ll describe the arc produced in a dc constant current lamp. The arcs produced in the other types of lamps are very similar.

Figure 1 shows two rods or electrodes connected to the supply circuit with the upper electrode at a positive potential with respect to the lower electrode. The D inside the circle stands for dynamo or generator. The lines connected to the circle’s circumference at an angle are meant to represent brushes that allow current to flow from the rotating part of the generator to the stationary circuit conductors. The details of this are beyond the scope of this article. For our purposes, you can think of the generator as a battery.

The potential difference (voltage) between these two electrodes is chosen sufficiently high that when the lamp is started and the electrodes begin to open, an arc is drawn between them.

**table 1. Arc lighting systems.**

<table>
<thead>
<tr>
<th>Constant Current (dc)</th>
<th>Alternating Current (ac)</th>
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<tbody>
<tr>
<td>Open</td>
<td>Enclosed</td>
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<td>Open</td>
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The most visible (ahem) early use of electric power changed forever the face and life of our cities. In this delightful column, Robert Barnett describes the technology, which was remarkably sophisticated. Bob insists he is a technologist, not a historian. “It’s a technology article that just happens to be about old stuff,” he said. But in 1982, he formed the Niagara Society for Industrial History as a support group for a proposed museum in a former Niagara Falls power plant, and he has written a lot of history. A Senior Member of the IEEE, he graduated from the University of Waterloo and Niagara College. He supports his technology/history interest as an industrial control and power designer. He is a senior electrical engineer with Cascades Containerboard Packaging Inc.

Hyde Merrill
Associate Editor, History
This arc is the result of the current heating both the air and the electrodes to a very high temperature (3,500 °C). Electrodes are made from carbon and are frequently referred to simply as “carbons.” The carbon used is usually made from petroleum coke specifically for use in arc lamps. The electrodes are about .25 in (about 6 mm) in diameter.

Figure 2 is a detail showing the gap between the electrodes where the arc is formed. Notice that the upper electrode (positive) has a concave crater in its end, and the lower electrode (negative) is pointed. Current flows from the top positive electrode to the bottom one. The heat produced by this flow of electricity is so high that the carbon volatilizes into a vapor. The melting carbon in the crater of the top electrode and the extremely hot gases in the arc are the chief source of light. In roadway lighting, the top electrode is always positive so that the crater is above the road to project light down onto the street.

Some of the carbon vapor is redeposited on the lower electrode, producing the pointed shape.

Figure 3 shows the distribution of light from a dc open arc lamp, the type we have been discussing. It has no inner globe enclosing the arc, and the arc is open to the surrounding air. All arc...
lamps have an outer globe to protect the arc from the weather and keep the arc’s high temperature and the electrode’s voltage from coming in contact with workers. Notice that the light is projected down toward the street with practically none of it projected upwards. This makes it very suitable for street lighting, although the area directly under the light is darker than that a few feet out. Because of the intense light from the arc, the shadows thrown by it are very prominent.

The carbon vapor from the arc readily combines with oxygen in the surrounding air. This forms a deposit on the outer globe that requires frequent maintenance. More important, however, is the fact that this combined carbon vapor results in a rapid erosion of the carbons.

**Figure 3.** Light distribution from the arc. (From Electric Lighting and Railways. Scranton, PA: ICS, 1901.)
If a street lamp is required to burn all night, it is very frequently fitted with two sets of electrodes. One electrode burns down, and when it is close to being depleted, the second electrode automatically takes over.

As a later modification, a tight-fitting inner globe was added to reduce electrode consumption and the frequency of globe cleaning. An arc lamp with an inner globe is shown in Figure 4. The cylindrical “can” structure above the outer globe contains the arc-gap regulating mechanism that will be described shortly.

General minor maintenance of the arc lamps was known as trimming, no doubt a throwback to the tending of the wicks of oil lamps. Arc lamp trimming involved cleaning the globes and replacing the carbon electrodes. The upper carbons burn down at a higher rate than the lower ones. Cleaning the electrodes was also necessary to ensure that the control system could feed them properly into the arc as the gap lengthened.

