

2ND ANNUAL MINI-RETREAT

Institute for Sustainable Energy



AGENDA

4:00 pm Introductions

4:20 Update on federal funding outlook for energy-related research, Emily Burlij

4:30 Update on ISE activities

4:40 Five-minute, one-slide presentations

Robert Kaufmann

Cutler Cleveland, Chris Meier, Michael Walsh

Patrick Kinney

Justin Ren and David Jermain

Richard Stuebi

Robert Metcalf

5:10 Eric Toone – Guest Presentation, plus Q and A

5:40 Discussion: new ideas for research/collaboration, advice to the ISE

6:00 Meeting adjourns; refreshments

A grayscale photograph of the U.S. Capitol building in Washington, D.C. The image shows the iconic dome and the neoclassical facade with numerous columns and a wide set of steps leading up to the entrance. The sky is overcast with some clouds. The entire image has a dark, semi-transparent overlay.

Department of Energy Update

LEWIS-BURKE

ASSOCIATES LLC

www.lewis-burke.com

Department of Energy (DOE)

- Department of Energy (DOE) has three core missions:
 - Science and Energy (basic and applied research)
 - Nuclear Security (maintaining a credible nuclear deterrent)
 - Environmental Management (cleanup of Cold War legacy sites)
- Since he assumed leadership of DOE, Secretary Perry has been consistent with his 3 major priorities: maintaining the nuclear weapons stockpile, cybersecurity of energy assets, and high performance computing
- Focus of the R&D portfolio is on early stage research and high risk projects where there is no industry investment
- Research priorities include subsurface science, advanced reactor technologies, CO2 utilization technologies, technologies for oil and gas recovery, lightweight materials, materials in extreme environments, quantum materials, sensors, and computing

DOE Leadership

- In addition to Secretary Perry, DOE now has five other Senate confirmed officials in place (six out of 55)
 - Deputy Secretary of Energy Dan Brouillette, most recently Senior Vice President and Head of public policy at USAA
 - Under Secretary for Science Paul Dabbar, most recently Head of Energy Markets and Acquisitions at J.P. Morgan
 - Under Secretary for Energy Mark Menezes, most recently Vice President of Federal Relations for Berkshire Hathaway Energy
 - Assistant Secretary of Energy for Fossil Energy Steve Winberg, most recently Senior Program Manager at Battelle Memorial Institute
 - Assistant Secretary of Energy for Electricity Delivery and Energy Reliability Bruce Walker, most recently the Deputy County Executive for Putnam County, New York
- Pending nomination for David Jonas as General Counsel

FY 2017 Appropriations

- Full FY 2017 appropriations were finally enacted on May 5, 2017
- Office of Science at \$5.39 billion (+0.8%); all program offices (with the exception of FES) received increases over FY 2016
- BES funded at \$1.87 billion (+1.2%)
 - No specific allocation for EFRCs, but all 36 are fully funded
 - \$24 million and \$15 million for JCESR and JCAP, respectively
- BER funded at \$612 million (+0.5%)
 - \$75 million for three BRCs, \$14 million short of FY 2017 request
- HEP (+3.8%), ASCR (+4.2%) and NP (+0.8%) all benefited; 13.2% cut to FES was result of dwindling support for ITER
- ARPA-E funded at \$306 million (+5.1%)
- All applied programs, including EERE, received increases

LEWIS-BURKE

ASSOCIATES LLC

www.lewis-burke.com

FY 2018 DOE Budget Request

- FY 2018 budget proposal includes major increases to defense spending at the expense of non-defense discretionary programs, including R&D
- Proposed cuts are predicated on the supposed need to reduce size of federal workforce and refocus investments on fundamental research not tied to specific applications
- Office of Science would be cut by \$920 million (-17%); all program offices except ASCR would see decreases
 - BES would be funded at \$1.55 billion (-16.9%); EFRCs would be cut by \$11 million, resulting in five fewer centers after FY 2018 competition
 - BER would be funded at \$349 million (-42.9%); BRCs would receive \$40 million, \$35 million below FY 2017 and \$49 million below proposed level for five centers
- All applied programs would see major cuts, ARPA-E would be eliminated entirely
- In keeping with Administration priorities, NNSA would see a 7.6% increase

FY 2018 Energy-Water Appropriations

- Congress has largely rejected proposed cuts in FY 2018 budget proposal as both the House and Senate would maintain or grow funding for Office of Science
 - House: \$5.39 billion (flat relative to FY 2017)
 - Senate: \$5.55 billion (+2.9%)
- While both bills would preserve funding for basic research, they divert substantially on applied programs
 - House would eliminate ARPA-E while Senate would increase by 7.8%
 - House would cut EERE by 47.2% while Senate would cut by 7.3%
 - Both bills would cut Nuclear, Fossil, and Electricity Delivery and Reliability
- NNSA would receive increases in both bills, though they would be smaller than those proposed by the Administration

FY 2018 Office of Science Appropriations

(dollars in thousands)

	FY 2016 Enacted Approp.	FY 2017 Enacted Approp.	FY 2018 President's Request	FY 2018 House Mark	FY 2018 Senate Mark
Science					
Advanced Scientific Computing Research	621,000	647,000	722,010	694,200	763,000
Basic Energy Sciences	1,849,000	1,871,500	1,554,500	1,871,500	1,980,300
Biological and Environmental Research	609,000	612,000	348,950	582,000	633,000
Fusion Energy Sciences	438,000	380,000	309,940	395,000	232,000
High Energy Physics	795,000	825,000	672,700	825,000	860,000
Nuclear Physics	617,100	622,000	502,700	619,200	639,200
Workforce Development for Teachers and Scientists	19,500	19,500	14,000	19,500	19,500
Science Laboratories Infrastructure	113,600	130,000	76,200	105,600	143,000
Safeguards and Security	103,000	103,000	103,000	103,000	103,000
Program Direction	185,000	182,000	168,516	177,000	177,000
Subtotal, Office of Science	5,350,200	5,392,000	4,472,516	5,392,000	5,550,000
Rescission of prior year balances	-3,200	-1,028
Total, Office of Science	5,347,000	5,390,972	4,472,516	5,392,000	5,550,000

Current Funding

- Since October 1, government has operated under a Continuing Resolution (CR) that keeps funding flat relative to FY 2017
- CR passed to give Congress time to negotiate a budget agreement to lift spending caps and work on omnibus bill for remainder of FY 2018
- Negotiations have started but progress is slow due to:
 - Disaster relief for hurricane and wildfire recovery
 - Budget resolution for tax reform
- Budget resolution has passed, but tax reform has a long way to go
- If broader budget agreement isn't reached by December 8 (when current CR expires), Congress will likely pass another short-term CR to allow for continued negotiations
- Lack of funding certainty has prompted DOE to delay release of major solicitations, including EFRCs, Clean Water Technology Centers, SBIR/STTR, and Early Career Faculty awards

AGENDA

4:00 pm Introductions

4:20 Update on federal funding outlook for energy-related research, Emily Burlij

4:30 Update on ISE activities

4:40 Five-minute, one-slide presentations

Robert Kaufmann

Cutler Cleveland, Chris Meier, Michael Walsh

Patrick Kinney

Justin Ren and David Jermain

Richard Stuebi

Robert Metcalf

5:10 Eric Toone – Guest Presentation, plus Q and A

5:40 Discussion: new ideas for research/collaboration, advice to the ISE

6:00 Meeting adjourns; refreshments

FACULTY ADVISORY BOARD



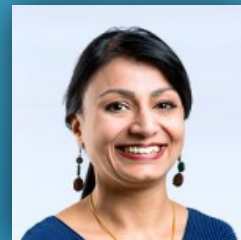
Anthony Janetos
Professor and
Director, Earth &
Environment



Pamela Templer
Associate
Professor of
Biology



Michael
Caramanis
CEESI Co-Director
and Professor,
College of
Engineering



Madhu Dutta-
Koehler
Associate Professor
of the Practice and
Program
Coordinator, City
Planning and Urban
Affairs



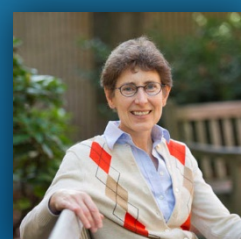
Nalin Kulatilaka
Wing Tat Lee
Family Professor
in Management,
Questrom School
of Business



James Rebitzer
Professor and Everett
W. Lord
Distinguished Faculty
Scholar/Chair,
Questrom School of
Business



Cutler Cleveland
Professor, Earth &
Environment

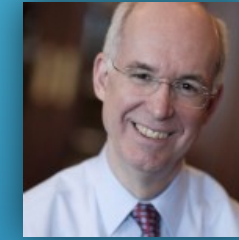


Alice White
Professor (ME, MSE)
Chair of the
Mechanical
Engineering
Department

Executive Committee A/K/A Cognate Deans



Ken Lutchen
Dean, College of
Engineering



Ken Freeman
Allen Questrom
Professor and
Dean, Questrom
School of
Business



Ann Cudd
Dean, Arts &
Sciences



Gloria Water
Vice President
and Associate
Provost for
Research

Ex-Officio



Dennis Carlberg,
Sustainability
Director



Katharine Lusk
Executive
Director,
Initiative on
Cities

HIGHLIGHTS OF YEAR 1

- ▶ \$1 MM in project commitments
- ▶ 9 staff and 11 Senior Fellows
- ▶ Debut of Seminar Series
- ▶ 12 events
- ▶ New space at 650 Beacon Street
- ▶ 1st Annual Briefing

BOSTON UNIVERSITY

Science and Environment: A JOURNALIST'S PERSPECTIVE

Science and policy issues in energy and the environment have become a rich source of material for authors and journalists across the media spectrum. In particular, both the science of climate change and the reporting on that science have become heavily politicized, posing unique challenges for journalism.

This panel discussion explores the evolving role of authors and journalists who work in the energy and environment fields. Each panelist will discuss the evolution of their professional experience and their views on the challenges of writing and reporting in these fields, especially in the wake of the 2016 presidential election.

Featured Panelists



JOSEPH BOMM
Associate Editor,
Water, Climate & Energy
for American Progress
and science editor to
The Christian Science Monitor



MEERA SURBHAMANIAN
Associate Editor, Climate,
Water & Energy for
Science Journalism Fellow



SETH BORENSTEIN
Associate Editor, Climate
and Environment for
Science & the Public



NAOMI ORESKES
Harvard Professor,
co-author of "Merchants
of Doubt" and science
historian

Moderator



JOHN ROGERS
Senior Lecturer, Energy
Studies

**THURSDAY
FEBRUARY 16
4:00–5:30pm
FREE AND OPEN TO ALL**

**WESTIN COPLEY
PLACE HOTEL
10 HUNTINGTON AVENUE
BOSTON, MA 02116**

**Click for Reception to Cellar
Discussion: <http://bit.ly/202724>**

Union of Concerned Scientists

Boston University Institute for Sustainable Energy

**FROM RISK TO RETURN
INVESTING IN A CLEAN ENERGY ECONOMY**

Don Lachof, Chief Operating Officer of American Climate Action, will discuss the new *Risky Business Project* report, *From Risk to Return: Investing in a Clean Energy Economy*. The report goes beyond risk analysis to look at the many opportunities for American business to address climate change risk by building a clean energy economy. The best estimates suggest that we need to reduce greenhouse gas (GHG) emissions by 80% by 2050. To do so will mean transforming the way we produce and use energy. *From Risk to Return* examines the technological and economic feasibility of doing so, using commercial or near-commercial technology.



DON LACHOF
Chief Operating Officer,
American Climate Action

GOALS

- Analyze different energy pathways, focusing on sources of energy that produce little to no carbon dioxide emissions.
- Detail the level of investment needed for each pathway.
- Identify areas of economic opportunity to be created by these energy transitions.

EXAMINING OPPORTUNITIES FOR BOTH AMERICAN BUSINESSES AND INVESTORS TO THRIVE IN A CLEAN ENERGY ECONOMY, THIS REPORT FOCUSES ON:

- The major technological and industrial changes necessary to shift to a clean energy economy.
- The size and timing of capital investments, including comparison with forecasts of nuclear and other major recent investments in technology and industrial use.
- The effect of this transition on different sectors of the economy and regions of the country, including focus on jobs.

