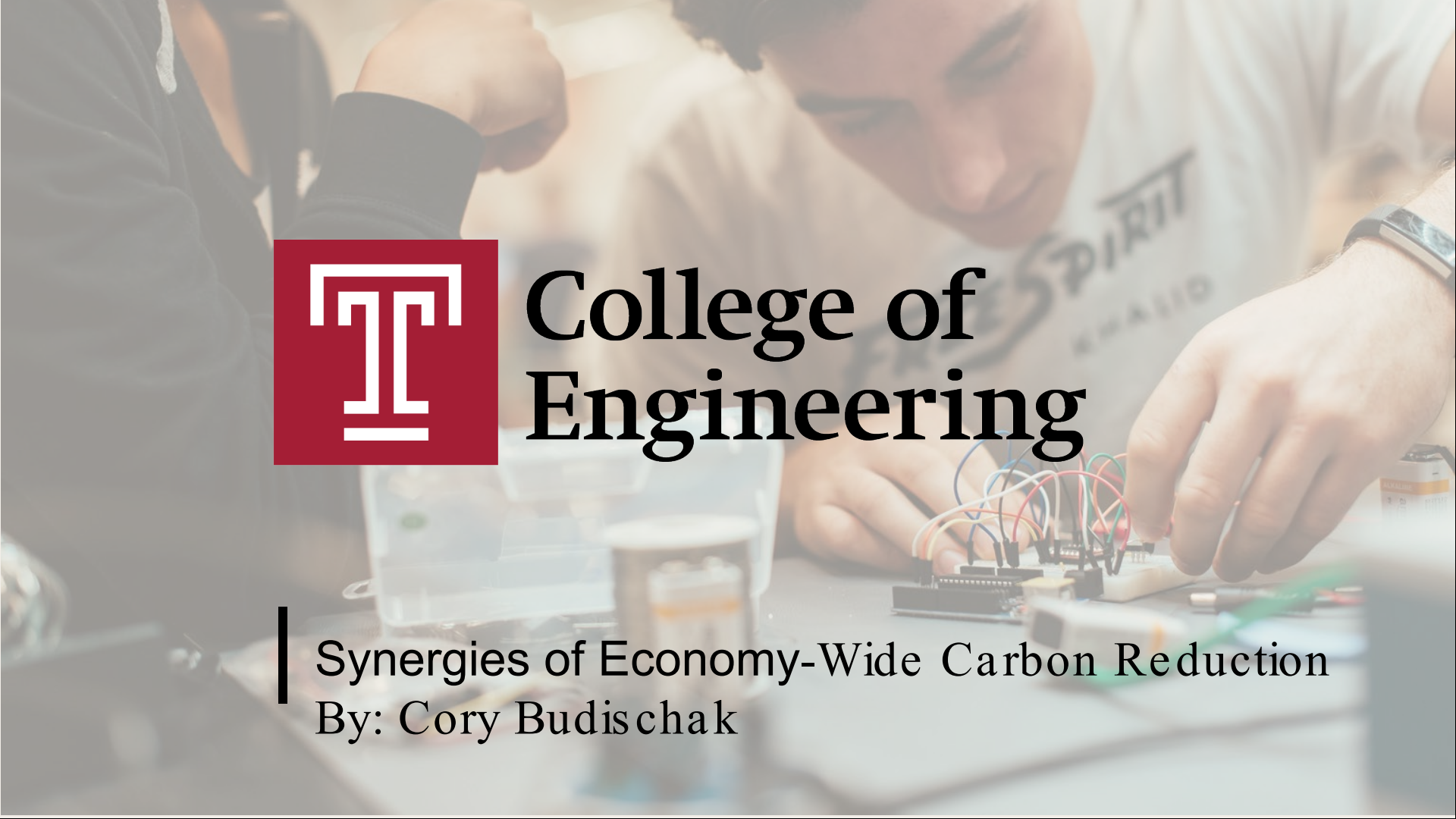
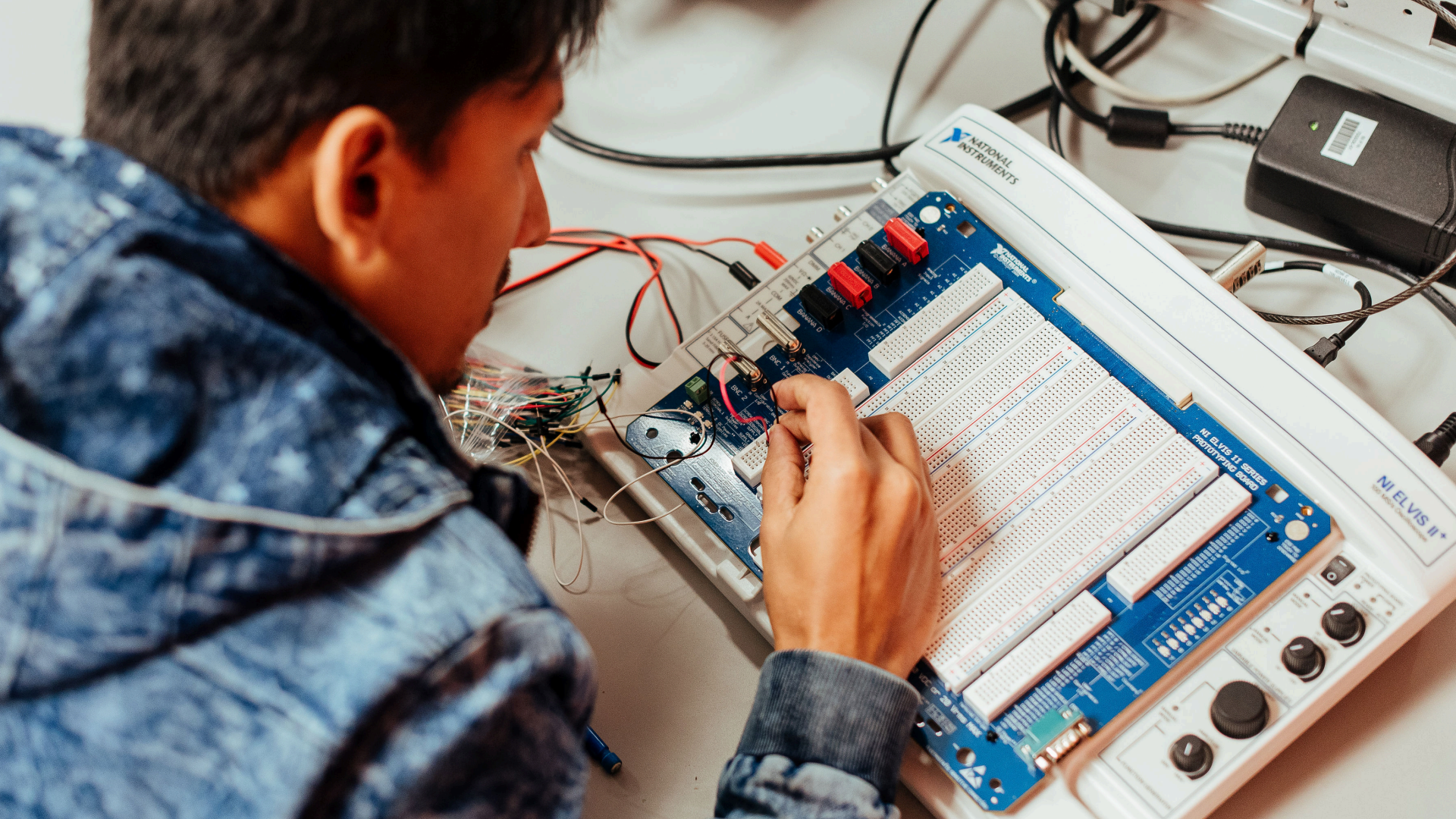