It is important that the current through and the voltage across the arc remain more or less constant. A change in either of these quantities can have a great effect on the quality of the light. For the series-arc light system, a device known as a voltage regulator controls the current flowing through the lamp. This device is normally located near the generator in the powerhouse. It senses the current in the line and changes the voltage output of the generator to hold the current constant. As lights are added or removed from the circuit due to maintenance or failure, the resistance of the circuit changes; more lights give more resistance, and fewer lights give less. If the generator voltage was

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**figure 4.** An arc lamp with an inner globe. (From Electric Lighting and Railways. Scranton, PA: ICS, 1901.)
not regulated, the current would fluctuate. For instance, a smaller number of lights would allow more current to flow than was designed for the system. This value was about 5–8 A per open-series lamp, depending on its make and model. The details of how this generator regulator controls the current won’t be dealt with here.

The other quantity that must be controlled is the arc voltage. The wider the gap, the greater the voltage is across the arc and, conversely, the shorter the gap, the lower the voltage. Holding the arc gap constant, or nearly so, controls this voltage. Arc gap voltage is about 6 V in an open-series lamp. Again, this value depends on the lamp’s make and model.

**Arc Gap Control**

In a dc constant current lamp, the arc voltage is controlled by controlling the arc gap. The operation is as follows (see Figure 5). Because this is a series system, when the switch is closed, the lamp is disconnected from the circuit and may be removed for service. Opening the switch places the lamp in operation. Current that the system generator is holding constant then flows through solenoid $S_1$. A magnetic field is established by $S_1$ that produces an upward force on the top electrode. The electrodes that were closed begin to open. This $S_1$ force is opposed by the downward pull of gravity. The field from $S_1$ is tuned so that it just balances the weight of the electrode at a point where the arc is the proper length. During normal operation, carbon is consumed and the arc lengthens. This results in an increased voltage drop across the arc and increases current through $S_2$. $S_2$ is wound in such a direction as to oppose...
the force from S1. Because S2 is wired across the arc gap, its weakening effect is in proportion to the length of the gap; the larger the gap, the greater the voltage across it, and so the more magnetizing current flows in S1. This weakened force allows gravity to begin to move the upper electrode down, closing the arc gap and reducing the weakening effect of S2. This re-establishes the original balance between the two magnetic fields and brings the gap back to the proper length. This is an early example of electrical feedback control.

Figure 6 shows how the upper electrode moves. Notice that the lower electrode is fixed and does not move. The distances in the figure are greatly exaggerated to show how the control operates. In actual operation within the bounds set by friction, the gap is always changing, and the control system (S1 versus S2) is working to bring it back to the correct gap.

In Figure 6, at A, the arc is burning and the gap is in the control range. At B, however, the gap has widened to the point where the arc is not capable of efficiently producing light. The voltage across the arc gap increases and, as described previously, causes the upper electrode to move down to close the gap at C. Notice that the top of the electrode at C has moved down as well. The upper electrode has been shortened as a result of the consumption of its carbon in the arc.

The process begins again at D, where we see that more carbon has been consumed, and the arc has lengthened to the point where control action is again initiated. At E, the proper arc gap length has been restored. Now, however, the length of control that the solenoid can accomplish has reached its limit. This control range is the limit of the length of stroke that the solenoids can accommodate, no more than a few inches. The carbons, however, are in the order of 24-in long to allow them to burn for the length of darkness present where

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**Figure 6.** A carbon feed sequence of control. (From R. Barnett, *The Historical Technologist.* Niagara Falls, ON, NSIH, 1986, p. 36, used with permission.)

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the lamps are installed. A means of feeding the upper electrode into the control range is required.

Initially, this was accomplished by a clockwork mechanism. By the beginning of the 1880s, most arc lamp feeding mechanisms took the form of a clutch. In Figure 6, this clutch is represented by a disk with an internal diameter just slightly larger than the outer diameter of the top electrode. Under its own weight, the upper electrode will slip through the disk when it is horizontal. But if the disk is not held horizontal, it will tend to be rubbed by the close-fitting electrode as the electrode moves by. This will cause the disk to tip and grab the electrode, stopping the electrode’s downward motion.