THURSDAY, DECEMBER 8, 4–6PM
**HARVARD'S SHAW, BOSTON UNIVERSITY SCHOOL OF LAW
705 COMMONWEALTH AVENUE
BOSTON, MA 02216**

**FREE + OPEN TO THE PUBLIC
PLEASE RSVP
<http://bit.ly/202724>**

BOSTON UNIVERSITY

Boston University Institute for Sustainable Energy

BOSTON UNIVERSITY

You're Invited

INSTITUTE FOR SUSTAINABLE ENERGY INAUGURAL ANNUAL BRIEFING

OCTOBER 19 – 20, 2017

Boston, MA

Participation is Non-Transferable

1ST ANNUAL BRIEFING

Presenters

Jacqueline Ashmore
Stephen Byrd
Michael Caramanis
Cutler Cleveland
Peter Fox-Penner
Michael Gevelber
Jennifer Hatch
John Helveston
Malika Jeffries-EL
Patrick Kinney
Nalin Kulatilaka
Cheryl LaFleur
Michael Lapides
Tom Little
Rob Metcalfe
Uday Pal
Nathan Philips
Jonathan Schrag
Sheldon Simon
Richard Stuebi
Pam Templer

Attendees

AES Solar Energy
Commonwealth Edison
Current powered by GE
The Energy Biss
Enviance
Federal Energy Regulatory Commission
Global Energy Interconnection
Development and Cooperation
Organization (GEIDCO)
Goldman Sachs
Invenergy LLC
Moody's Investor Services
Morgan Stanley
National Grid
New York Power Authority
Noble Americas
Schlumberger-Doll Research
SourceOne
Timberland
US General Services Administration
US Navy
Veolia North America



FERC Commissioner Cheryl LaFleur
presents at the ISE 1st Annual Briefing

YEAR 2 PRIORITIES

- ▶ Move and get settled
- ▶ Execute on our projects!
- ▶ NSF and DOE funding
- ▶ Continue supporting our affiliated faculty
- ▶ Advisory committee and alumni outreach
- ▶ Evolve management structure

AGENDA

4:00 pm Introductions

4:20 Update on federal funding outlook for energy-related research, Emily Burlij

4:30 Update on ISE activities

4:40 Five-minute, one-slide presentations

Robert Kaufmann

Cutler Cleveland, Chris Meier, Michael Walsh

Patrick Kinney

Justin Ren and David Jermain

Richard Stuebi

Robert Metcalf

5:10 Eric Toone – Guest Presentation, plus Q and A

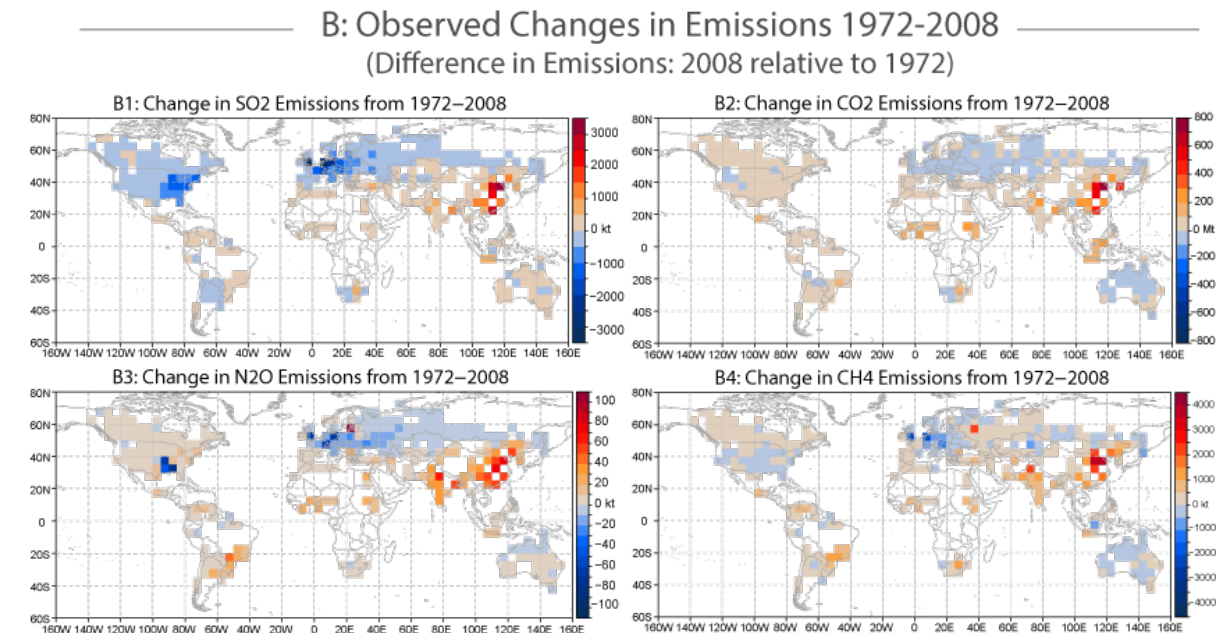
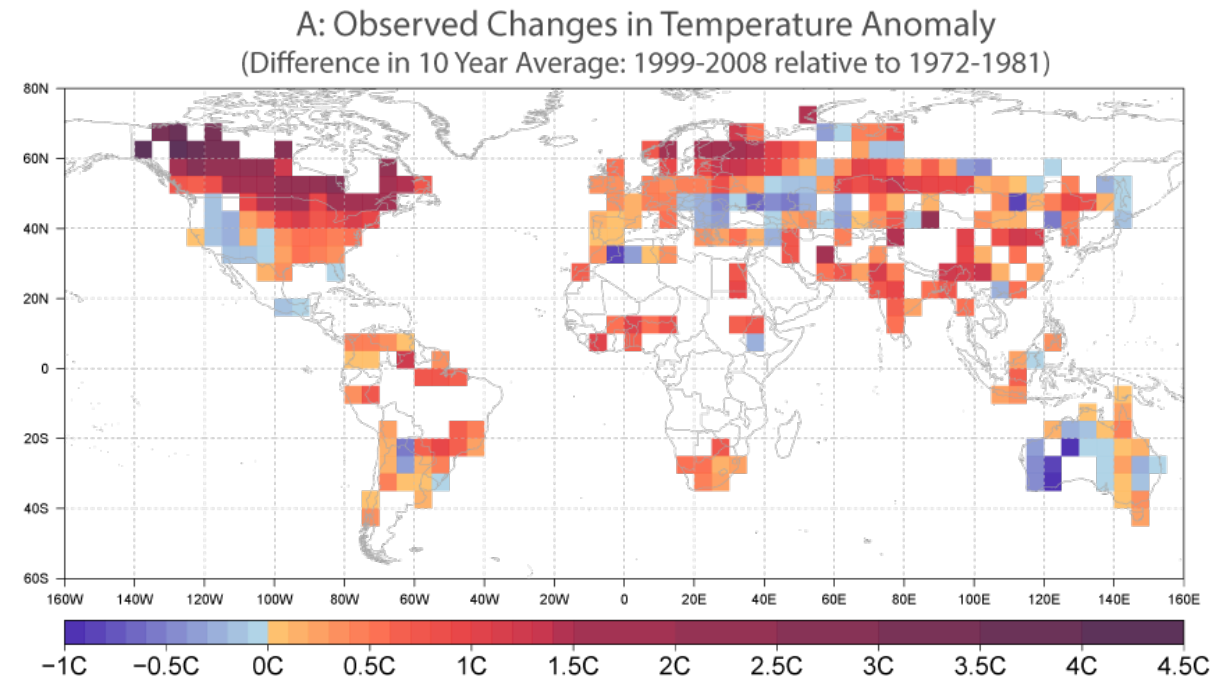
5:40 Discussion: new ideas for research/collaboration, advice to the ISE

6:00 Meeting adjourns; refreshments

Why is this important?

- **Policy Analysis** Reducing emissions generates local changes in temperature
- **Climate Impact** Systematic differences between developed and developing nations
- **Attribution** First direct evidence between human activity and climate

Pretis, F., R.K Kaufmann°, and S. Gopal, Local emissions affect local climate: attribution, impacts, and policy



Health Benefits Assessment of EVs in Boston

A concept note – Pat Kinney

- Compute pollution emission reductions for complete conversion of light duty and/or heavy duty fleets to electricity
 - ▣ Focus on region inside Rt 95?
- Convert emission reductions to particulate matter and ozone air pollution levels at ground level using GEOS-Chem and statistical downscaling
 - ▣ Both within and outside emission reduction region
- Overlay pollution levels with populations, and compute changes in health status (e.g., mortality, hospital admissions, asthma exacerbations, school absences)
- Extend to other cities

Richard Stuebi: Portfolio of ISE Activities

Area of Activity	ISE Collaborators	Status
Haiti	<ul style="list-style-type: none"> Jennie Hatch Jacque Ashmore 	<ul style="list-style-type: none"> Phase One literature review half-complete Phase Two (2018) deep-dive on implications of electric cooking on microgrid economics
Energy Finance	<ul style="list-style-type: none"> Nalin Kulitilaka Paulina Swartz 	<ul style="list-style-type: none"> Funded project under discussion with Hannon Armstrong to investigate correlation between stock performance and carbon emissions Project under development regarding consequences of bundling solar loans through installers Opportunity being explored for ExecEd on finance to solar project installers
Northeast US Energy Research	<ul style="list-style-type: none"> Kira Fabrizio Jacque Ashmore 	<ul style="list-style-type: none"> Partnership discussions underway with NECEC to form regional economic/policy/strategy research capability One funding sponsor already identified, others TBD
Greentown Labs	<ul style="list-style-type: none"> Jacque Ashmore Tess Kohanski Paul McManus 	<ul style="list-style-type: none"> Early-stage of partnership discussions (a la Greentown-Tufts)

BU/Columbia-Bloomberg-GEIDCO Project

- (1) BU/Columbia: An overview of potential energy transition roadmaps of China and US (2030, 2040, 2050), primarily including energy structure, technical economy, carbon emission situation and key policies.
- (2) GEIDCO: Electrification in Africa and Latin America
- (3) BU/Columbia: A comparative study of electric vehicle and charging infrastructure network development in China and US

GEIDCO Vision

- Ultra high voltage transmission
- Globally interconnected renewable resources
- Universal access to affordable sustainable energy platforms

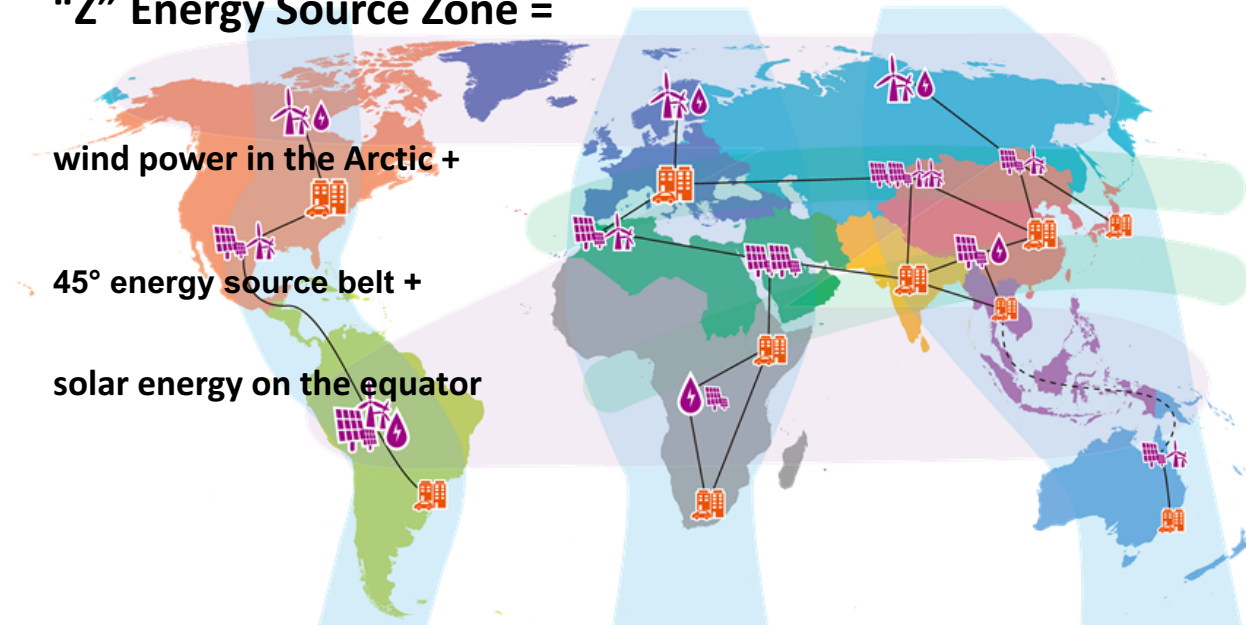


BU Team

- _ Principal investigator: Dr. Peter Fox-Penner
- _ Co-Leader: Dr. Justin Ren
- _ Senior Fellow ISE: David Jermain

Columbia University as partner is the effort

“Z” Energy Source Zone =



AGENDA

4:00 pm Introductions

4:20 Update on federal funding outlook for energy-related research, Emily Burlij

4:30 Update on ISE activities

4:40 Five-minute, one-slide presentations

Robert Kaufmann

Cutler Cleveland, Chris Meier, Michael Walsh

Patrick Kinney

Justin Ren and David Jermain

Richard Stuebi

Robert Metcalf

5:10 Eric Toone – Guest Presentation, plus Q and A

5:40 Discussion: new ideas for research/collaboration, advice to the ISE

6:00 Meeting adjourns; refreshments

The Origin of Breakthrough Energy



Breakthrough Energy Ventures

- One year later, BEC members committed more than \$1 billion to Breakthrough Energy Ventures (BEV).
- BEV evaluates potential investments based on four primary criteria:

01

CLIMATE IMPACT

We will invest in technologies that have the potential to reduce greenhouse gas emissions by at least half a gigaton.

02

OTHER INVESTMENTS

We will invest in companies with real potential to attract capital from sources outside of BEV and the broader Breakthrough Energy Coalition.

