

Power Engineering Education in the Age of Climate Crisis – A Holistic View



Presented by –

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NSF EPCN Workshop on Power Electronics-enabled Operation of Power Systems

IIT-Chicago, Nov 1, 2019

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“Everything we hear is an opinion,
not a fact. Everything we see is a
perspective, not the truth.”

Marcus Aurelius, *Meditations*



“The greatest accomplishment
of 20th century science has been
the discovery of human
ignorance.”

Lewis Thomas



Electricity – A Basic Human Right

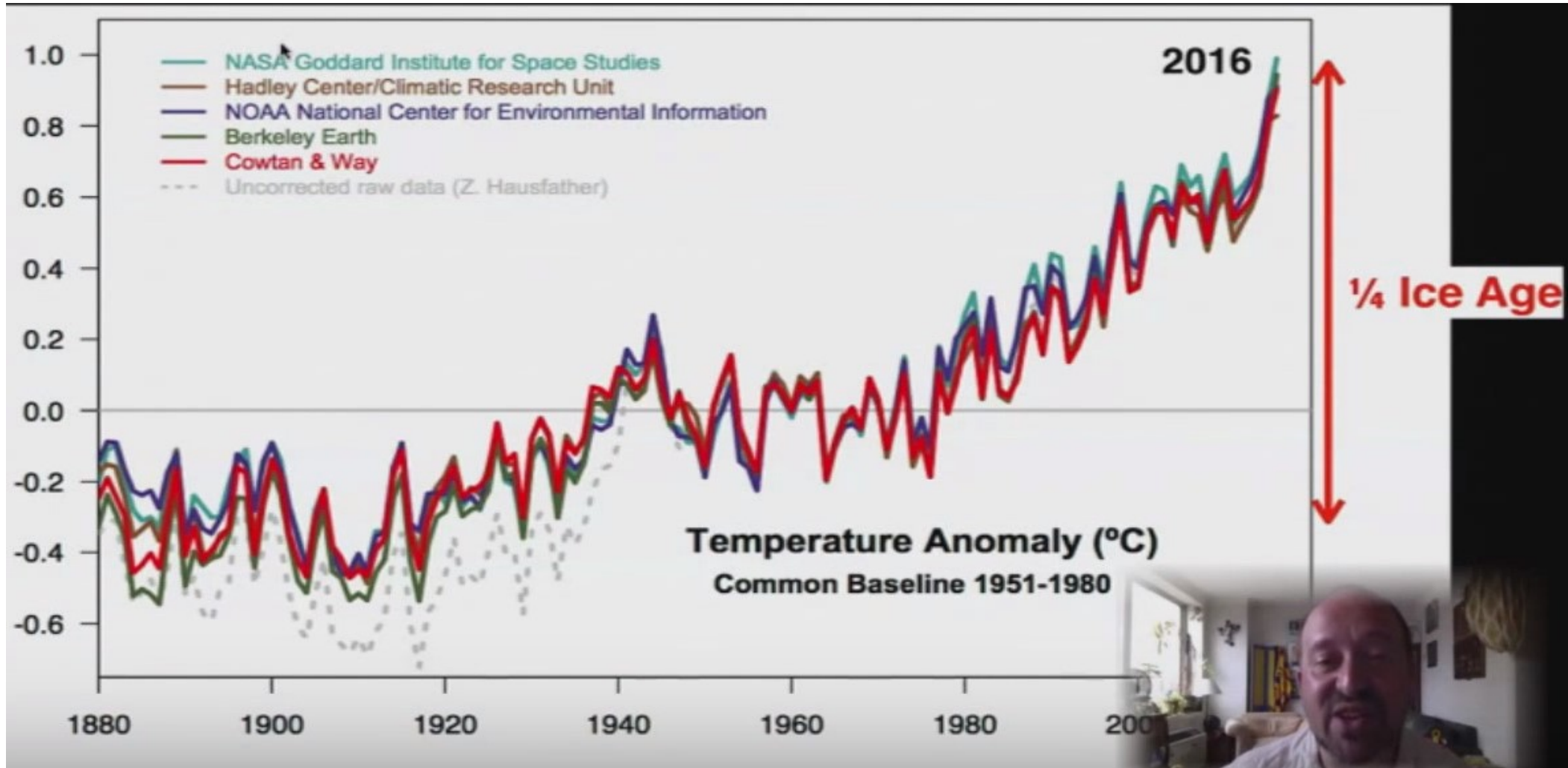
- **1.3 Billion people (1/6th of humanity) have no access to it**
- **Over 1 Billion more will be joining us in just ten short years**



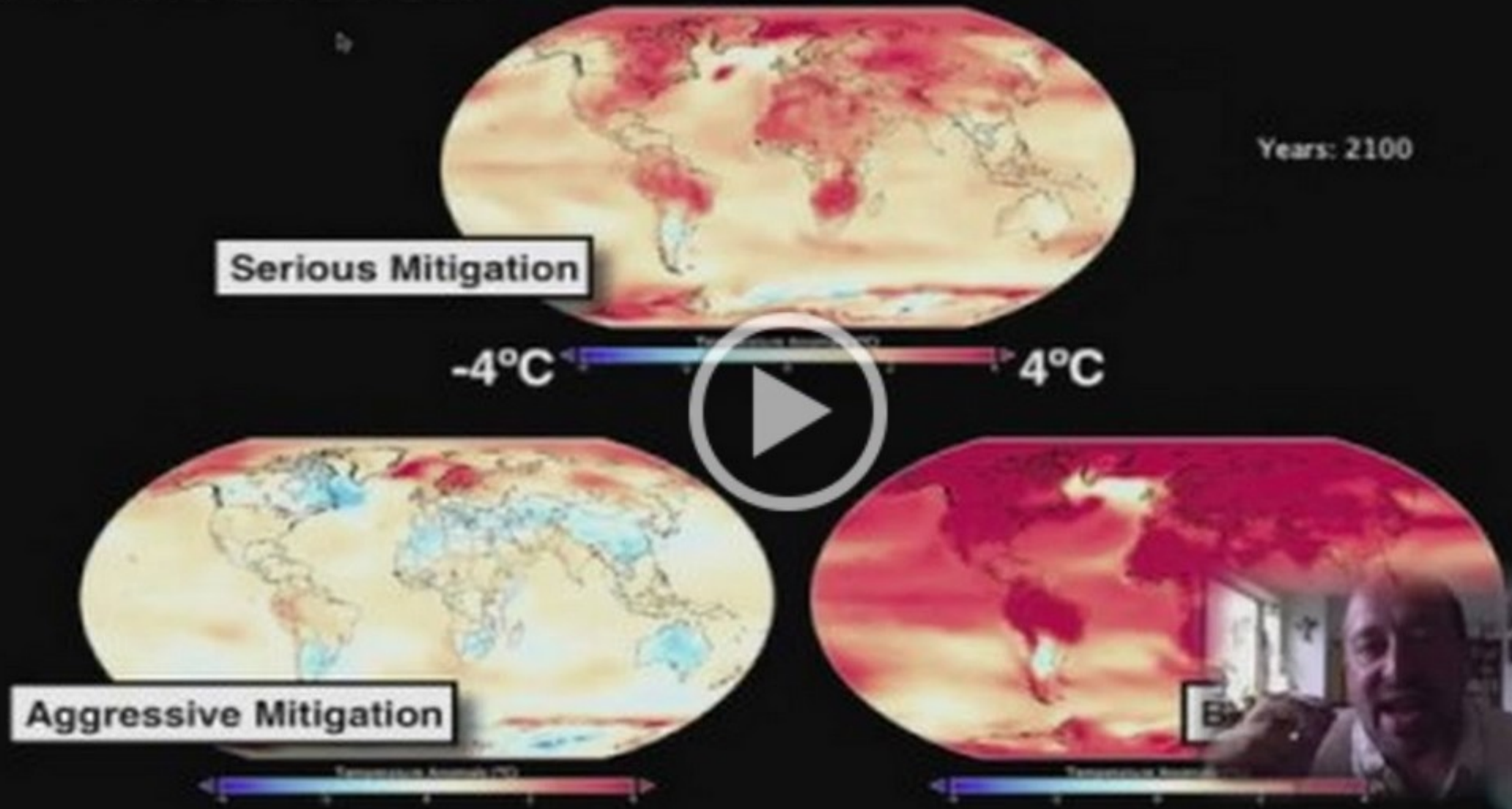
Climate Change – Attribution and Prediction

<https://z.umn.edu/GavinSchmidt>

- Poorest of the poor are at the front line



On to the 21st C...