At E, the disk is forced horizontal because it has hit a stop. The disk no longer holds the electrode, which slips down F, closing the arc gap even further. This closure reduces the arc voltage and hence reduces the influence of S2. S1 is allowed to assert control and move the electrode back up to the control range at G. The process repeats until the usable portion of the upper electrode has been consumed.

This process has simplified the control process and does not properly portray the sophistication required by a well-designed arc lamp regulator. For instance, in Figure 5, there is no resistor shown in series with the coils. This was often provided to determine the set point or the voltage at which the arc is to be controlled. This could be somewhat different for each lamp in a series string. This string would often contain more than 100 lamps. Another resistor might be required to reduce the tendency of the coils’ inductance to cause the electrodes to oscillate or “hunt” during the changing of the arc length. The removal of a lamp from the string due to malfunction or maintenance would cause a momentary change in current through the lamps. This might also result in electrode oscillation. Today, this control system might be mathematically analyzed for stability. Whether or not that was done in the design of any turn of the century arc lamp would be interesting to determine.

Figure 7 shows details of the operating mechanism, with the outer protective can removed, of a Brush Electric Company series dc arc lamp. The globes, which are not shown in this figure, would be mounted below. The series coil is labeled S (S1 in Figure 5), and S’ is the shunt coil (S2 in Figure 5). The control stabilizing resistances are shown as r and r’. N and P are the negative and positive terminals of the lamp, which take the form of hooks used to attach the lamp to a supporting bracket arm. K is the switch used to “short out” the lamp when it is to be removed or worked on. This lamp has two carbons and thus two clutches shown as z. R is a rocker arm that attaches to the armature (not visible in this figure) that
works in conjunction with \( c \) and \( C \) to short the lamp out of the circuit when a malfunction occurs. The two carbons that would be enclosed by the globes are shown at \( u \) and \( v \).

**Power Distribution**

For street lighting, the constant-current series distribution system was very common. This did not just apply to arc lamps but was the case for incandescent street lighting as well. Parallel or constant potential systems were used in building lighting or general applications where the lamps were not a great distance apart.

To fully understand this, one needs a beginner’s understanding of electrical theory. For our purposes, we can begin by taking certain things for granted.

If we add or remove a lamp from the string, then the generator will sense a drop or rise in current and adjust its voltage to bring the current back to the proper value (−10A was typical). This will also bring the voltage that each lamp sees back to 50V. Any lamp, regardless of how far from the generator it is located, will see the same voltage and pass the same current. This was a characteristic of constant-current series distribution systems that made them suitable for street, river, or canal lighting where all the loads were nearly identical.

Even though the system voltage could frequently reach values over 1,000V, the voltage at each device was low.

However, the chief advantage with a series system is that only one conductor is required to feed loads. More often than not, the wires were carried on poles down one side of a street, along a cross street, and then back to the powerhouse on the opposite side of the block. Because the current was low, the size of the conductor can be small. Although #8 AWG was common, a smaller size could have been used. The #8 wire was the minimum size used chiefly because of mechanical strength considerations.

AC systems would eventually be used to deliver current at high voltage and drop this voltage down by means of transformers to a value suitable for lamp operation. Even so, series constant-current lighting systems, both dc and ac, were in use well past the middle of the 20th century. It was a low-current, and hence low-power-loss...
system, that at one time caused the constant-current dc system to be considered (but not seriously) as a means for transmitting power from Niagara Falls to Buffalo.

Probably a greater drawback to the constant-current system was that the only motor that could be used was a constant-current series motor. A series constant-current motor can only produce a constant torque, meaning that the mechanical load determined the motor speed. The more load, the slower the speed. This was not practical for most machines that expected an electric motor to act like a steam engine with a governor—the speed was more or less constant as the mechanical load changed. Typically, lighting installations wanted to add motors because they could then supply power to factories during the day and street lights at night. They didn’t want to replace the constant-current lighting systems in which they already had already invested a great amount of money. There were literally dozens of patents to allow constant current series motors to operate at constant speed on series arc lighting systems. None were practical.