03

SCIENTIFIC POSSIBILITY

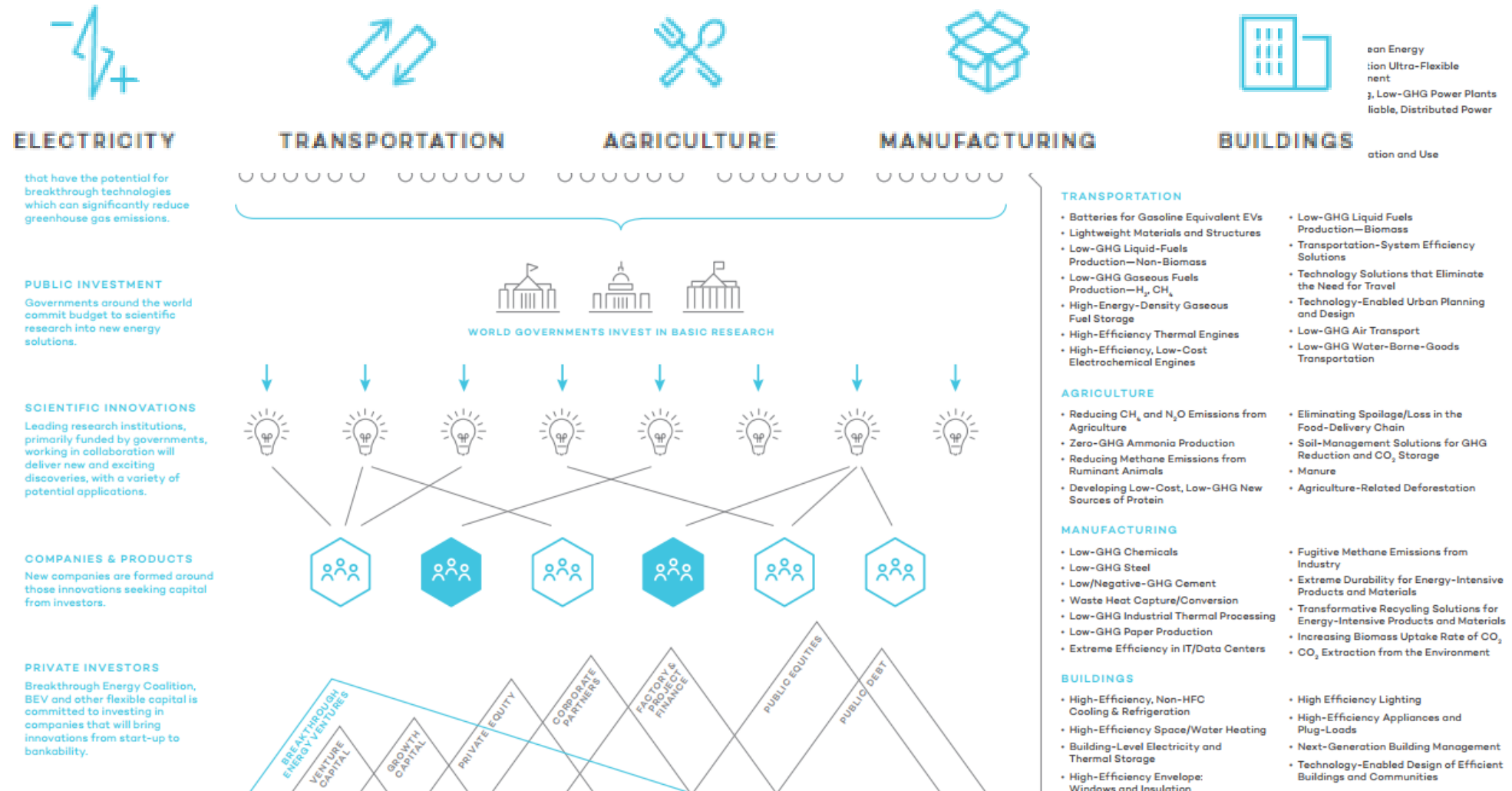
We will invest in technologies with an existing scientific proof of concept that can be meaningfully advanced.

04

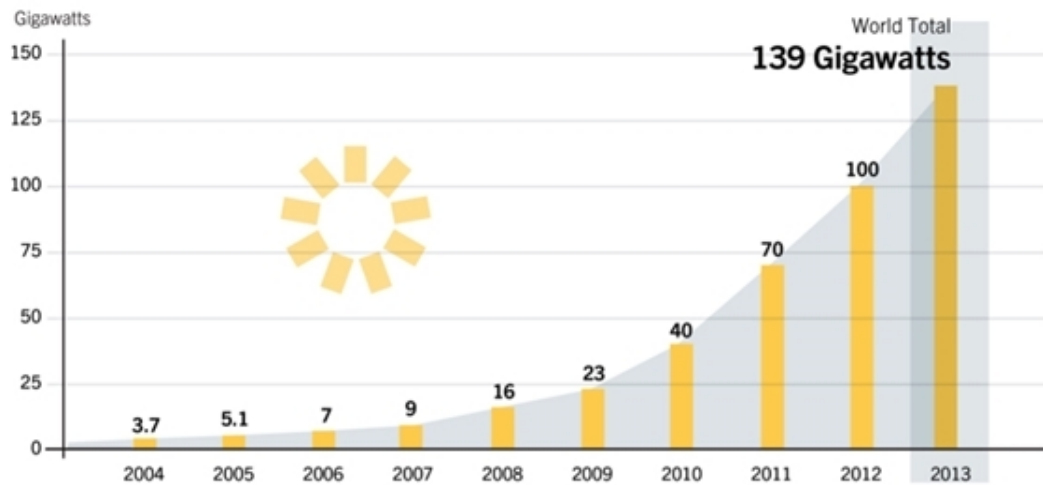
FILLING THE GAPS

We will invest in companies that need the unique attributes of BEV capital, including patience, judgment by scientific milestones, flexible investment capabilities, and a significant global network.

Breakthrough Landscape of Innovation



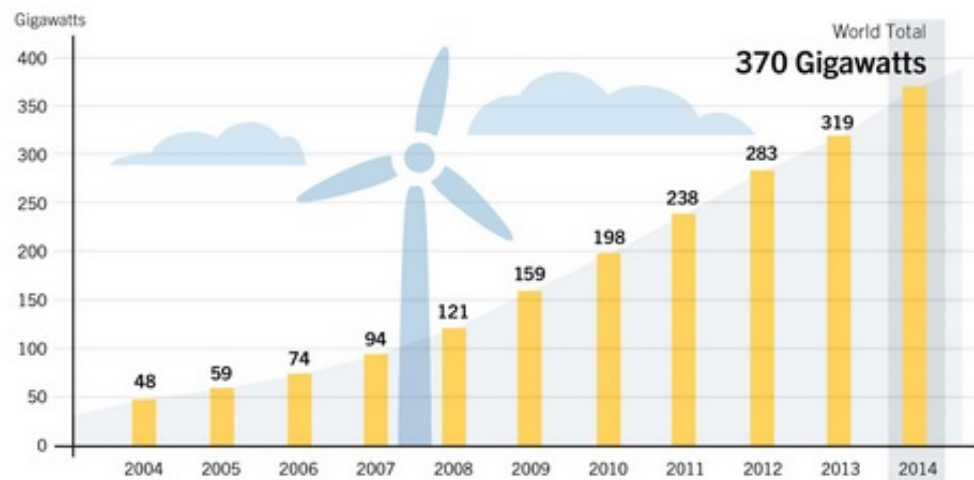
Solar PV Total Global Capacity, 2004–2013



REN21 Renewable Energy Policy Network for the 21st Century

REN21. 2014. *Renewables 2014 Global Status Report* (Paris: REN21 Secretariat).

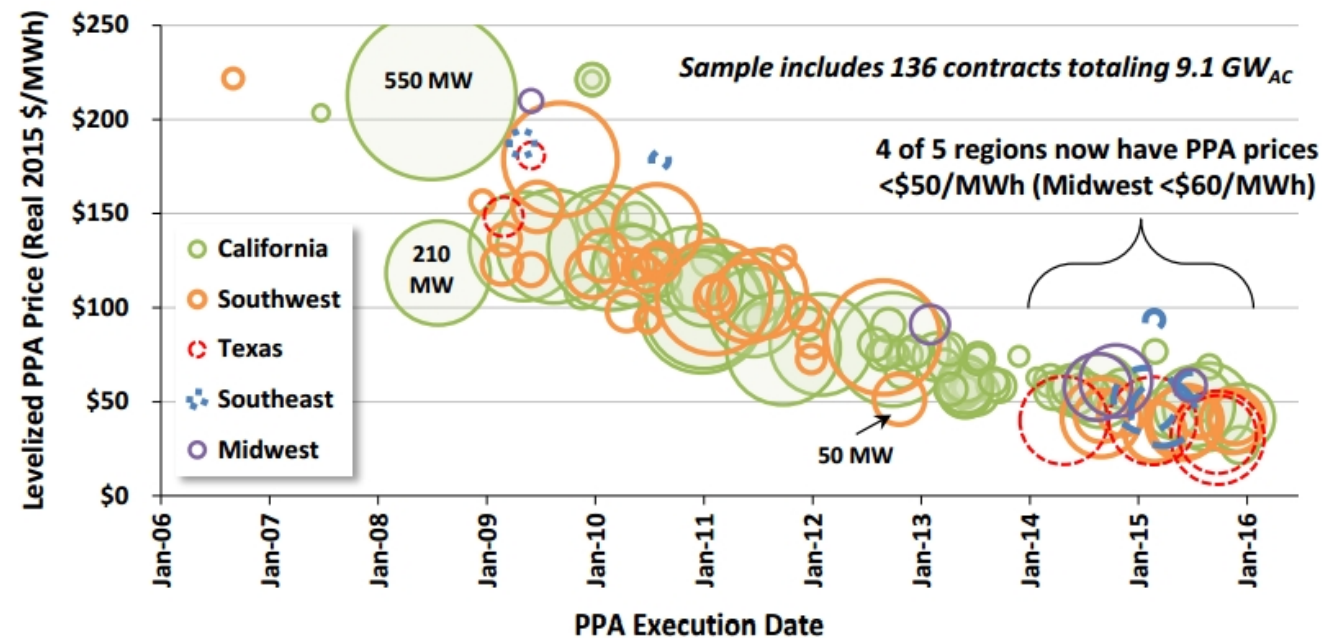
Wind Power Global Capacity, 2004–2014

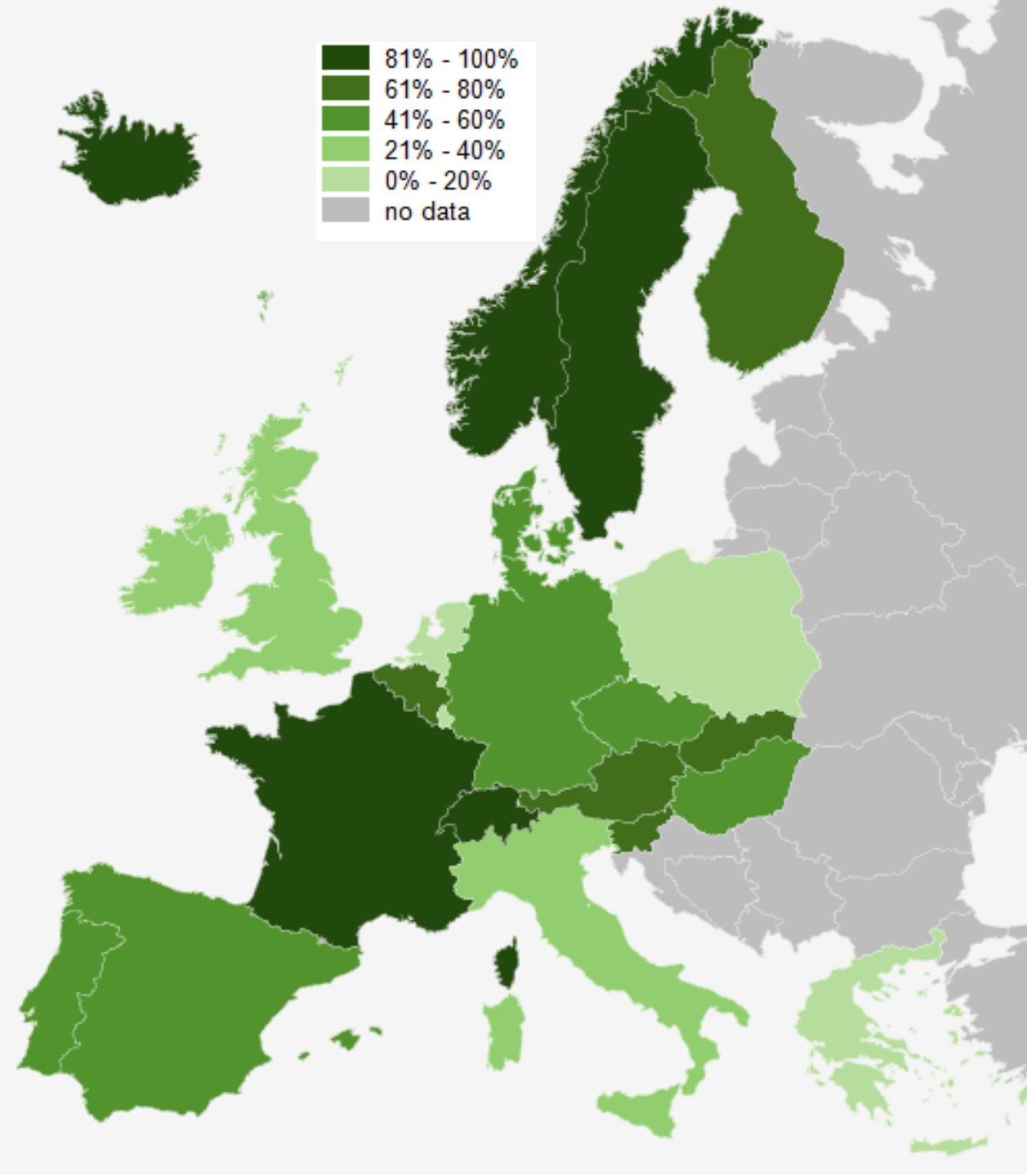


REN21 Renewable Energy Policy Network for the 21st Century

REN21 *Renewables 2015 Global Status Report*

Megatrend 1: Enormous Quantities of Low Price Renewable Electricity





China Puts Chill on New Wind Capacity

Six regions of northern China were ordered to suspend the approval of new wind projects this year. That's because too many turbines already sit idle, the result of grid constraints and other factors that highlight China's growing pains on the road to cleaner power.