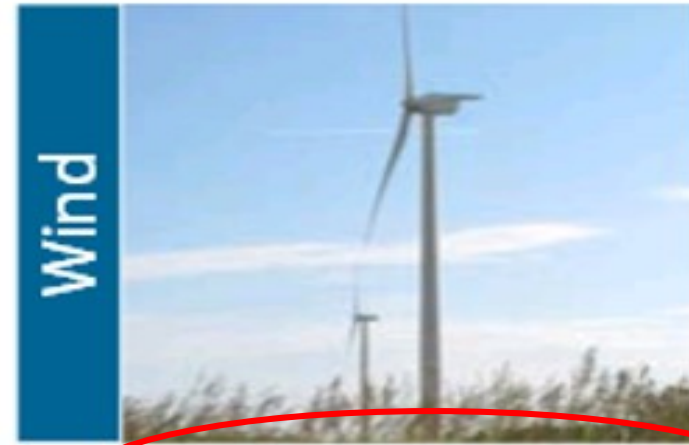


How “clean” are Renewables?



Coal

~1000 g CO₂eq/kWh



Wind

~10 g CO₂eq/kWh

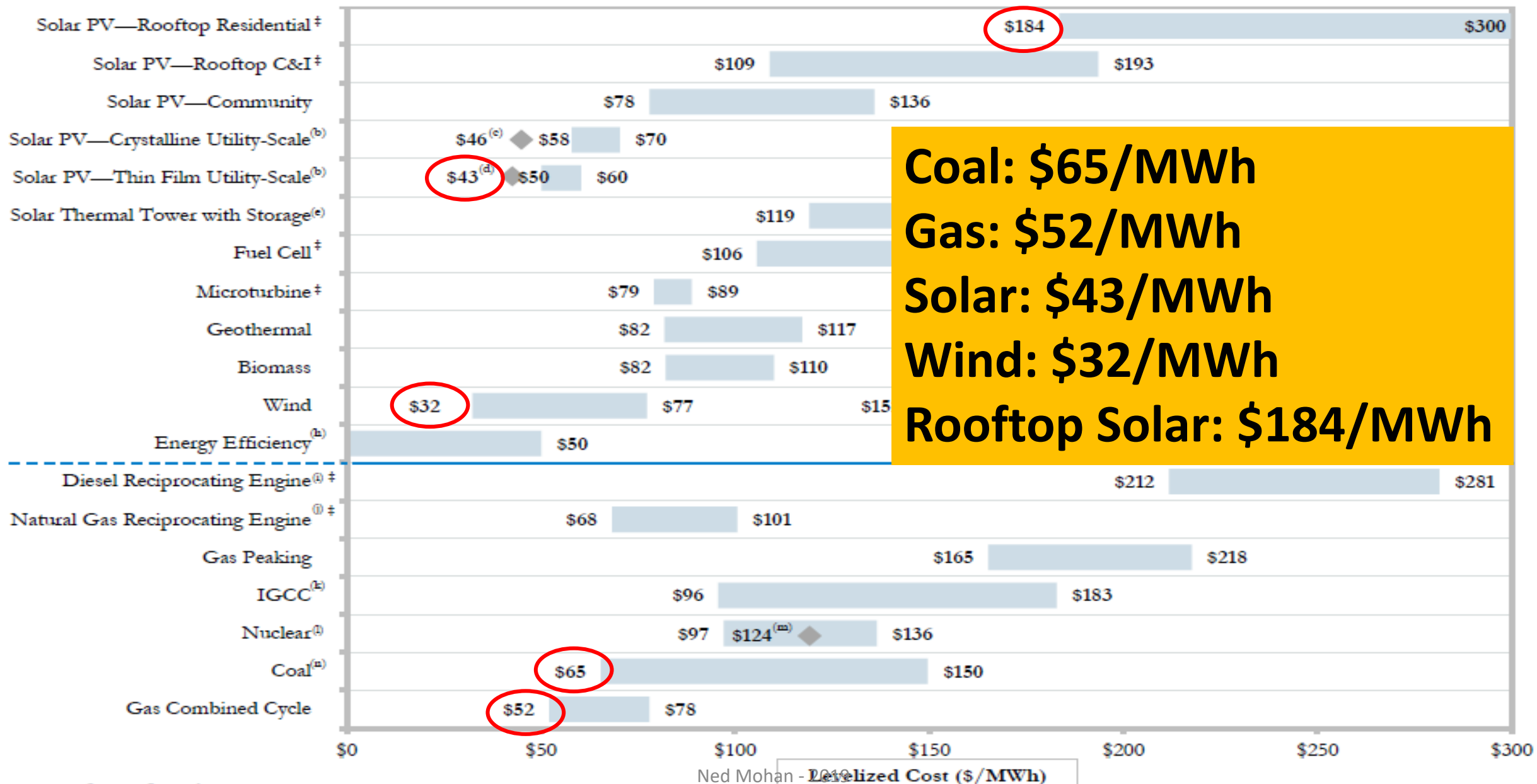
Photovoltaics (PV)



~40 g CO₂eq/kWh

- Wind 100 times cleaner
- Solar 25 times cleaner

Comparative Costs of Energy: How Wind and Solar Stack Up



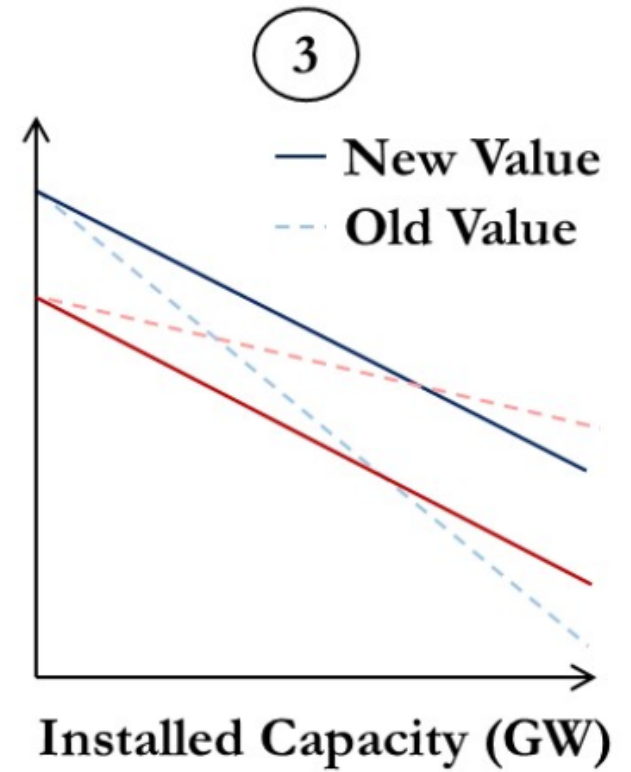
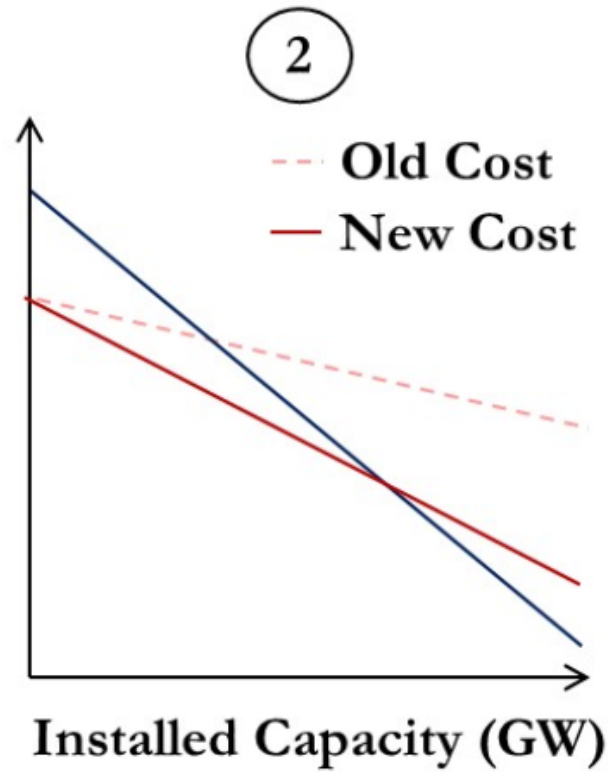
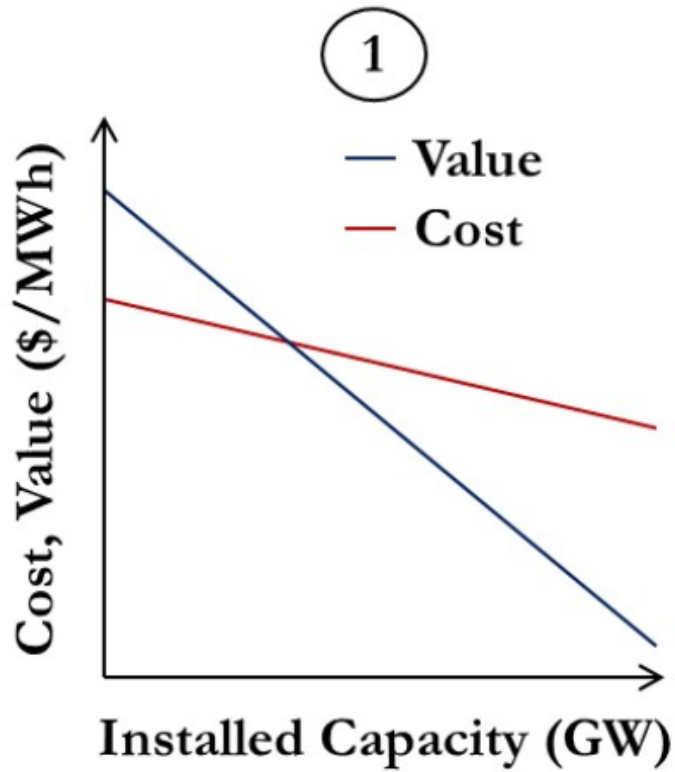
Source: Lazard estimates.