As electric street railways began to proliferate about a decade after arc lighting systems, these street railway powerhouses, using constant potential generators, were the ones that supplied power to the constant-potential, constant-speed motors that would eventually replace the steam engine. By that time, a well-developed electrical manufacturing industry was in place, thanks largely to the large market for arc lamps.

For Further Reading
PowerAfrica 2018 will be a platform for participants from academia, electric utilities and industry to discuss experiences, best practices and associated technical developments that can be applied towards the electrification of Africa, enabling socio-economic development. Power delivery regulations, investments and policies will also be addressed.

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A RECORD-SETTING 3,500 IEEE Power & Energy Society (PES) members and industry enthusiasts blew into the windy city of Chicago 16–20 July 2017 to explore the state of the grid and work toward furthering its security, resiliency, and adaptability. The week followed a proven formula for the PES General Meeting that incorporates informational, technical, and tutorial sessions; committee and working group meetings; poster sessions; a job fair; networking events; tours of technical facilities of interest; companion activities; and the all-important Members Meeting where the business of PES is reviewed.

PES President Damir Novosel remarked, “Our General Meeting exemplifies the value IEEE PES provides to the membership, such as sharing of best practices and innovative solutions addressing fast-paced grid modernization topics among a diverse global audience (utilities, vendors, academia, regulators, and researchers) through panels, papers, committee meetings, and other events. It is great to meet with colleagues we have known for years and welcome new members to this highest-attended General Meeting ever. Sometimes it may be overwhelming to follow the impressive content provided, but the organizing committee and volunteers have done an amazing job to help us get the best value and feel at home in the great city of Chicago.”

The week kicked off at the historic Navy Pier with a bountiful and delicious Welcome Reception where old contacts were reignited and new ones were forged. As a bonus, 2017 was the 100th anniversary of the Navy Pier, the largest public pier in the world, and celebratory events were held throughout the week.

One of the many highlights of the meeting was the Plenary Session, where Joe Svachula, of the host utility, ComEd, officially welcomed the attendees to Chicago, and Shay Bahramirad, also of ComEd, led a creative format of speaker talks, employing a sit-down group interview style. The exciting lineup of participants included:

✓ J. Andrew (Drew) Murphy, senior vice president, Strategic Planning, Edison International
✓ Gordon van Welie, president and chief executive officer, ISO New England Inc.
✓ Terence R. Donnelly, executive vice president and chief operating officer, ComEd
✓ Donata Susca, head of network development within Global Infrastructure and Networks, Enel Group.

The Members Meeting featured an update of PES activities from Novosel
Re-imagining the Electric Grid
Join us for the 2018 PES General Meeting in Portland, Oregon

The 2018 IEEE Power & Energy Society General Meeting will be held from August 5-10, 2018 at the Convention Center and Crown Plaza.

The PES General Meeting attracts over 3,400 professionals from every segment of the electric power and energy industries. It features a comprehensive technical program with paper presentations, poster and panel sessions, a number of technical tours, a student program and companion activities.

As always, IEEE PES has put together an outstanding program, with Super Sessions addressing such topics as:
• Extreme Events and Grid Resiliency
• Energy Storage
• Cyber and Physical Security
• Distributed Generation (DG) Regulation, Engineering, Modeling, and Impacts

Don’t miss this spectacular event- make plans now to attend!

We look forward to seeing you in Portland!

IEEE PES – More Power to the Future!

For more information visit: pes-gm.org/2018
Audience members listen intently to the plenary session panel.

The poster sessions stimulated interesting discussions.

Many attendees congratulated award winners at the dinner.

and stump speeches from the PES candidates for the 2018 offices of president elect, treasurer, and secretary.