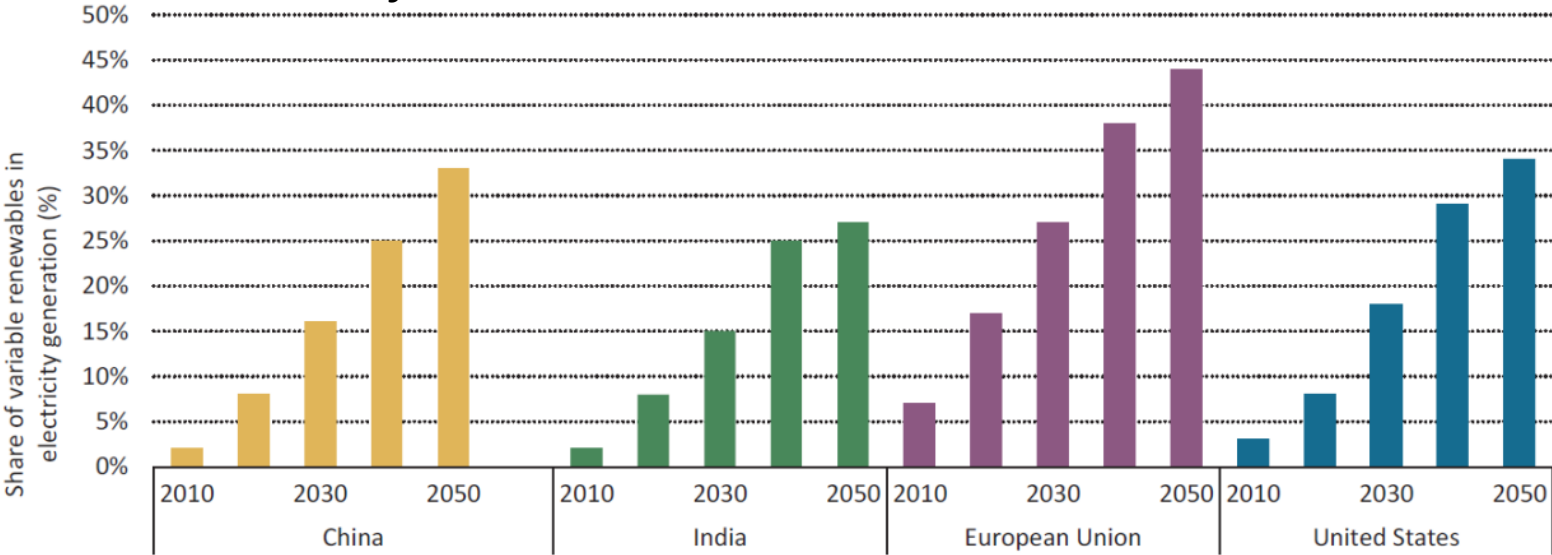
	TOTAL GRID-CONNECTED INSTALLATION AT THE END OF 2015 (in gigawatts)	WIND POWER CURTAILMENT RATE (percentage of energy wasted)	
		2014	2015
CHINA	129.34 GW	8%	15%
Inner Mongolia	24.25 GW	9%	18%
Ningxia	8.22 GW	0%	13%
Gansu	12.52 GW	11%	39%
Jilin	4.44 GW	15%	32%
Heilongjiang	5.03 GW	12%	21%
Xinjiang	16.11 GW	15%	32%

SOURCE: China's National Energy Administration
PAUL HORN / InsideClimate News

Deep Penetration of Intermittent Renewables:

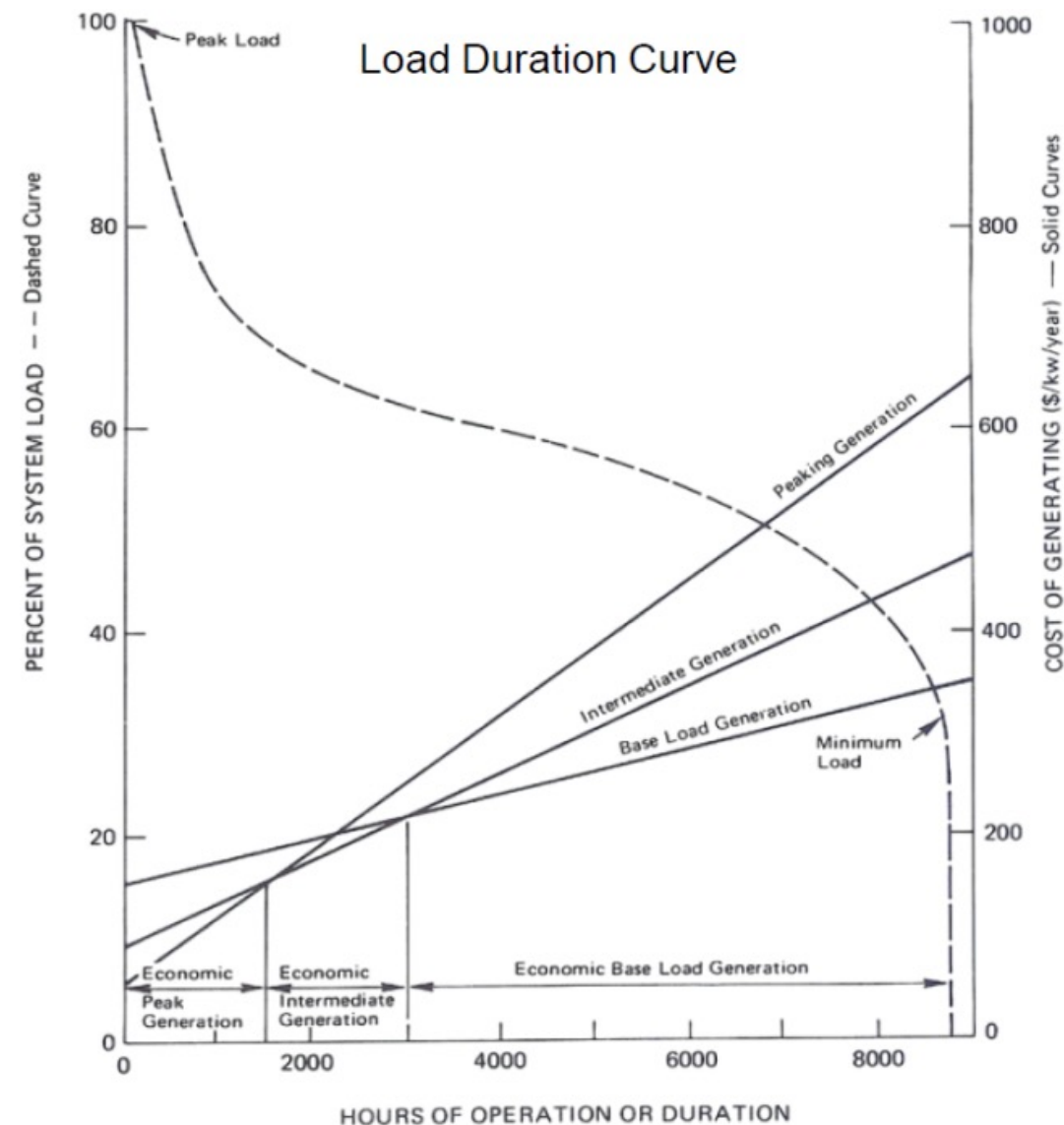
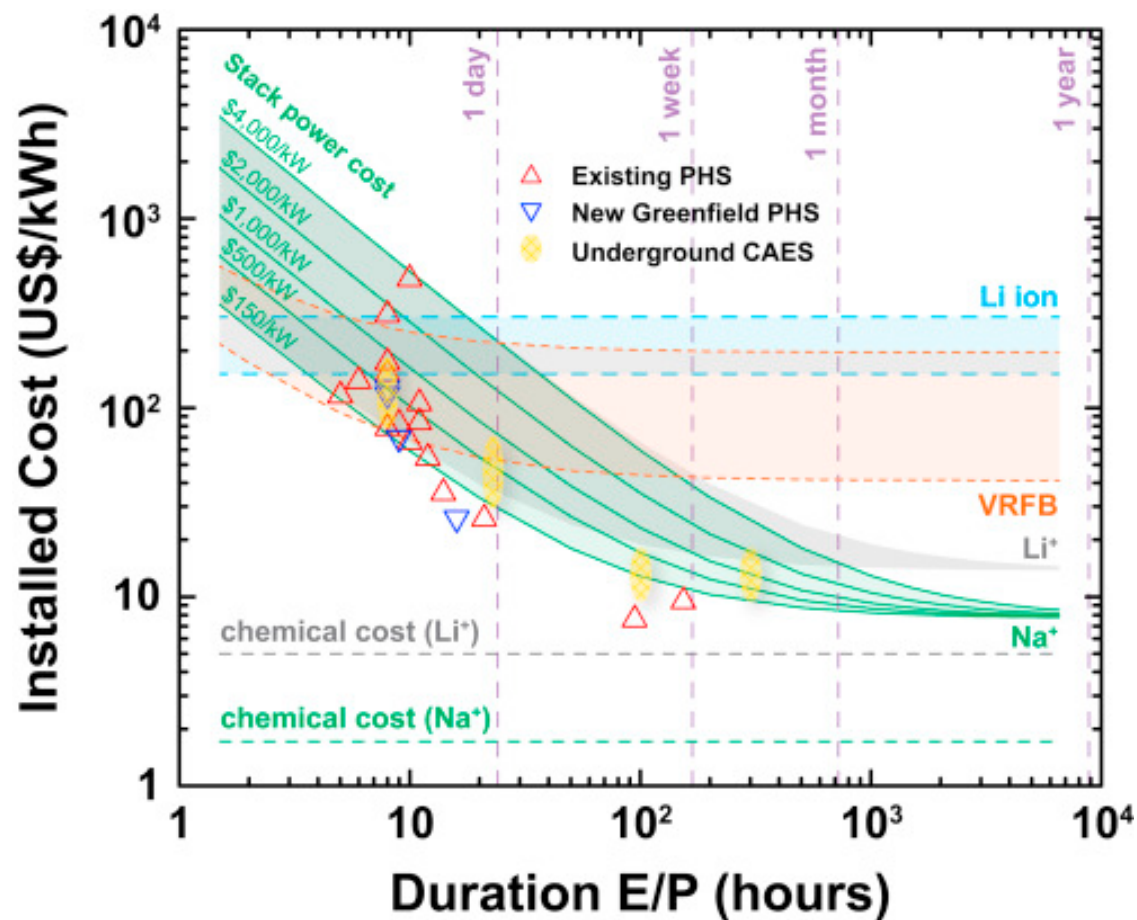
- Use an optimal mix of wind and solar resources.
- Use transmission to connect regional grids.
- Adjust industrial use patterns.
- Develop long-term storage technologies.
- Develop flexible, dispatchable zero-carbon power sources.

Projected Growth in Intermittent Renewables

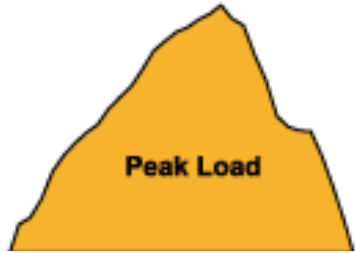


How Much Can That Storage Cost?

$$LCOS = \frac{\sum (Capital_t + O\&M_t + fuel_t) \times (1 + r)^{-t}}{\sum MWh_t \times (1 + r)^{-t}}$$



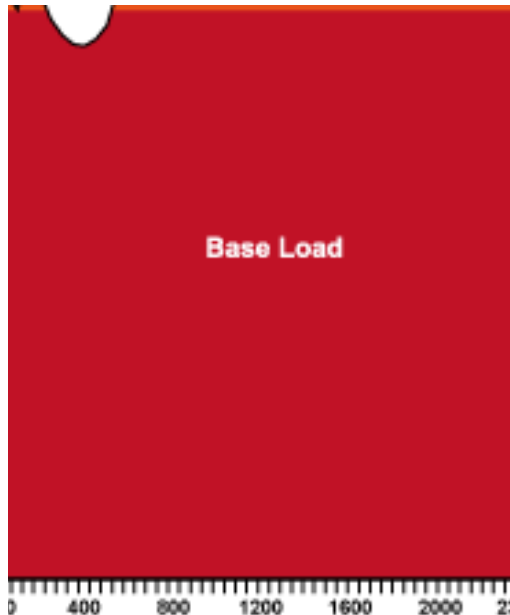
Where Are We Now?