So the answer (?) is.....

- Shift all our Energy Use to Electricity**
- Generate Electricity from Renewables**
- Conservation**
- Sustainability mindset**

Science Alone Cannot Stop Global Warming

- human attitudes must change.**



Financial
Innovation

+

Technological
Innovation

+

Systemic
Innovation

Total U.S. Electricity Generated in 2018:

Wind: 6.6%

PV: 1.5%

Source: EIA

U.S. electricity generation by source, amount, and share of total in 2018 ¹		
Energy source	Billion kWh	Share of total
Total - all sources	4,178	
Fossil fuels (total)	2,651	63.5%
Natural gas	1,468	35.1%
Coal	1,146	27.4%
Petroleum (total)	25	0.6%
Petroleum liquids	16	0.4%
Petroleum coke	9	0.2%
Other gases	12	0.3%
Nuclear	807	19.3%
Renewables (total)	713	17.1%
Hydropower	292	7.0%
Wind	275	6.6%
Biomass (total)	63	1.5%
Wood	41	1.0%
Landfill gas	11	0.3%
Municipal solid waste (biogenic)	7	0.2%
Other biomass waste	3	0.1%
Solar (total)	67	1.6%
Photovoltaic	63	1.5%
Solar thermal	4	0.1%
Geothermal	17	0.4%
Pumped storage hydropower³	-6	-0.1%
Other sources	13	0.3%

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A Holistic View – The world is not compartmentalized into Power, Power Electronics, Electric Drives and Control

Electricity Generation, Transmission and End-Use:

- Renewables/storage
- Conservation

Transportation

- Trains
- Planes
- Hybrids/EVs

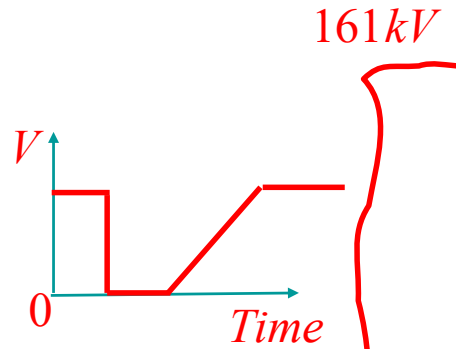
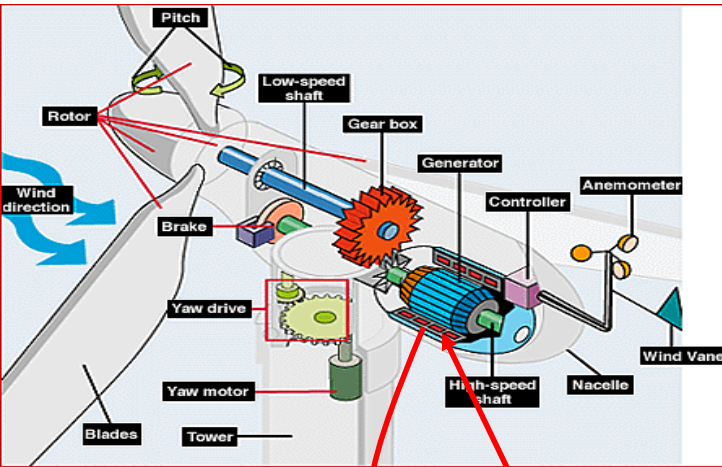
Defense

- Navy
- Air Force
- Army

Industrial Competitiveness

- Automation/Robotics/Advanced Manufacturing

Wind



0 – 690V
10 – 60 Hz

Generator

Power Electronics
Converters



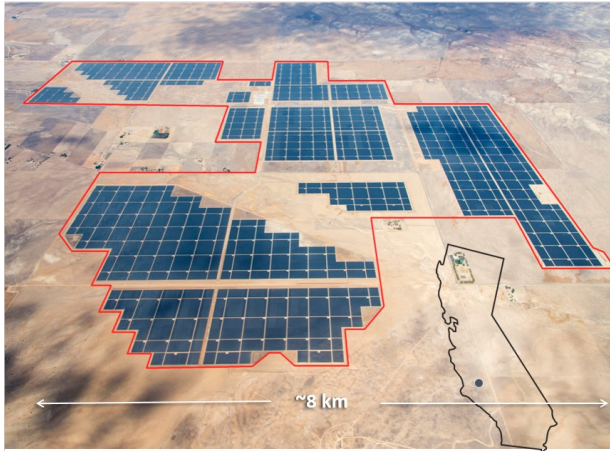
690V
60 Hz



34.5 kV



Solar



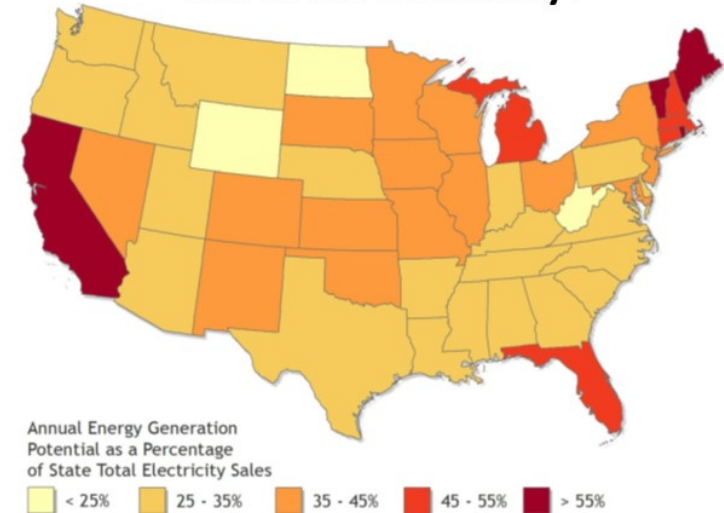
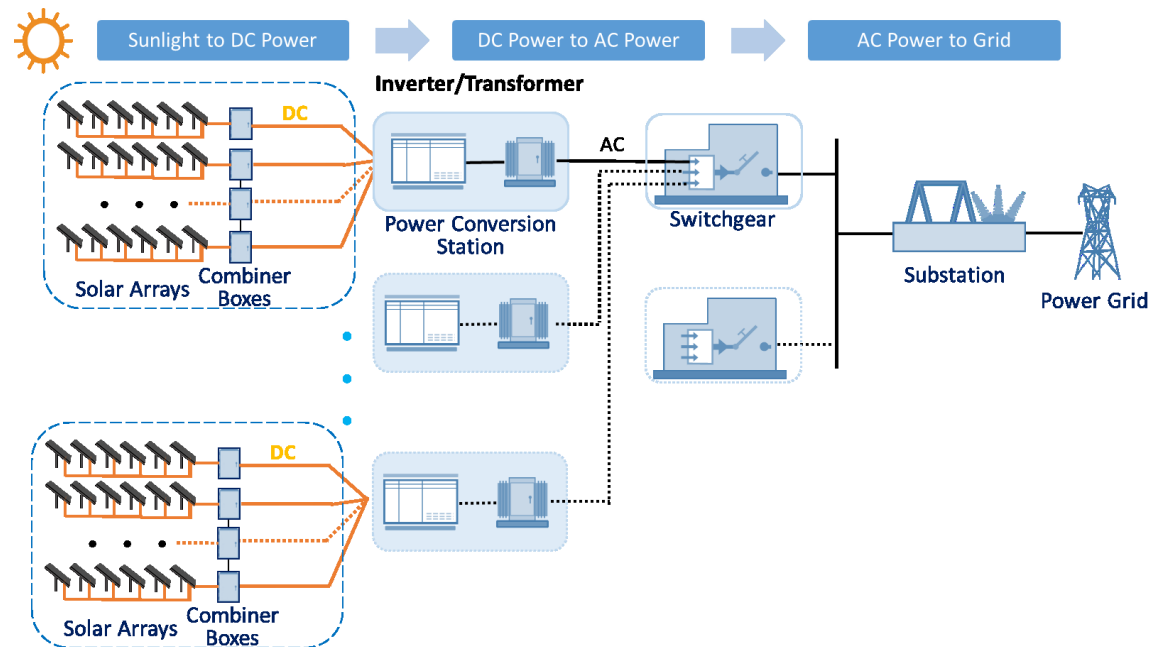
San Luis Obispo County, California
 Customer: MidAmerican
 Size: 550MW (AC)
 Construction Time: 2011—2015
 Acres: ~7,500 site
 Modules: ~9 million
 Equivalent to:



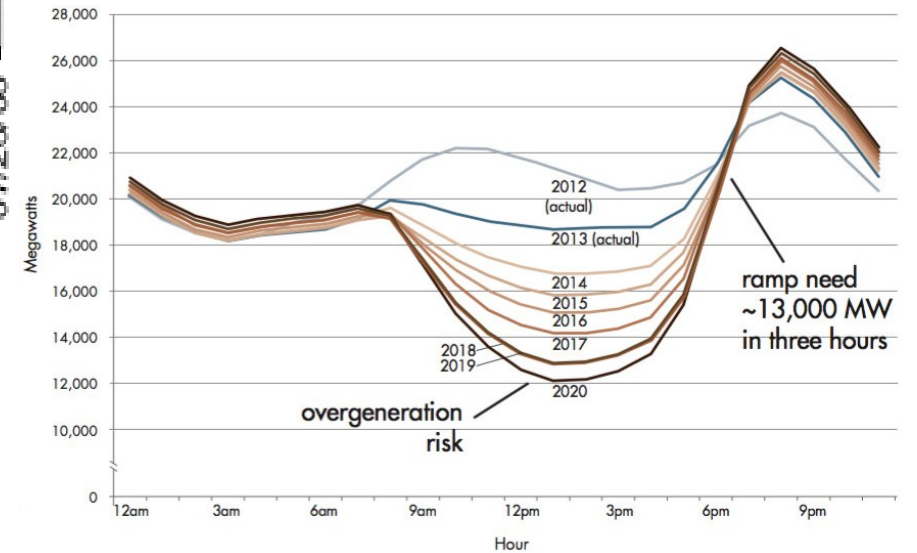
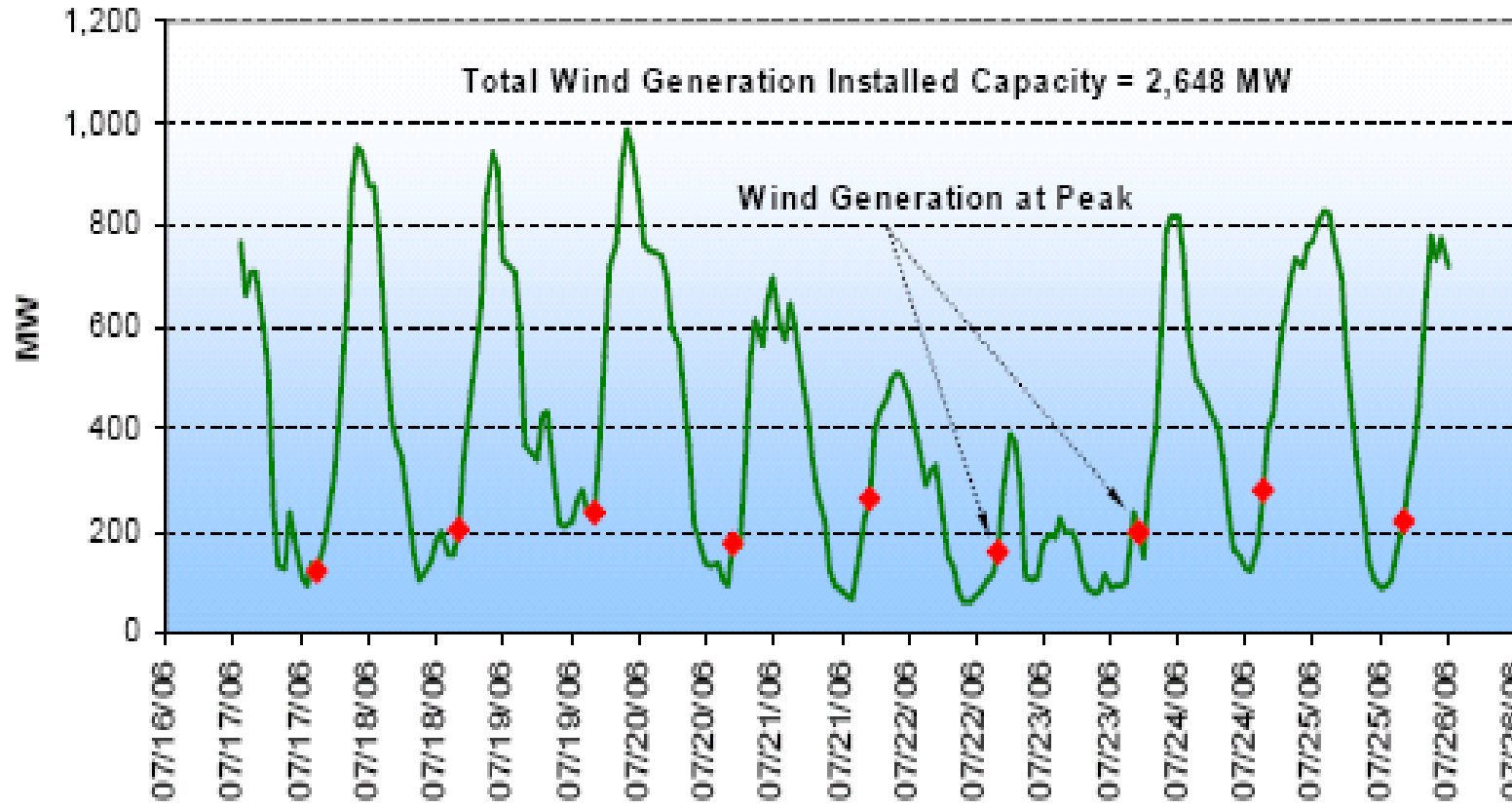
Topaz Solar Farm



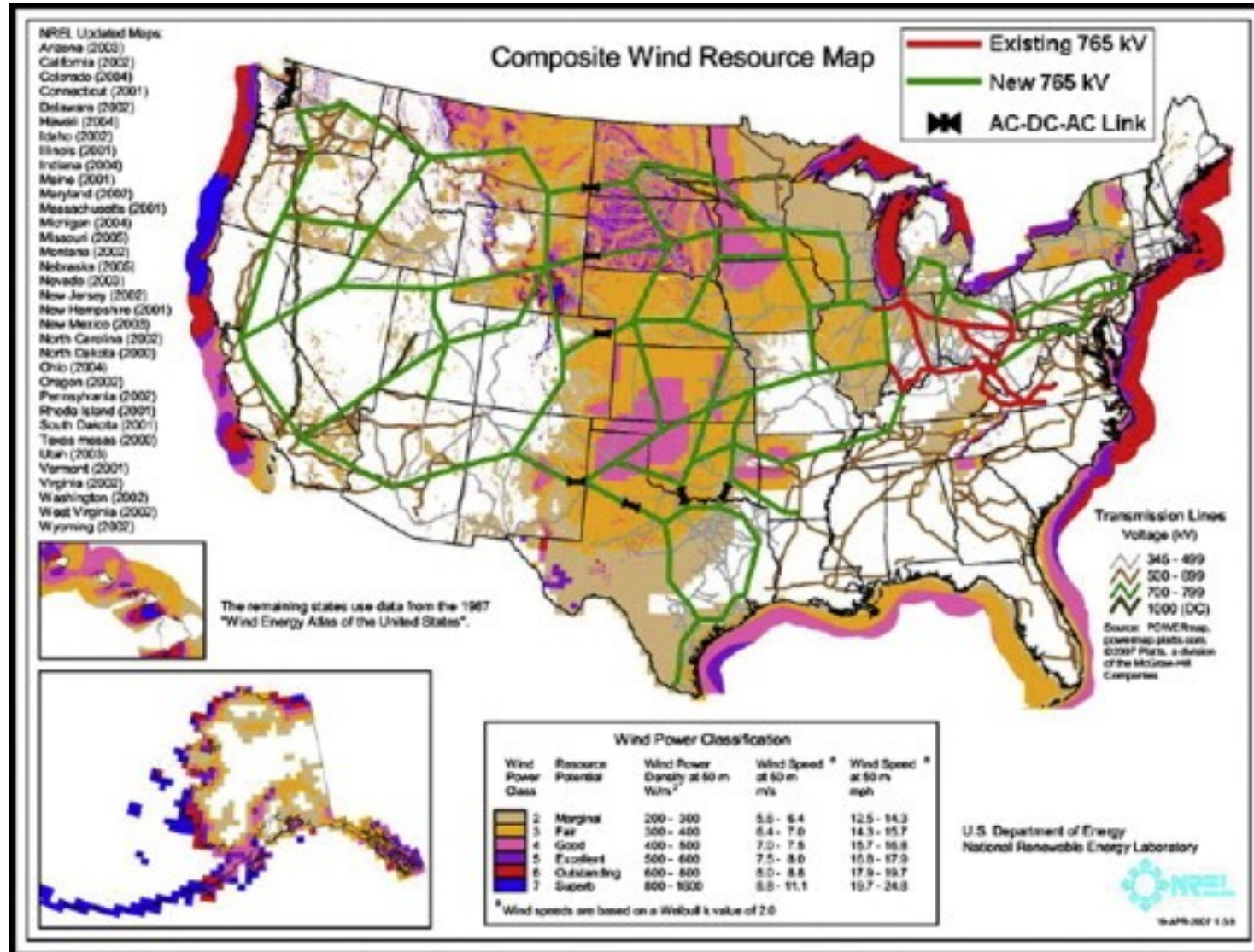
Rooftop solar can generate
 ~40% of our electricity!