Timely and emerging topics were explored in various session formats during the week, including the highly attended Super Sessions, where topics closely followed this year’s theme:

- extreme events and grid resiliency
- energy storage
- cyber and physical security
- distributed generation regulation, engineering, modeling, and impact.

All in all, a total of more than 500 tutorials, technical sessions, paper sessions, poster sessions, committee meetings, working group meetings, and task force meetings were held, disseminating the latest technical information and developing leading practices and standards for the power and energy industry.

For a break from meetings and sessions, a slate of six technology-related tour locations were available to choose from as well as an offering of five general interest locations geared toward companies traveling with members. Other must-mention highlights of the week include the Awards Gala and the Student Program. The Awards Gala, a celebration of the outstanding achievements of IEEE and PES award winners, was reimagined this year to include sombreros for the Fellows and a mariachi band for entertainment. This change from the typical banquet dinner was well received by all. The Student Program included a Scholarship Plus Reception, a Student/Industry/Faculty Luncheon with a career-focused panel session, and a job fair attended by leading companies and organizations in the industry.

Now it’s on to the 2018 General Meeting, “Reimaging the Electric Grid,” Portland, Oregon, 5–10 August.
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THE IEEE POWER & ENERGY Society’s (PES’s) website (http://www.ieee-pes.org) features a meetings section, which includes calls for papers and additional information about each of the PES-sponsored meetings.

January 2018

February 2018

April 2018
IEEE PES Transmission and Distribution Conference and Exposition (T&D 2018), 16–19 April, Denver, Colorado, United States, contact Tommy Mayne, mayne25@charter.net, http://www.ieee-td.org/

May 2018

June 2018
IEEE Transportation Electrification Conference & Expo (ITEC 2018), 13–15 June, Long Beach, California, United States, contact Omer Onar, onaroc@ornl.gov, http://itec-conf.com/

August 2018
IEEE PES General Meeting (GM 2018), 5–10 August, Portland, Oregon, United States, contact Richard Goddard, richard.goddard@pgn.com, or Shane Freepons, Shane.Freepons@pgn.com, http://pes-gm.org/2018/

September 2018
IEEE PES Transmission and Distribution Conference and Exposition—Latin America (T&D LA 2018), 18–21 September, Lima, Peru, contact Alex Arquinego Paz, alex.arquinego@ieee.org, http://ieee-tdlia2018.org/

October 2018

IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe 2018), 21–25 October, Sarajevo, Bosnia and Herzegovina, contact Senad Huseinbegovic, shuseinbegovic@etf.unsa.ba, http://sites.ieee.org/isgt-europe-2018/

November 2018
IEEE International Forum on Smart Grids for Smart Cities (SG4SC 2018), 26–28 November, Genk, Belgium, contact Geert Deconinck, geert.deconinck@kuleuven.be
in my view  (continued from p. 76)

generating equipment or selling power back to the grid. There is power in numbers, and energy consumers have much to gain by joining forces. But at the same time, such a utilitarian view would be overlooking the idealistic, pro-green and pro-environmental motivations driving at least some energy cooperatives or, by contrast, the desire to disengage, even become autarchic from society that may be motivating some others. Clearly, there are collective action dimensions at work here that cannot be adequately captured by the notion of energy consumers alone.

Collective action dynamics can also influence the relations between local energy associations on the one hand and energy providers and municipal governments on the other. The falling cost and greater accessibility of renewable energy technologies—solar photovoltaics in particular—has put these associations into a position where they cannot bargain not just over the price of the energy they consume but also the way in which this energy is produced. For example, the inhabitants of a given city, or even specific city neighborhoods, may decide to produce some or all of the energy they need by installing solar panels on their roofs.

This would obviously affect the way in which they relate to local energy providers—they may no longer need as much gas to heat their homes, for instance, but they may instead have a greater need for energy-related services (e.g., for installing and maintaining solar photovoltaic panels). What they expect from local decision makers—council members, mayors, municipal administrations—may also change, certainly when it comes to the impact of local energy choices on residents’ tax bills, but possibly also with regard to the climate friendliness of broader local energy or transport policies.