2 - 4 Hour blocks; $>\$200/\text{kWh}$



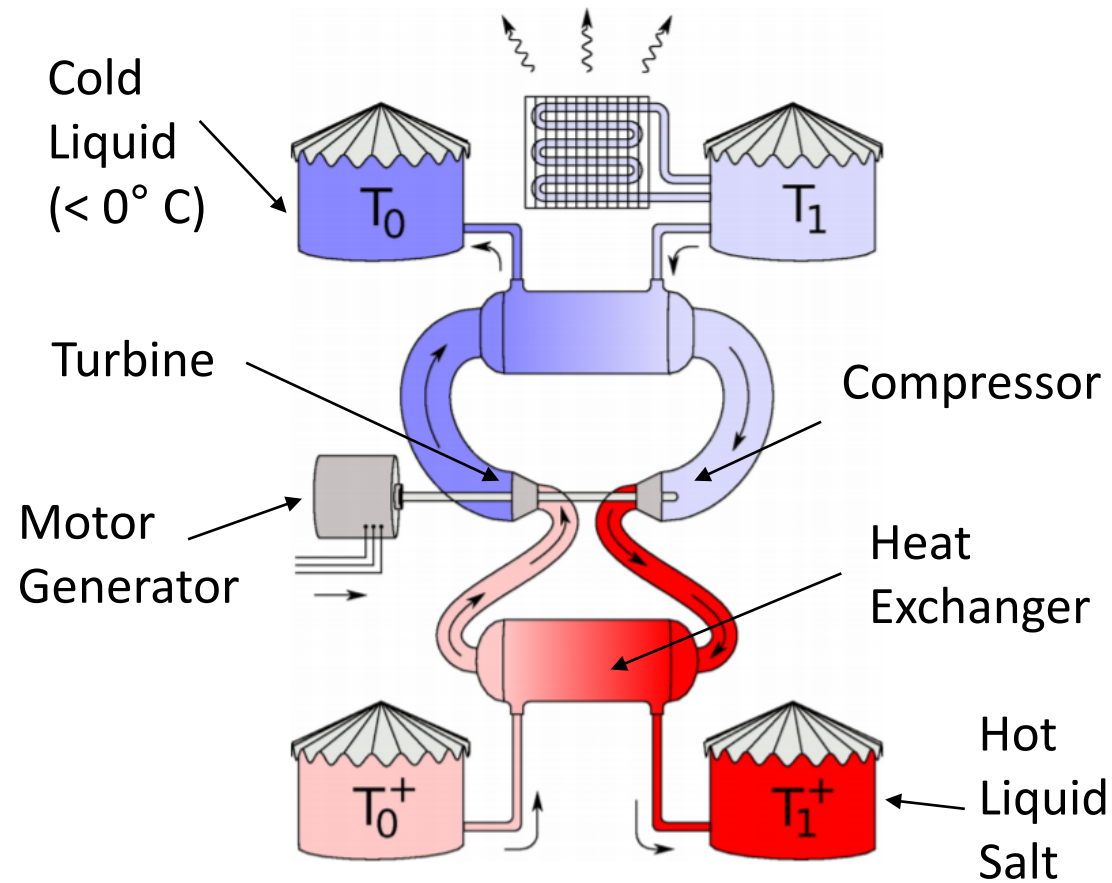
6 - 12 Hour blocks; $<\$100/\text{kWh}$



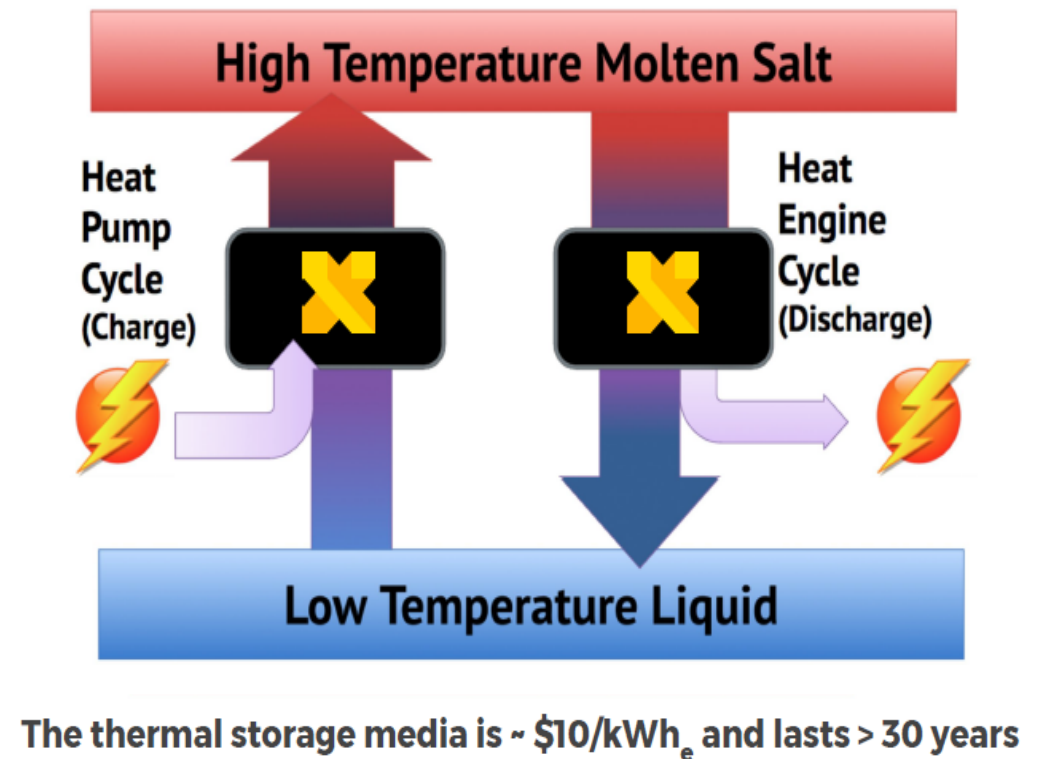
Multi-day blocks; $<\$10/\text{kWh}$



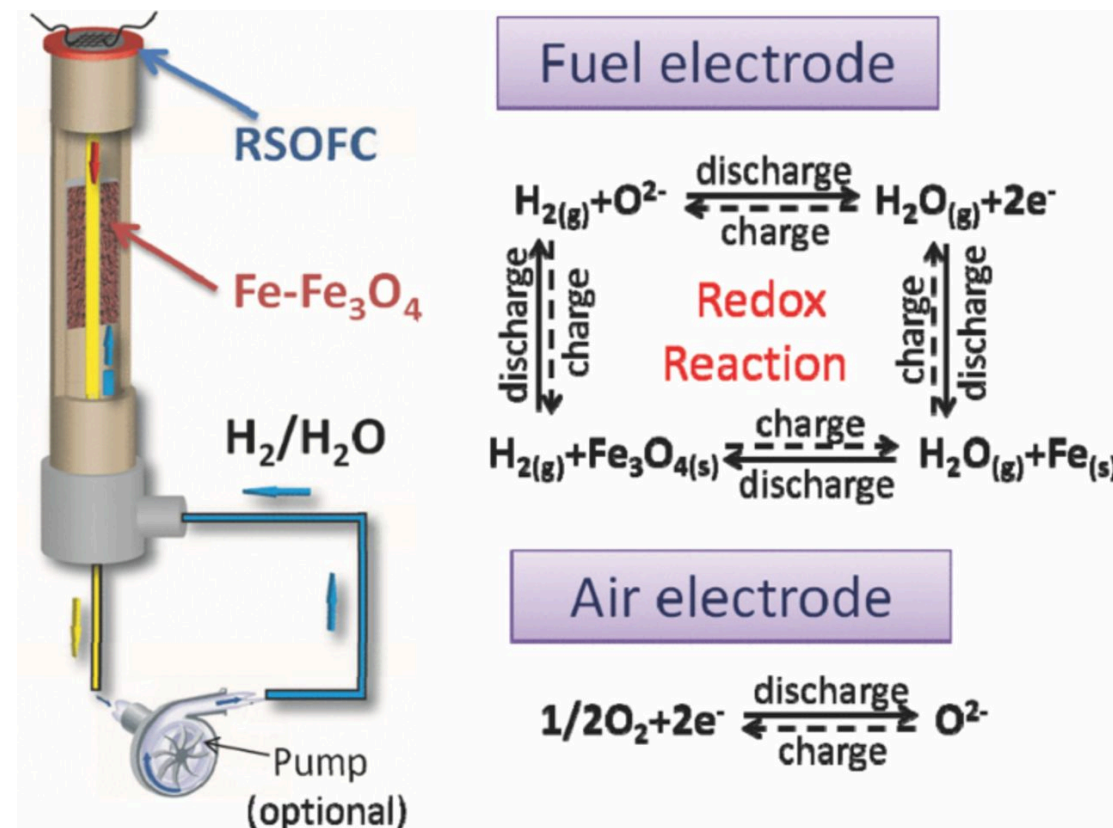
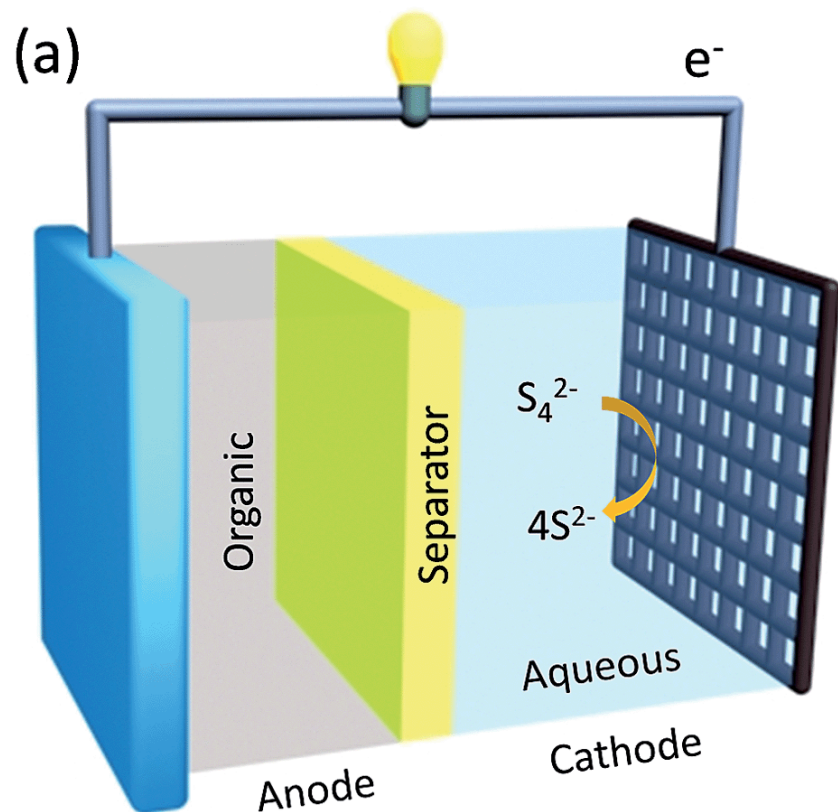
Storage Using Heat Pump and Engine



Store Energy as Heat



Ultra-Cheap, Earth Abundant Electrolytes



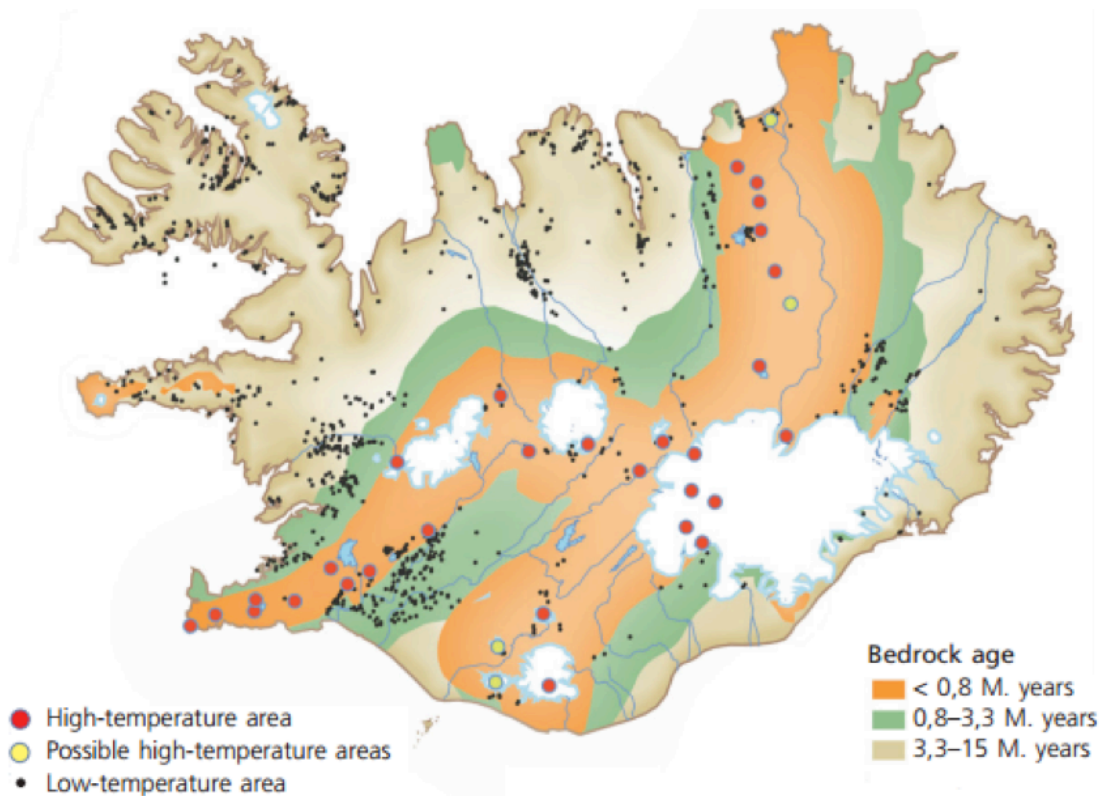
Li et al., *Energy Environ. Sci.*, **2014**, 7, 3307-3312

Zhao et al., *J. Electrochem. Soc.*, **2013**, 160, 1241-1247.