Need for Storage



HVDC?



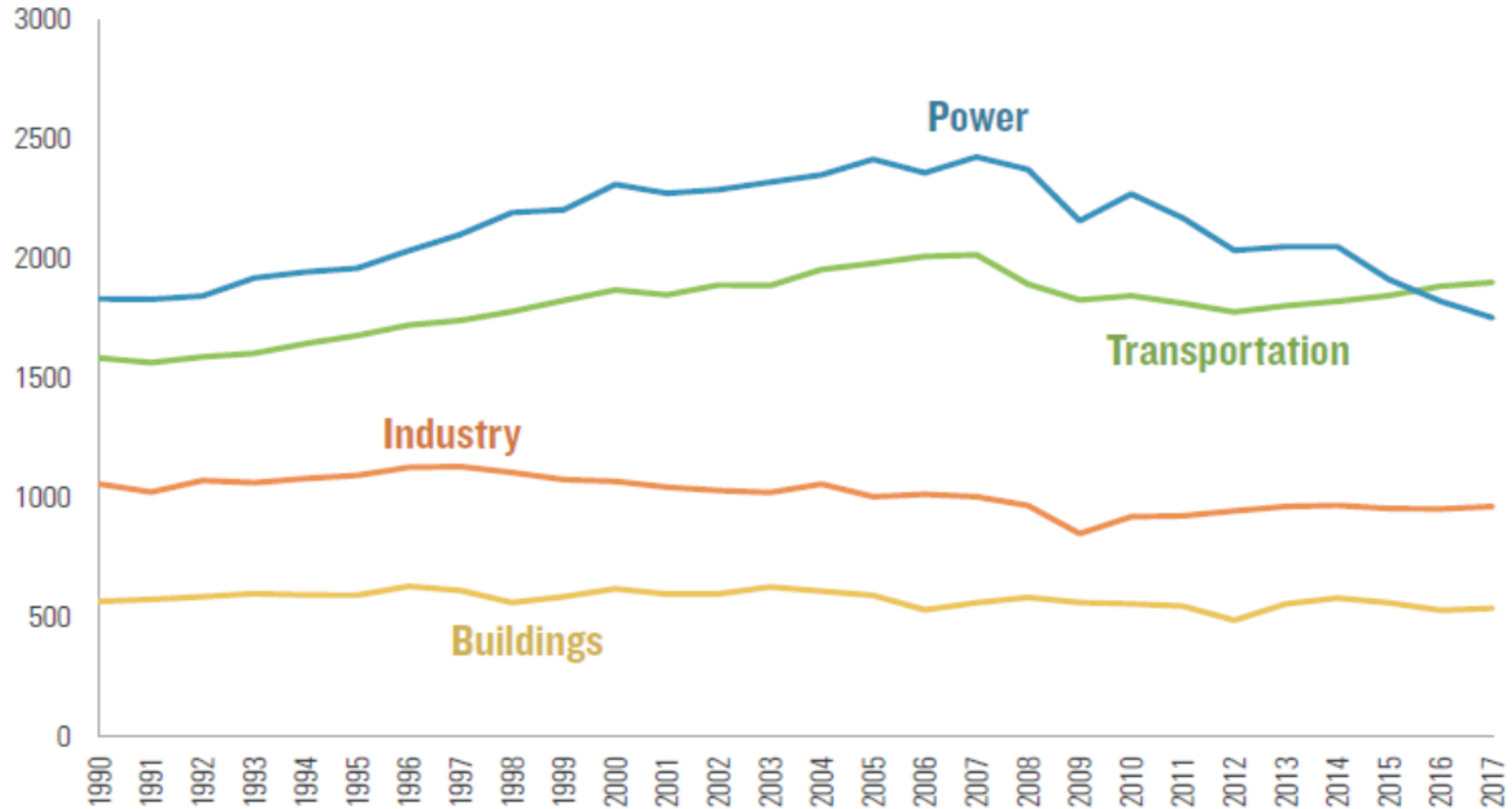
Electric Machines and Drives

- A large fraction of electricity is generated and consumed by systems using rotating machines
- Transportation
- Wind Plants
- Concentrated Solar Power
- Nuclear Power Plants