Similar issues play out at higher levels also, regionally or even nationally, up to and including fundamental decisions on how to confront climate change and build the low-carbon society of the 21st century. But the main point is the same: as energy consumers get empowered, they begin to make choices, some of which will take them beyond utilitarian cost-benefit calculations and turn them into energy citizens (of course, some people become active around energy or climate issues for nonutilitarian reasons to begin with).

Does any of this matter for energy research and innovation? Of course it does. For example, the drivers and motivations behind energy-related choices and behavior, so important for the success or failure of energy-efficiency measures, have been a central concern for behavioralists and public policy specialists for some time. There is still much we don’t know about the way in which individuals—as well as households or businesses—make these choices. Does it matter whether households are headed by women or men? Do groups—housing co-ops, resident associations, etc.—make different choices than individuals? Are businesses different from households, and if so, in what way? How much of these choices can be attributed to simple cost-benefit calculations, and how do values, gender or social roles, even the way people see themselves and would like to be seen by others, come into the picture? Does naming and shaming work? How about nudging?

The interplay between the choices made by individuals (or households or businesses) and the institutional and governance frameworks surrounding them is an even greater puzzle. In principle, these frameworks should be as open and transparent as possible to encourage maximum engagement and involvement by citizens affected by, for example, plans for a new wind park or additional energy transmission lines in their neighborhoods. In practice, however, citizen involvement is often minimal or token; quite frequently, public engagement strategies are used to generate “social acceptance” for measures planned and decided long in advance. Such strategies can easily backfire, fueling social resistance instead of the hoped-for acceptance and adding to already widespread distrust in politicians and the political process.

So much is known, but how do we make citizen engagement better? What are the hallmarks of a citizen engagement strategy that “works,” allowing policy measures that are in the public interest to go ahead—having been properly aired and debated—but taking due account of the interests and
So much is known, but how do we make citizen engagement better?

concerns of affected communities and individuals? This is much less certain. What, for example, is the best way to bring those concerned around the same table, without the process being hijacked by well-organized pressure groups? What mechanisms work best, well-established methods such as surveys and interviews, combined with public dialogues and debates, or new ones based largely on social media? How should consultative mechanisms relate to elected assemblies and political representatives, who will make the final decisions on the measures considered (or should this be done via public referenda)? Finally, how should businesses and private enterprises go about citizen engagement, over and above their customary engagement with customers to improve the quality of services and products?

Most areas of energy research and innovation struggle with these kinds of questions, all the more so when novel technologies and solutions make the leap from laboratory to marketplace and therefore society (which is why Horizon 2020, the EU-sponsored research framework program, treats the social sciences and humanities as a cross-cutting priority). Yet there is a further frontier: that of energy poverty. Indisputably, when living standards fall due to rising energy prices or falling incomes and livelihoods are endangered by shifts from one energy source to another, the effects can be profoundly disempowering for consumers and citizens alike. Although it would be unfair to blame all of this on the clean-energy transition—retooling the current energy system running on dirty, polluting fossil fuels would require almost as much investment as switching to a new, decarbonized one—it is clear that the corrosive effects of energy poverty, on individuals, regions, even national polities, need more attention.

One way to confront energy poverty is to raise social benefits for vulnerable individuals and families (which, in the European Union, is the prerogative of the member states). But this may not be enough to meet the multiple challenges faced by regions still heavily dependent on fossil-fuel-based industries or the extraction of fossil fuels themselves. What these regions need are comprehensive, multistakeholder strategies in which governments, the private sector, and civil society work together to counter the decline of key industries and the corresponding threat to individual and collective livelihoods. Far from preserving economic models that have become obsolete, these strategies need to make the most of the many opportunities inherent in the clean-energy transition, helping to develop new lines of business, raising overall competitiveness, and thus creating new livelihoods.