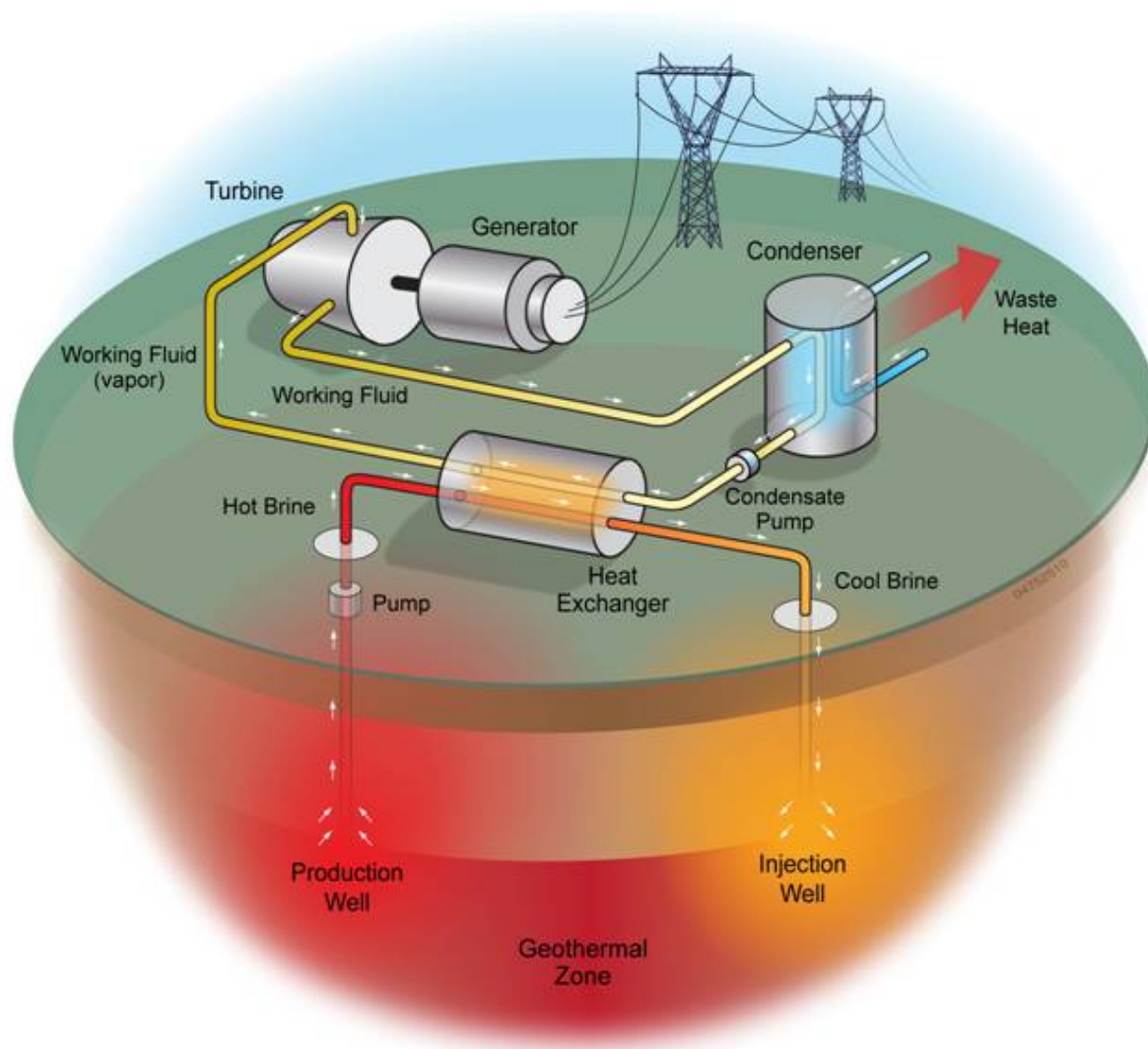
Geothermal: A Zero-Carbon Alternative?

Geothermal is an important, but small, resource.

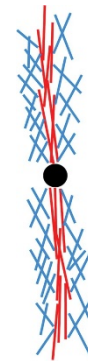
Traditional geothermal requires highly specialized geology



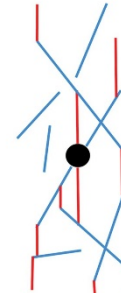
EGS: A 100 GW Opportunity



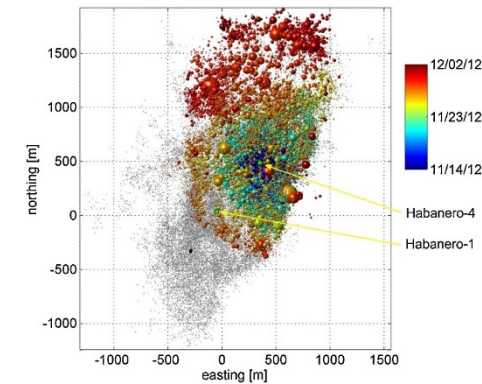
Enhanced (or Engineered) Geothermal induces flow through the use of fluid and/or induced porosity.



PFSSL

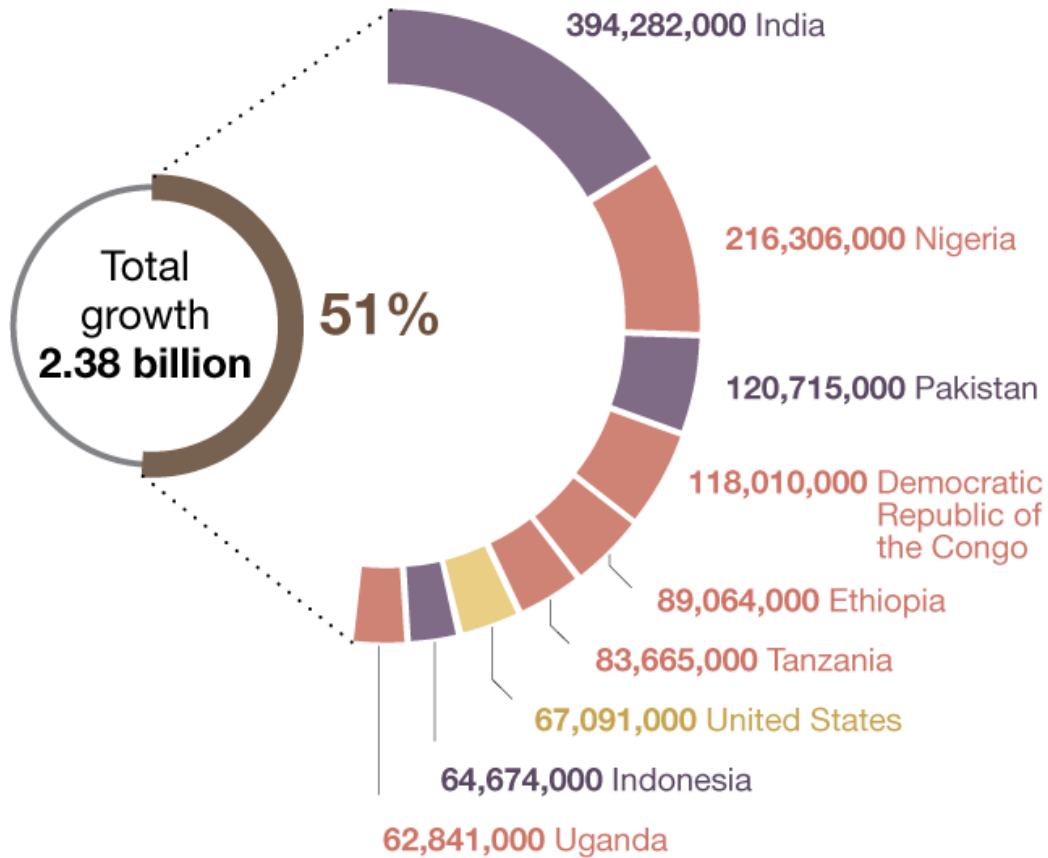


MMS

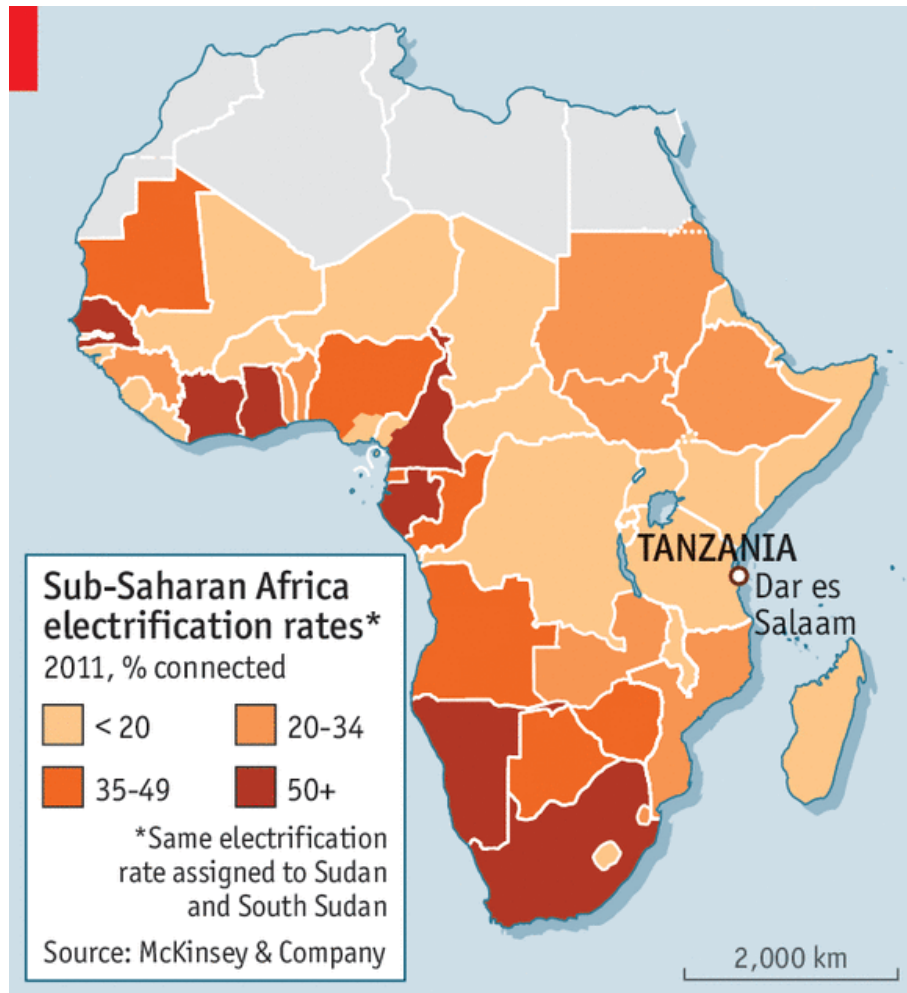


Advances from shale extraction coupled with fundamental research in porosity and flow enable a massive opportunity.