Figure 4: Energy-related CO₂ emissions by sector

Million metric tons

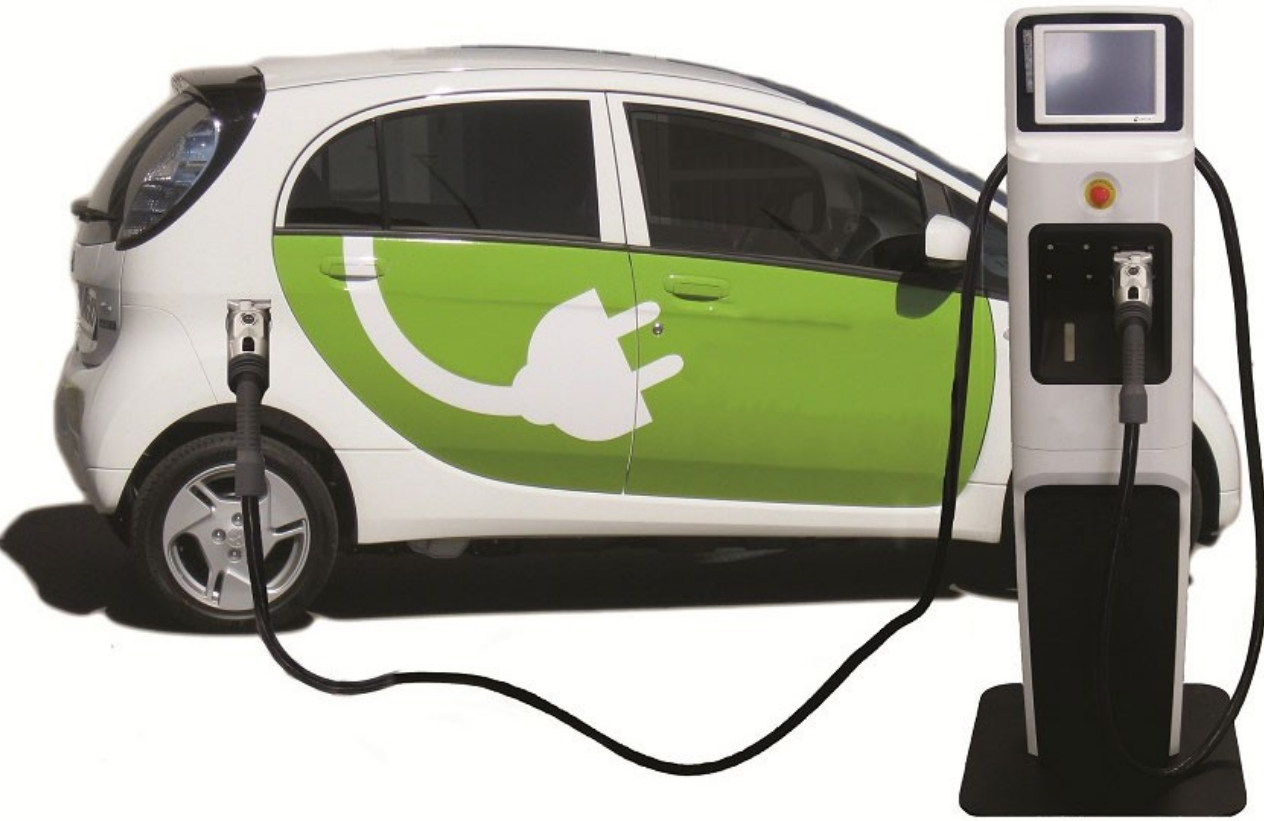


Source: EIA and Rhodium US Climate Service

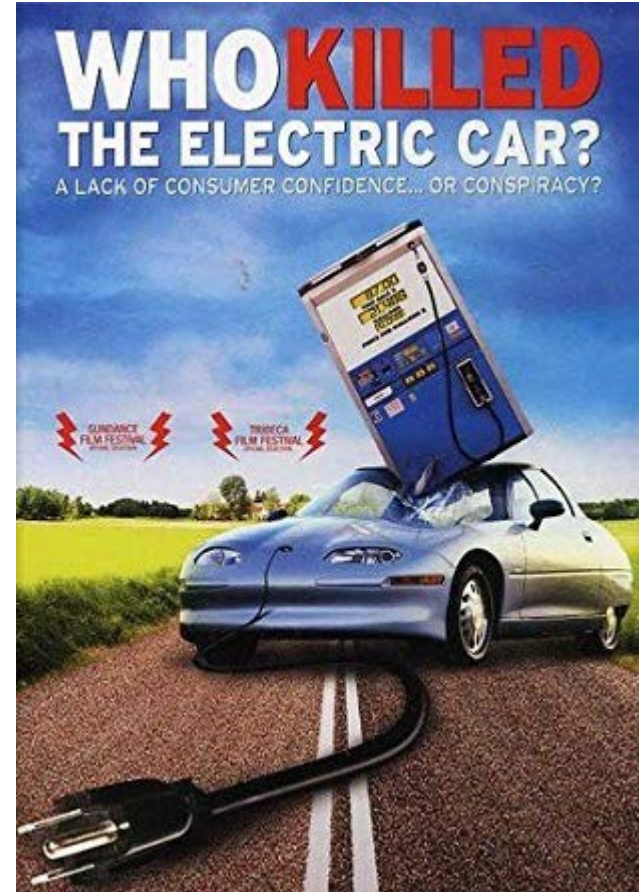
<https://rhg.com/research/final-us-emissions-numbers-for-2017/>

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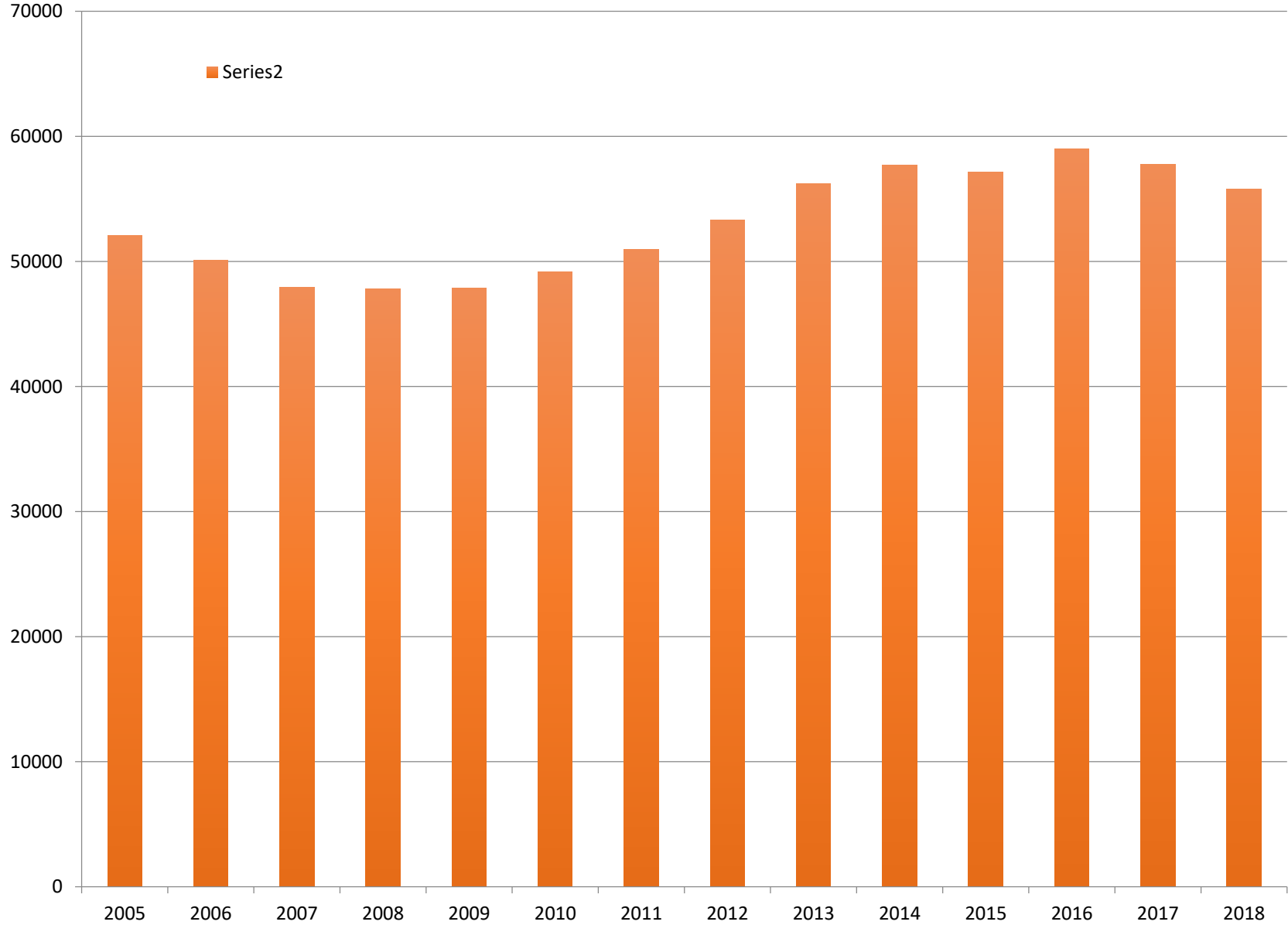
EVs



Minnesota Rectifier



Total undergraduate enrollments in EE programs



Source: ASEE

History of Electric Energy Curriculum and Interest Nationwide



- EE curriculum started with power engineering in the 1880's
- Interest in power engineering declined after mid-1900's
 - ✧ Courses did not change
 - ✧ Students were not excited
 - ✧ Instructional capacity declined
- Power engineering is now seen as critical to growth and sustainability
 - ✧ Requires rethinking the curriculum

Proposed Approach

- A pipeline course
- Fewer, carefully designed, undergraduate Courses
- Graduate courses shared with colleagues across the country - online



EE1701/EE1703: CLIMATE CRISIS: Implementing Solutions

The basics of clean energy and climate change for everyone

Home

EE1701

EE1703

EE2701

CIS Program

Events

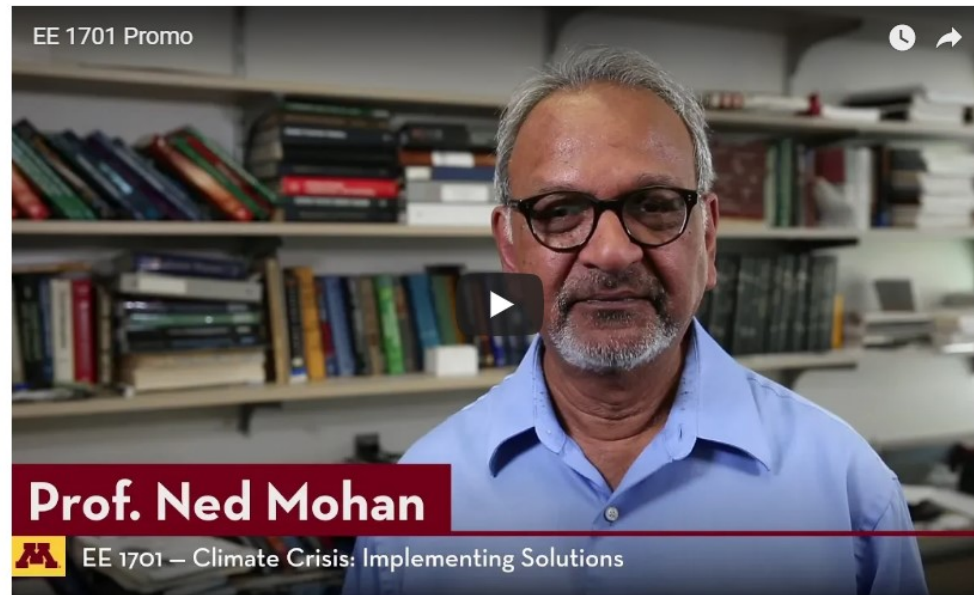
Contact

Credits

Climate Crisis: Implementing Solutions

EE1701/EE1703 meet the Physical Sciences Core and LE Theme of Technology and Society.