Devising ways to reach these goals remains a challenge for decision makers and their constituencies but, also and perhaps, especially for researchers. In the absence of well-thought-out strategies, outward migration is set to continue, with the risk of further fueling economic decline but also the spread of populist ideologies, with ill effects on social and political cohesion, even democratic stability. “Empowering” carbon-intensive regions and their citizens therefore isn’t just about livelihoods and economic well-being, much less about “consumption.” It is about demonstrating that modern, democratic states—acting alone or in the context of intergovernmental or supranational organizations—can devise solutions to pressing societal problems that find the backing of broad popular majorities and that they are reaching out to those in need of special support.

Acknowledgment

This article reflects the views of the author and not those of his employer, the European Commission.

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The IEEE PES Innovative Smart Grid Technologies Conference is being held 19-22 February 2018 at the Washington Hilton in Washington D.C. Registration is now open.

Experts around the world gather annually at the ISGT North America Conference to discuss state-of-the-art innovations in smart grid technologies.

The ISGT 2018 program will focus on the advancements and applications of technologies and practices applied to grid planning, operations, markets and policies to address the effective integration of variable and distributed energy resources, as well as the growing importance of participation of customers and third parties in the generation and management of electricity.

The conference is organized along three tracks:
- Emerging methods and approaches for transmission and distribution system planning and analysis
- The application of technology and supporting tools for transmission and distribution system operations
- Market and policy considerations associated with grid transformation.

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I

IS IT TRUE THAT THE SHIFT TO cleaner, more sustainable forms of energy is “empowering” energy consumers, putting them at the center of the new, greener energy system of the future? Is power really seeping away from the giant energy behemoths of the past to the nimble, green-energy prosumers and cooperatives of the future?

In the face of today’s energy landscape, still dominated by relatively few large, centrally structured energy utilities and system operators, these claims may seem overblown. But the energy landscape is changing, and this has major implications for energy research: the transition to a decentralized, low-carbon energy system powered mainly by renewables—which has only just begun—really does open new horizons for energy consumers and energy citizens alike (an important distinction to which I will return). As they come to grips with these changes, energy researchers must not lose sight of the profoundly disempowering effects of energy poverty and a lack of alternatives for carbon-intensive regions, which can prolong the inevitable exit from the dirty fossil fuels of the past.

Just what does empowering consumers mean? For the European Commission, it means essentially three things: 1) giving consumers more information about their energy bills and greater freedom in choosing their service providers, 2) enabling consumers to manage their energy consumption via novel digital technologies (such as smart meters and demand-response systems) and to become less dependent on the grid by producing and selling energy themselves, and 3) ensuring the protection of consumer privacy and sensitive data while providing safeguards against catastrophic system failure, a growing concern as the digitization of the energy sector is blurring the borderlines to other sectors such as home comfort, entertainment, and even health.

“Providing a fair deal to consumers” is a key theme running through the Energy Union “winter package” (see http://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition) that the European Commission tabled in November 2016. It spells out how innovation and changes to regulation and market design will give consumers a greater say and more control over their energy choices (along with supplementary measures to protect vulnerable consumers and tackle energy poverty). For example, consumers will be able to access certified online price-comparison tools to find the best suppliers, adjust their energy consumption using smart meters that support variable pricing, and store or sell electricity they have produced themselves using a variety of small-scale generation techniques.

This is an important agenda that will strengthen the position of individual consumers, households, or (small and large) businesses in their dealings with energy service providers. But not only that: it has the potential to fundamentally alter the relations between energy consumers on the one hand and the institutional and governance structures surrounding them on the other. Put differently, aside from turning formerly passive energy consumers into more active and informed ones, empowering consumers can also help to make them act as energy citizens.

Why is this distinction important? Because whether you look at people as consumers or as citizens matters: conceptually, when trying to understand energy-related choices and behavior, practically, when designing policies to address people’s concerns, and of course politically, when people get involved and become active participants in energy-related policy making themselves.

Take, for instance, the case of energy cooperatives. One could argue that these are nothing but groups of individual consumers banding together to get a better deal, say, when purchasing

Just what does empowering consumers mean?

(continued on p. 71)
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