Megatrend 2: A Burgeoning Middle Class



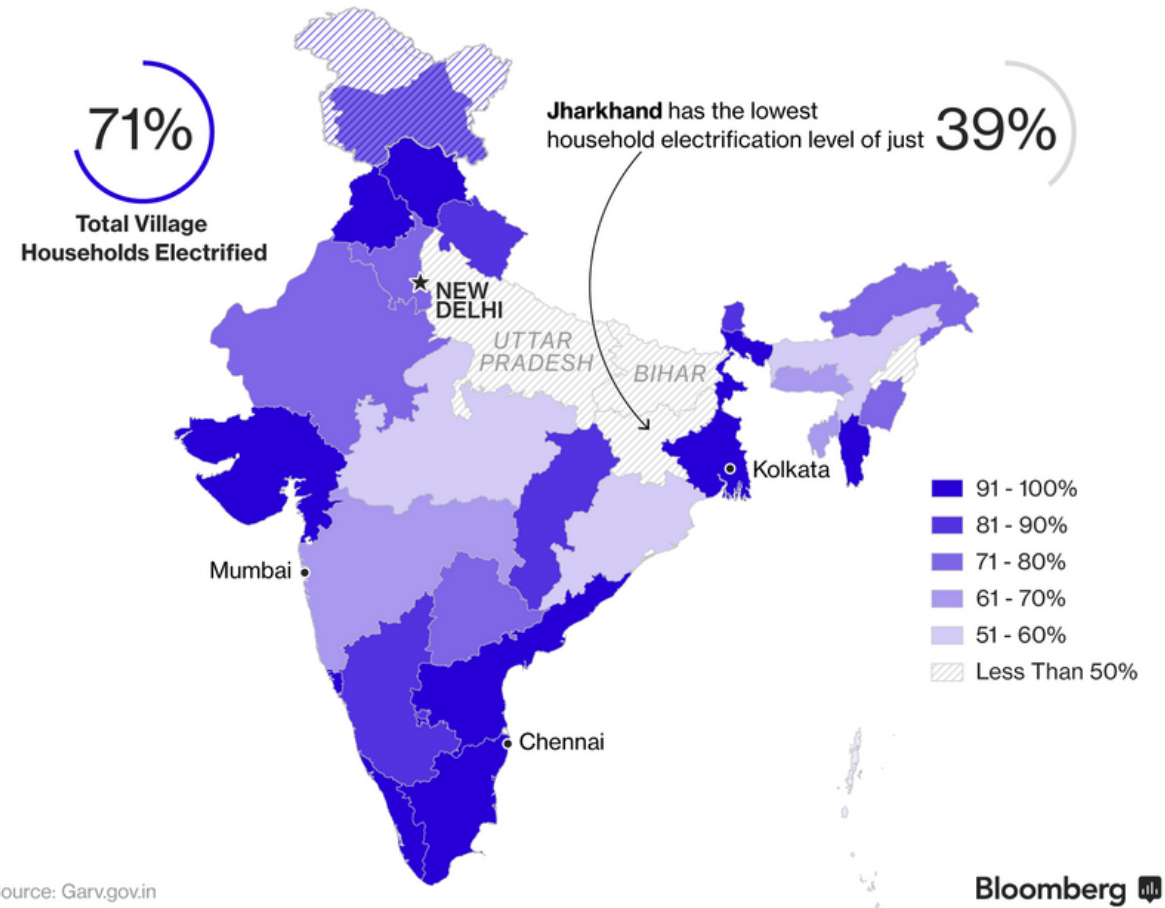
Implication 1: Access to Energy



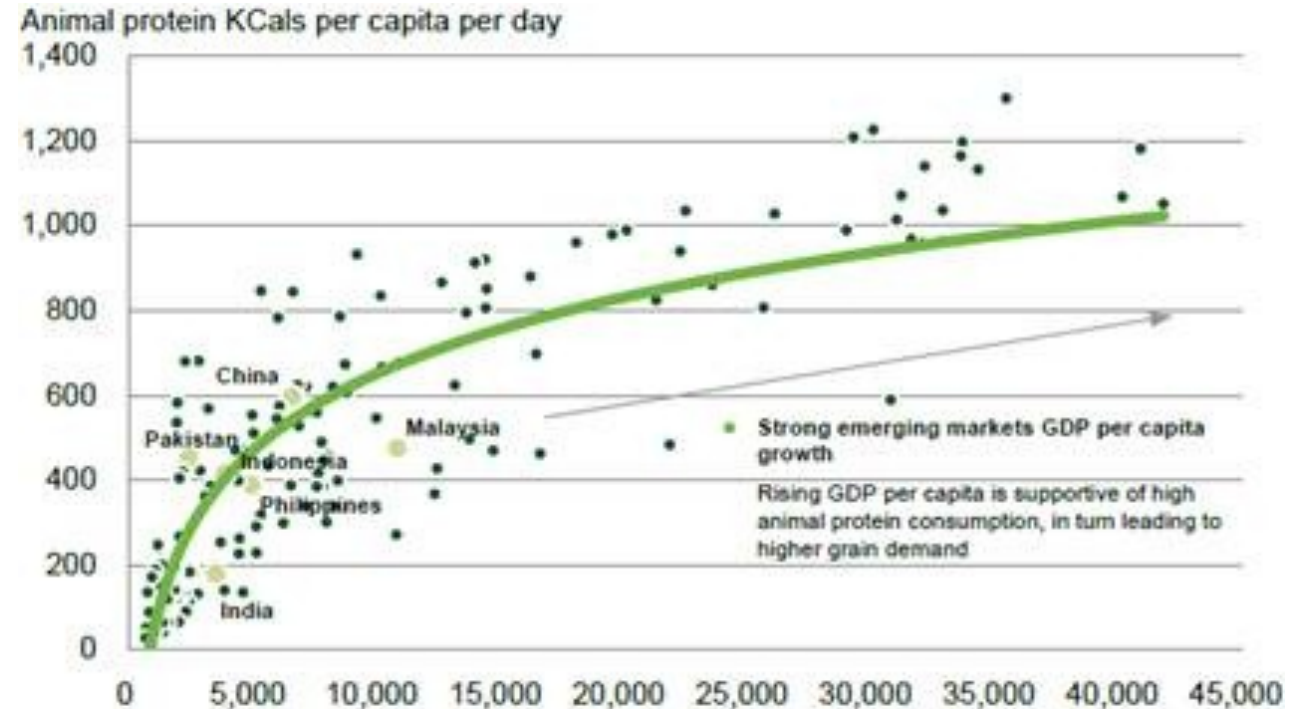
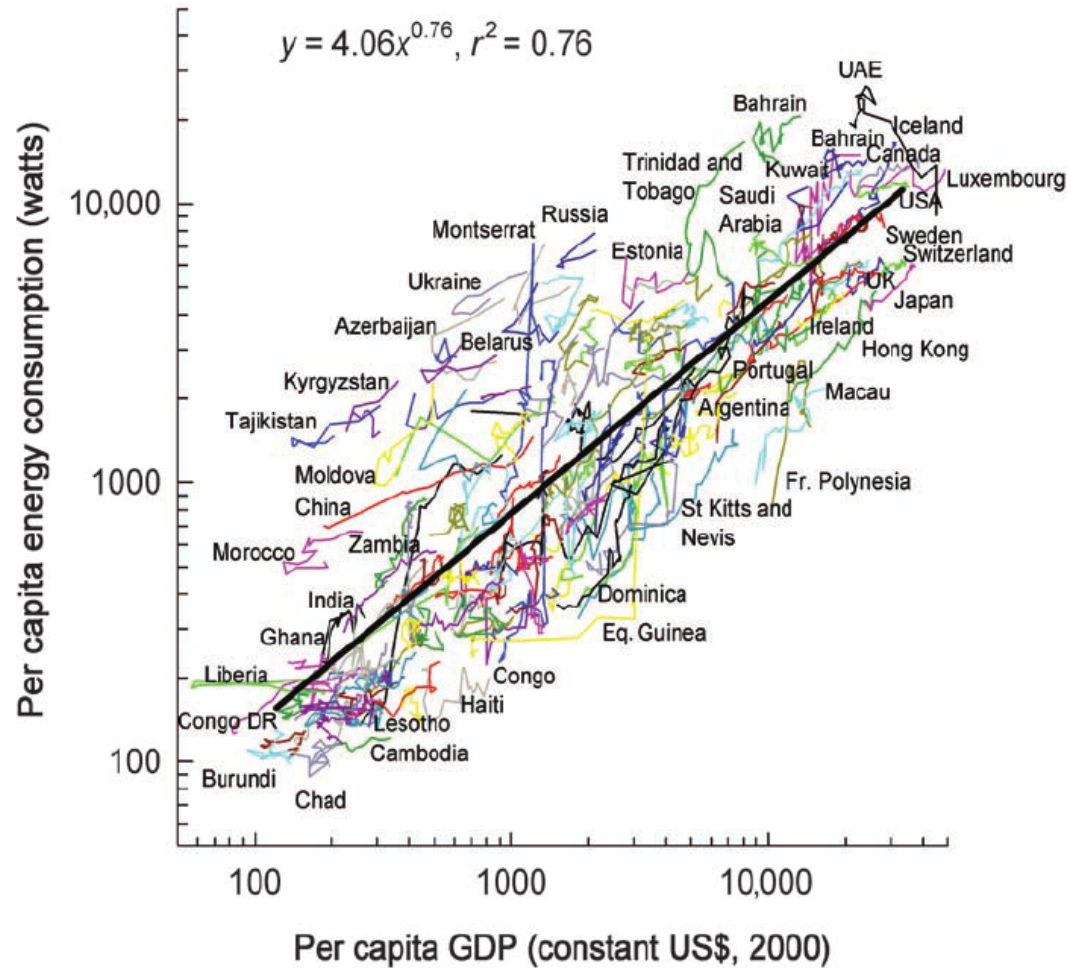
Economist.com

Electrifying India

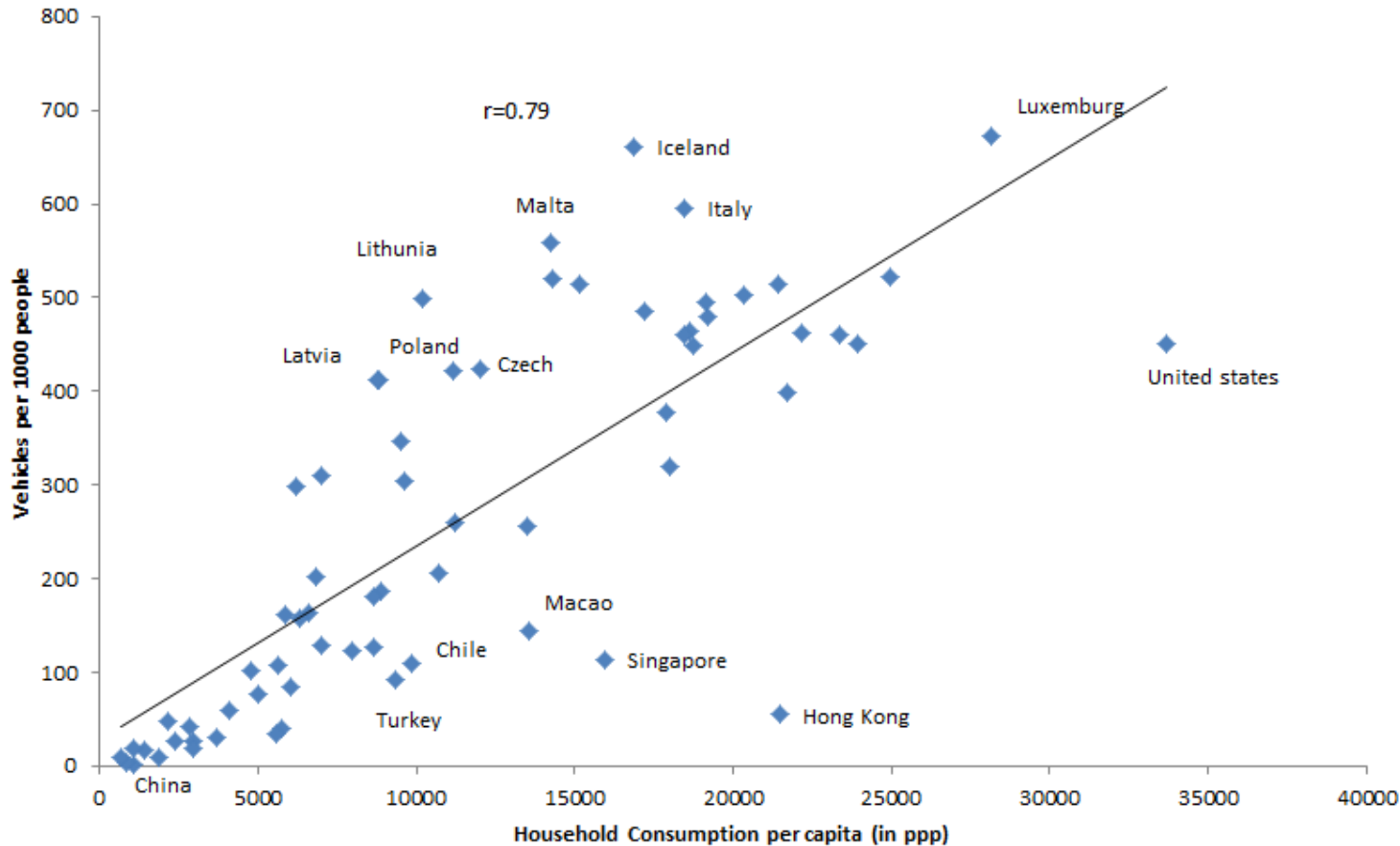
Percentage of village households with electricity, by state



Implication 2: What Will We Eat?



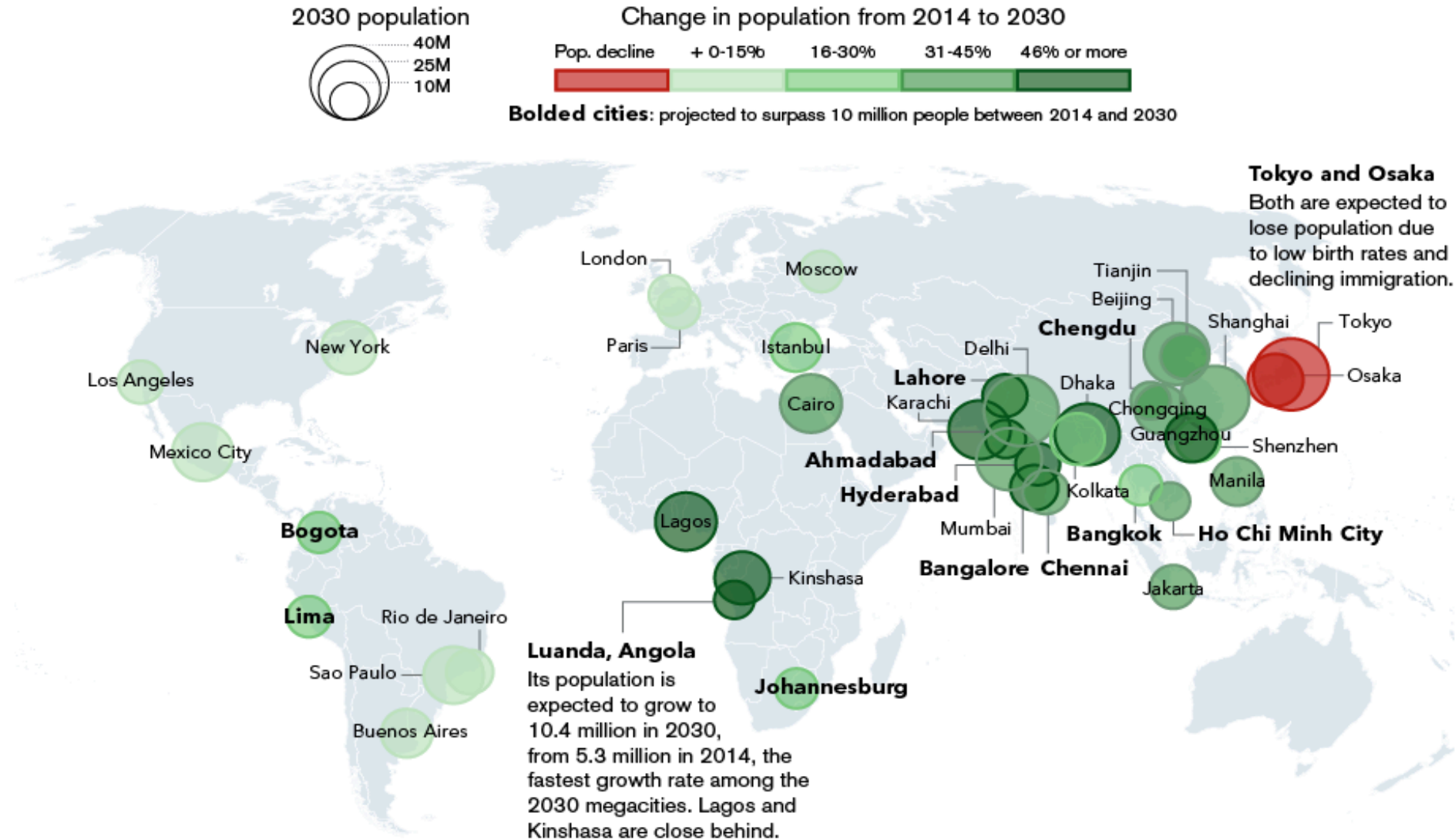
Implication 3: How Will We Move?