EE1701 by itself meets only LE theme of Technology and Society.



Course Information

EE1701: 3 Credits Online ONLY
(Online ONLY for Fall 2019)
For more details, see [here](#).
UMN Course catalog listing is [here](#).

EE1703: 1 Credit Companion
Lab
For details, see [here](#).
UMN Course catalog listing is [here](#)

EE1701 satisfies **LE theme of Technology and Society**

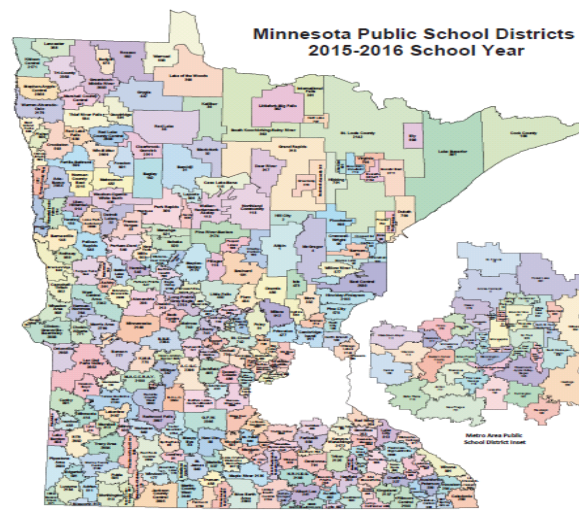
EE1701+EE1703 together satisfy **Physical Sciences Core**

EE1701 is available through the PSEO Program

EE1703 is available through

- **Online only**
- **111 students**
 - **85% from other colleges**
 - **60% female**

Dual-Credit, Concurrent-Enrollment Program



NATIONAL ACADEMY OF ENGINEERING

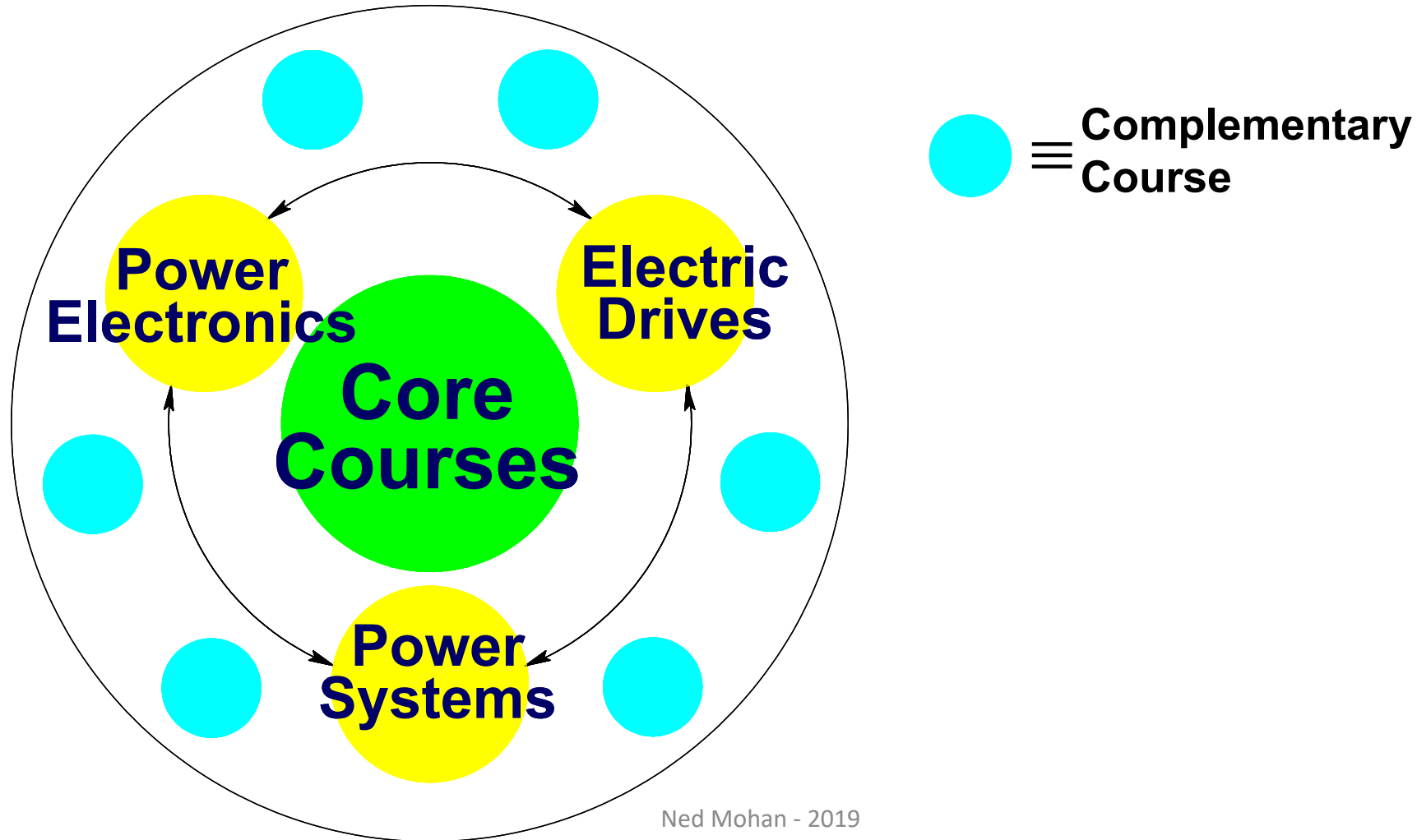
- **NSF/NAE-Sponsored ECE Department Heads Workshop, University of Minnesota, April 19, 2019**
- **Next NSF Workshop (in collaboration with ECEDHA), March 21, 2020, Orlando, FL**

Electric Power Engineering

- Power Systems
- Power Electronics
- Electric Machines and Drives
- Controls

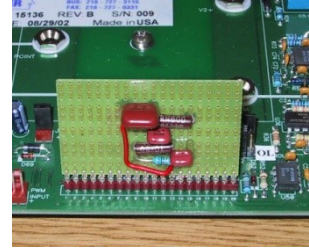
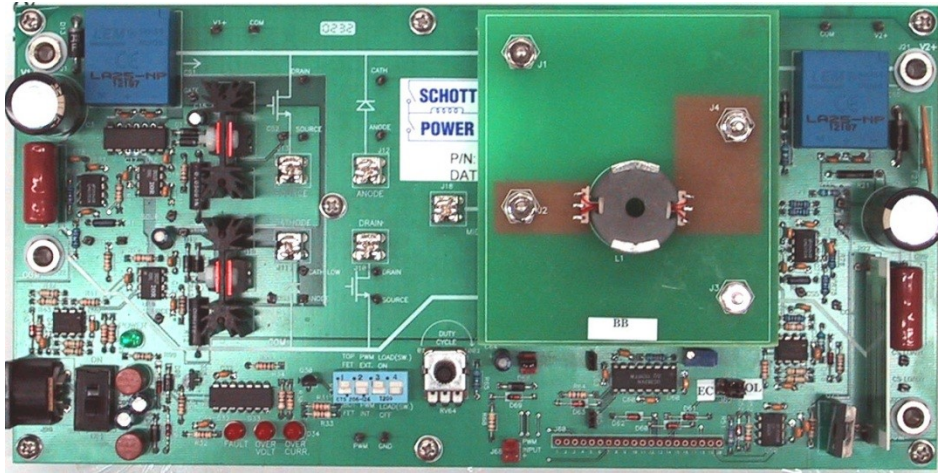
Undergraduate/First-Year Graduate Courses -

