



# **Smart Grid (R)Evolution**

**Electric Power Struggles**



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## Smart Grid (R)Evolution

The term “smart grid” has become a catch-all phrase to represent the potential benefits of a revamped and more sophisticated electricity system that can fulfill several societal expectations related to enhanced energy efficiency and sustainability. Smart grid promises to enable improved energy management by utilities and by consumers, to provide the ability to integrate higher levels of variable renewable energy into the electric grid, to support the development of microgrids, and to engage citizens in energy management. However, it also comes with potential pitfalls, such as increased cybersecurity vulnerabilities and privacy risks. Although discussions about smart grid have been dominated by consideration of technical and economic dimensions, this book takes a sociotechnical systems perspective to explore critical questions shaping energy system transitions. It will be invaluable for advanced students, academic researchers, and energy professionals in a wide range of disciplines, including energy studies, environmental and energy policy, environmental science, sustainability science, and electrical and environmental engineering.

JENNIE C. STEPHENS is an Associate Professor and the Blittersdorf Professor of Sustainability Science and Policy at the University of Vermont’s Rubenstein School of Environment and Natural Resources and its College of Engineering and Mathematical Sciences. Jennie’s research, teaching, and community engagement focus on the sociopolitical aspects of energy technology innovation, electricity system change, and climate change communication. She has contributed to the understanding of the social dynamics of wind power, carbon capture and storage, and smart grid, and she brings to this project experience in stakeholder engagement and communication with experts, academics, and the public. She is particularly interested in facilitating social learning as we transition away from fossil fuel-based energy systems toward renewables-based systems.

ELIZABETH J. WILSON is Associate Professor of Energy and Environmental Policy and Law at the Humphrey School of Public Affairs and a Fellow at the Institute on the Environment, both at the University of Minnesota. Elizabeth brings to this project extensive knowledge on the importance of subnational factors in shaping energy policy and technology deployment, with a special focus on policies, regulatory and legal frameworks for emerging energy technologies in states, and Regional Transmission Organizations. Her research has also focused on regulatory and governance systems for carbon capture and sequestration, energy efficiency, and wind power.

TARLA RAI PETERSON is Professor of Environmental Communication at the Swedish University of Agricultural Sciences and holds the Boone and Crockett Chair of Wildlife and Conservation Policy at Texas A&M University. Tarla Rai has published several books and numerous articles on the intersections between communication, policy, and democratic practice, particularly as these intersections relate to science and technology. Her most recent book, *The Housing Bomb*, explores these intersections as they relate to public participation in development of policy that could enhance sustainability. She brings to this project extensive theoretical and critical expertise on public perceptions of environmental issues and technologies and the critical role of both mediated and interpersonal communication in the practice of democracy among members of a pluralistic society.

*We dedicate this book to our families*



## Foreword

What makes a book worth reading? Has it a *theme*, a topic of importance that matters? Perhaps we can use it as a *tool*, to do good things? Can it take us on a *journey* to new worlds? Will it *stretch our minds* and challenge the old thoughts in them? This book, **Smart Grid (R)evolution**, offers value by each of those measures.

If you want a grand and vital *theme*, here it is. No crisis is more all-threatening than climate-change, and nothing we can do about it is more important than controlling the generation of electricity, and no campaign to optimize generation of electricity is viable without:

smarter decisions about which power-plants to turn on and off,  
smarter decisions about which transmission lines to open and close, and  
smarter ways to show customers how their acts affect operations and costs:  
in short, a smarter grid.

This book looks from several angles at the promises and pitfalls that lie between the grid systems of ‘today’ and the emergence of that smarter grid.

Is this book a *tool*? Yes; it’s a multi-task, Swiss-Army-knife, kind of tool, with tips for readers on everything from listening to customers, to looking at data across-the-board, to balancing the pace of infrastructure investments among retail, wholesale, and operational installations and practices. Anyone charged with operating an electrical system, anyone concerned about using an electrical system, and anyone worried about paying for one, will find useful insights in this text.

Is it a *journey*? Yes; this story takes us from the sea-flooded subways of New York, to the mountains of Boulder, to Austin in the Texas plain, and to the North Sea cliffs of Bornholm. Around the world, the book shows us the early seeds and the emerging shoots of a radically new system. It is a journey over time as well as over miles, and from mind to mind, from group to group. It treats, with respect, the hopes of many and the concerns of others. So we are led to both promises and fears, with a calm and reasoned summary of each.



In Emily Dickinson's words, the authors 'tell the truth, but tell it slant,' looking at reality and dreams from multiple angles. In their own analogy, they see disparate groups, each like the blind men touching different portions of an elephant, and they try to move us, together, past those unconnected and disparate views. Thus, they tell the emerging story of smart grid systems from multiple perspectives, with real respect for differing views, but without abandoning the authors' own judgments.