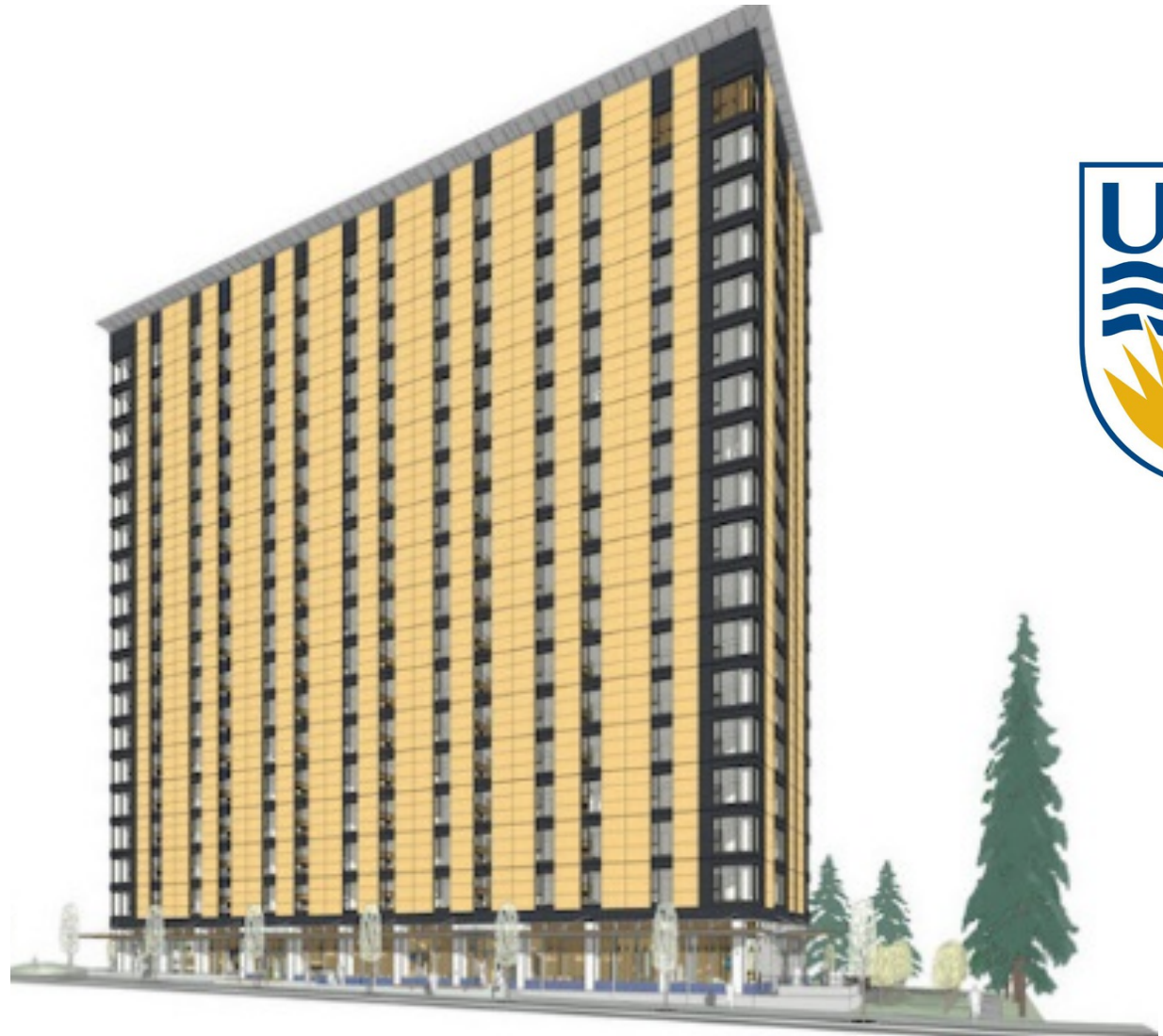
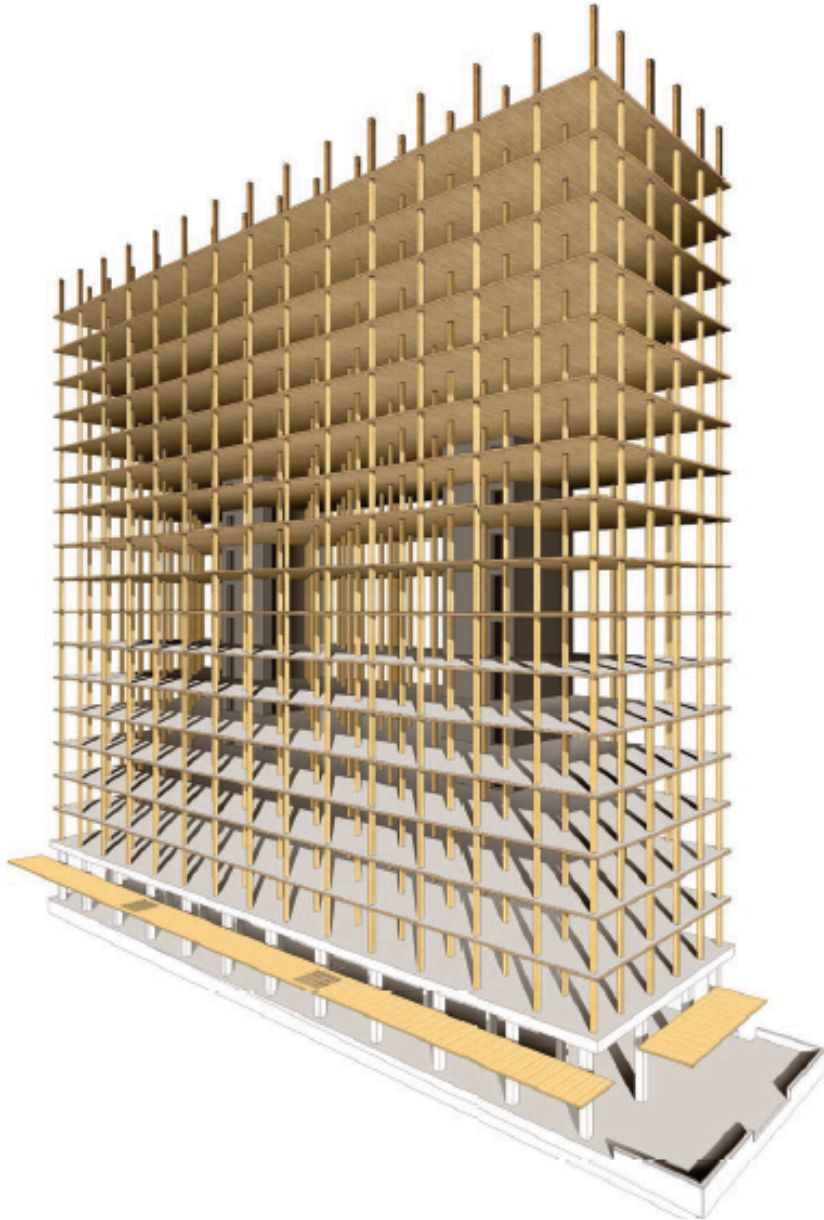
“In the developing world, buying a car is virtually synonymous with entry into the middle class... We propose the number of passenger cars in circulation serves as a reliable gauge of the size of a country's middle class.”

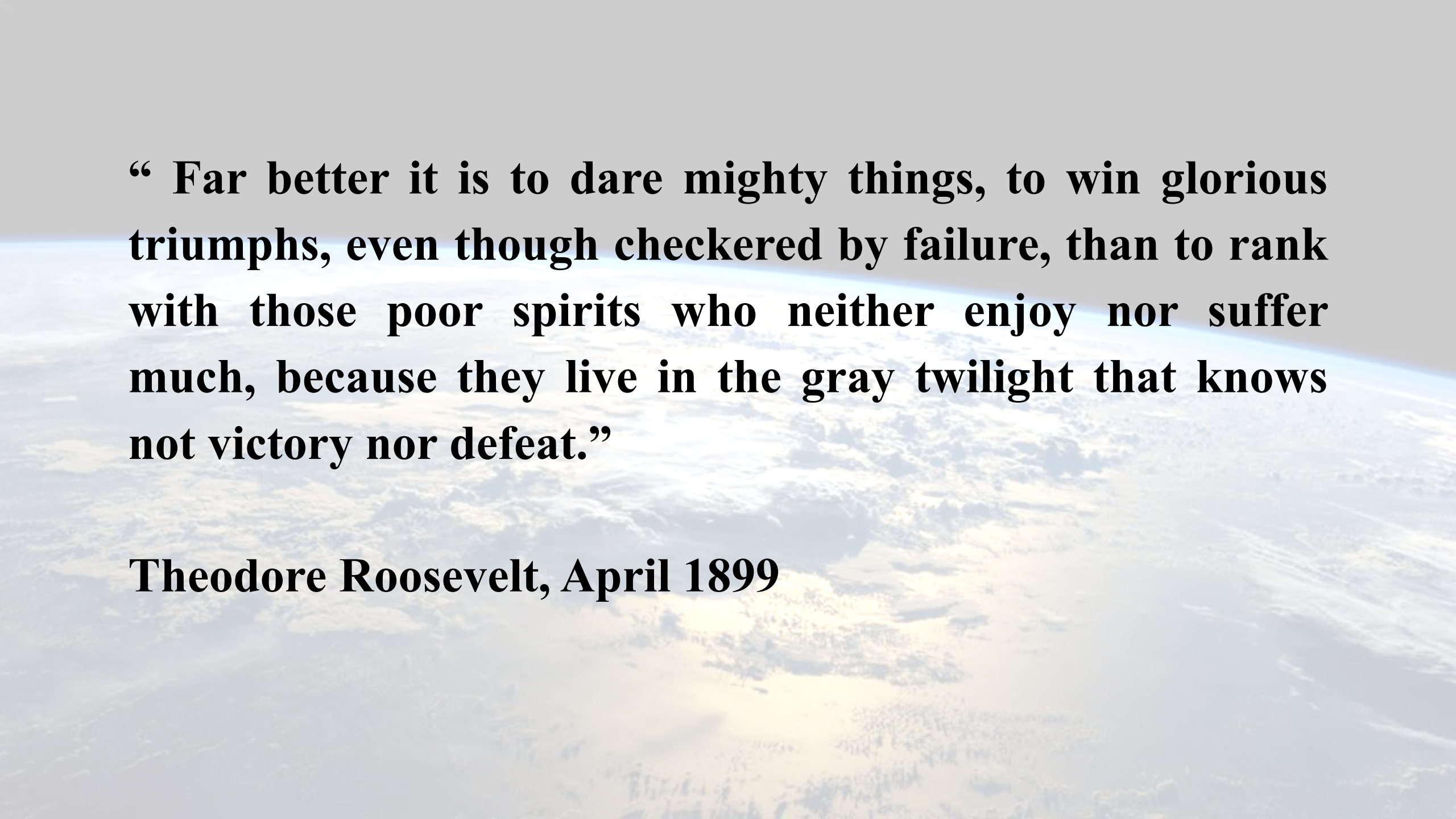
Shimelse Ali, Uri Dadush, 2012

Megatrend 3: Urbanization



Tall Wood: A Practical Reality





“ Far better it is to dare mighty things, to win glorious triumphs, even though checkered by failure, than to rank with those poor spirits who neither enjoy nor suffer much, because they live in the gray twilight that knows not victory nor defeat.”

Theodore Roosevelt, April 1899

AGENDA

4:00 pm Introductions

4:20 Update on federal funding outlook for energy-related research, Emily Burlij

4:30 Update on ISE activities

4:40 Five-minute, one-slide presentations

Robert Kaufmann

Cutler Cleveland, Chris Meier, Michael Walsh

Patrick Kinney

Justin Ren and David Jermain

Richard Stuebi

Robert Metcalf

5:10 Eric Toone – Guest Presentation, plus Q and A

5:40 Discussion: new ideas for research/collaboration, advice to the ISE

6:00 Meeting adjourns; refreshments