Only 3 Senior Electives

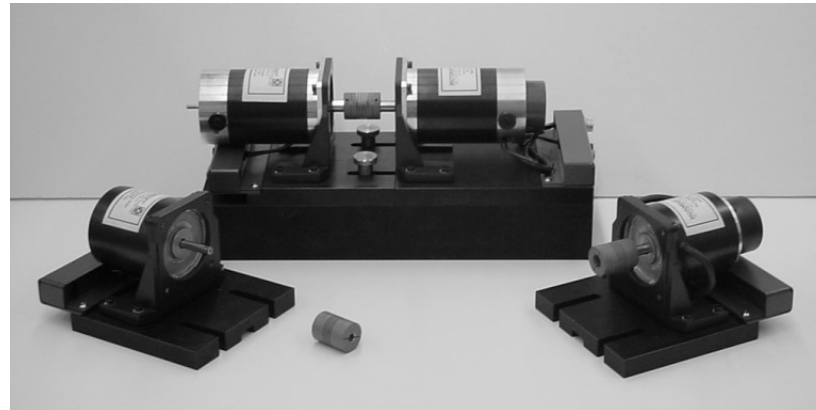
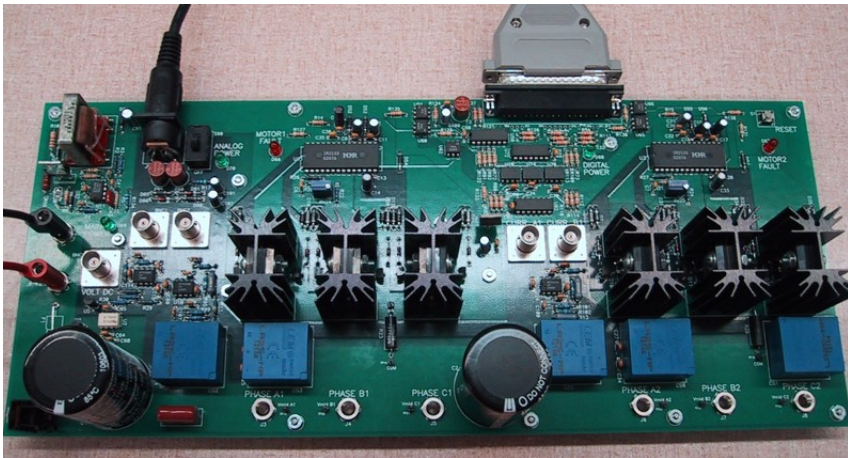




Commercialization of Hardware Laboratories

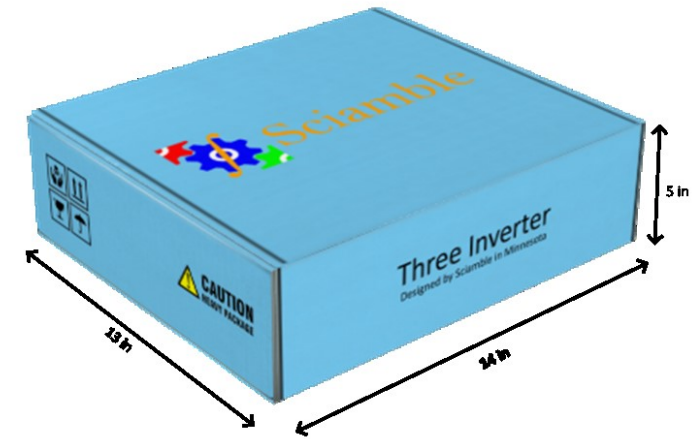
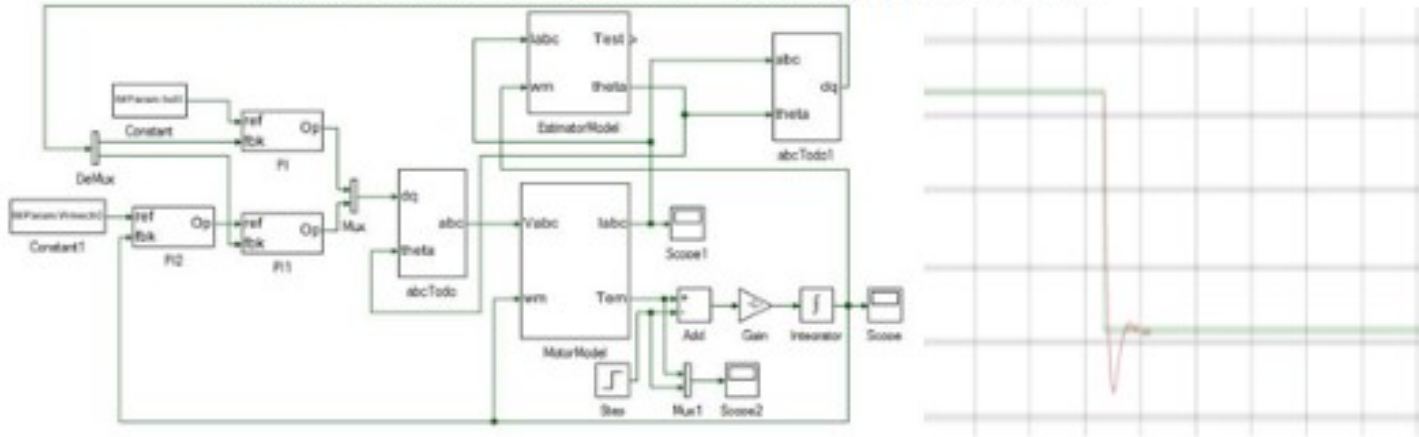


NSF - CCLI
Acquired by 109 US Universities



A Four-Year ONR Grant – To Develop WBG-Based, Extremely Low-Cost Laboratories for Power Electronics, Motor Drives, and Power System Protection and Relays for National Dissemination

Induction Motor vector control - step change in load torque



12x14x5cm

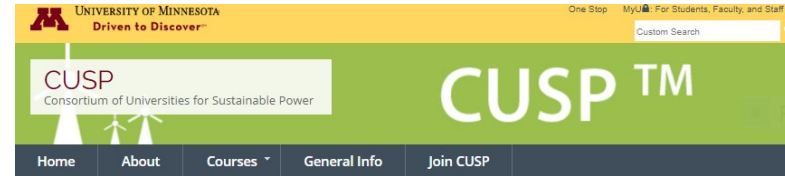


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Commercialization:
<http://Sciamble.com>

CUSP™

(Consortium of Universities for Sustainable Power)



Home

Welcome to CUSP

The vision behind CUSP™ is to provide all the resources an instructor needs in teaching his/her own courses in the field of Electric Energy Systems with an emphasis on sustainability. This effort has been funded from various organizations including NSF, ONR (Office of Naval Research), NASA and EPRI and is totally free-of-cost under the Terms of Use conditions.

CUSP Welcome Video



Welcome



RECENT EVENTS

NSF/NAE-Sponsored Workshop Courses

(Online ONLY)

July 2019

Click [here](#) for details

LOW COST LABORATORY

New low cost basic and advanced electric drives

- Content is totally free to download
- **235** U.S. Universities have become members

<http://cusp.dl.umn.edu>

13 Graduate Courses (41 Credits)

Power Systems (22 credits)

1. Power Systems + Lab (3 + 1 Credits)
2. Advanced Power Systems I (3 Credits)
3. Advanced Power Systems II (3 Credits)
4. Power Gen, Op and Control (3 Credits)
5. Protection and Relaying (3 Credits)
6. Electricity Markets (3 Credits)

Power Electronics (11 credits)

1. Power Electronics + Lab (3 + 1 Credits)
2. Advanced Power Electronics I (3 Credits)
3. Advanced Power Electronics II (3 Credits)

Electric Machines/Drives (10 credits)

1. Electric Machines/Drives (3 Credits)
2. Vector Control of Drives (3 Credits)
3. Electric Machine Design (3 Credits)

Renewable Energy (3 credits)

1. Wind Energy Essential (3 Credits) Ned Mohan - 2019

The screenshot shows the CUSP website interface. At the top, it features the University of Minnesota logo and navigation links. The main content area is divided into several sections:

- Welcome:** A video player showing a man speaking, with a "DEVELOPED BY EXPERTS" banner.
- Courses:** A grid of course categories including Power Systems, Power Electronics, Electric Machines & Drives, and Renewable Energy.
- Upcoming Workshop:** A section for the "Reinventing Electric Power Curriculum with Sustainability Focus" workshop, held from June 15-17, 2017, at the University of Minnesota, Minneapolis, Minnesota. It includes links for agenda highlights, location, registration, and accommodations.
- Join Now!:** A section encouraging users to become members and access resources.
- Terms of Use:** A section providing information about the website's content and licensing.

NSF-sponsored ONLINE Courses during Summer 2019

- Power Generation, Operation and Control
- High Voltage Insulation Technology Related to Power Systems
- Power Electronics for the Grid Integration of Renewables, Conservation and EV Charging
- Digital Control of Power Electronics
- Vector Control in Electric Drives - Analysis, Simulation and Practical Implementation for Electric Vehicles, Wind Turbines and Robotics
- Power System Protection
- Finite Element Analysis for Designing Electrical Apparatus

Rationale for Offering Online Courses and an Online Master's Degree

1. Educated Workforce to meet increasing demands related to electric energy
2. Make a large selection of courses available to students nationwide
3. Keep certain power-related courses, critical to national infrastructure, from disappearing
4. Keep evolving these courses
5. Master's Courses - kind of a niche for online
6. Offering Certificates after 9 or 15 credits(?)

Offering CUSP™ Courses Online for a Master's Degree

Through the Texas Tech University in Lubbock, TX

- Fall 2019 – Power Generation, Operation and Controls by Prof. Wollenberg
- Three courses planned for Spring 2020

Our Responsibility — There is no Planet B.



Carl Sagan: There is no hint that help will come from elsewhere to save us from ourselves.

Thank You!