Do the stories and the analyses *stretch our minds* and challenge our old thoughts? Speaking for myself, I've spent three decades nurturing technology change, worrying about climate change, overseeing electric system operations and searching for positive value from disputes as I judged and resolved contested cases about new policies. With that basis – or despite it! – I saw new things here, shifted my weighing of some risk assessments, opened my eyes to the emotions of people with whom I might disagree on policy judgments and widened my sense of the possible in our future. I have to think that any serious reader will see things here that make them reach beyond their old beliefs.

How do the authors do this? Well, part of the answer is simple old-fashioned hard work, since **Smart Grid (R)evolution** is the result of years of gathering of information by three talented and complementary scholars, with a track record of producing good work together. But, its not *just* hard work that makes this book good. There is also an intellectual framework, a conceptual structure, of real merit. The authors' approach is not just technical or economic, but they also consider and present the social and political elements of reaching a social consensus. This process can be labeled 'socio-technical systems analysis.' The label sounds arcane, but it reflects the deep roots and fundamental value of the approach used here.

The authors (like most of us) have emerged from an intellectual tradition that (since the Enlightenment) has increasingly treated knowledge as divided into what Lord Snow called 'Two Cultures,' one focused on literature and social understanding, and the other dedicated to technical and scientific rigor. Fortunately, the authors of this book recognize that few important questions are solely technical and few are solely social. A smart meter's real meaning emerges only as part of a smart grid, just as a smart phone's merit fades if not connected to a smart network. And a smart grid, like a smart network, requires co-ordination among human beings as much as it requires frequency regulation. More generally, the history of technical change illustrates the significance of what I have called 'the heaviness of existing reality.' Moving past the heaviness of current investment requires thinking seriously, and sympathetically, about social and political issues as well as about engineering ones. Yet, the converse is also true; mere social consensus (or even political unanimity) about goals will not hold back an incoming tide or alter "an inconvenient truth." The only likely path forward is to blend social and technical analyses in ways that bridge the divide between "The Two Cultures." This book's deepest and most important strength is that it will help its readers do just that.

Michael Dworkin is Professor of Law and Director of the Institute for Energy and the Environment at Vermont Law School. He serves on the Boards of the Vermont Electric Power Company (VELCO) and of the Vermont Energy Investment Corporation (VEIC) and has been adjunct faculty for the University of Houston Law Center, the University of Waikato Center for Energy Resources and the Environment, and the Engineering & Public Policy Department of Carnegie Mellon University. In the past, he was Chairman of the Vermont Public Service Board, President of the New England Conference of Public Utilities and Member of the Executive Committee of the Electric Power Research Institute.

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## Acronyms

AC	Alternating Current
AMI	Advanced Meter Infrastructure
AMR	Automatic Meter Reader
ARRA	American Recovery and Reinvestment Act
CAES	Compressed Air Storage
CO <sub>2</sub>	Carbon Dioxide
C-BED	Community-Based Energy Development
CREZ	Competitive Renewable Energy Zones
DC	Direct Current
DG	Distributed Generation
DER	Distributed Energy Resources
DIR	Dispatchable Intermittent Resources
DoD	Department of Defense
DoE	Department of Energy
DSM	Demand Side Management
EDF	Environmental Defense Fund
EMF	Electromagnetic Fields
EMS	Energy Management System
EPA	Environmental Protection Agency
ERCOT	Electricity Reliability Council of Texas
EU	European Union
ESCO	Energy Service Companies
FACTS	Flexible AC Transmission System
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information Science
GTI	Grid-tie Inverter
HVAC	Heating, Ventilation, and Air Conditioning
kV	kilo Volts
kWh	kilowatt hour



ICT	Information Communication Technology
ISO	Independent System Operator
MISO	Midcontinent Independent System Operator
MW	Megawatt
NASA	National Aeronautics and Space Administration
NE-ISO	New England Independent System Operator
NRDC	Natural Resources Defense Council
NREL	National Renewable Energy Lab
OLTS	On-Load Tap-Charger
OMS	Outage Management System
PEV	Plug-in Electric Vehicle
PG&E	Pacific Gas and Electric
PHEV	Plug-in Hybrid Electric Vehicle
PTC	Production Tax Credit
PUC	Public Utilities Commission
PUCT	Public Utility Commission of Texas
PURPA	Public Utilities Regulatory Policy Act
PV	Photovoltaic
R&D	Research and Development
REC	Renewable Energy Credit
RF	Radio Frequency
RPS	Renewable Portfolio Standard
RTO	Regional Transmission Organization
SCADA	Supervisory Control and Data Acquisition
SDG&E	San Diego Gas & Electric
SMUD	Sacramento Municipal Utility District
SPIDERS	Smart Power Infrastructure Demonstration for Energy Reliability and Security
SVC	Static Var Compensation
UMTDI	Upper Midwest Transmission Development Initiative
var	Volt-Ampere Reactive