College of Engineering

Synergies of Economy-Wide Carbon Reduction

By: Cory Budischak


DIVINE
LORRAINE
HOTEL
ONE WAY
NO TURN ON RED
Montgomery Av


NATIONAL INSTRUMENTS
NI ELVIS II SERIES PROTOTYPING BOARD
NI ELVIS II+

College of Engineering

COMMON FIRST YEAR CURRICULUM
All students take Intro to Engineering

UNDERGRADUATE ENGINEERING DEGREES

- BS Bioengineering
- BS Civil Engineering
- BS Electrical Engineering
- BS Environmental Engineering
- BS Industrial and Systems Engineering
- BS Mechanical Engineering
- BS Engineering: interdisciplinary
  - Electro-mechanical engineering
  - Electro-optical engineering
  - Computer hardware and software engineering
  - Energy and power engineering
  - Engineering Fundamentals

UNDERGRADUATE ENGINEERING TECHNOLOGY DEGREES

- BS in Engineering Technology
  - Mechanical/Manufacturing Track
  - Computer Track
  - Construction Track
  - Energy (Buildings) Track
  - General Track
- BS Construction Engineering Technology

College of Engineering

College of Engineering

MASTER OF SCIENCE

- MS Bioengineering
- MS Civil Engineering
- PSM Computer & Systems Security
- MS Electrical Engineering
- MS Engineering Management
- MS Environmental Engineering
- MS Mechanical Engineering

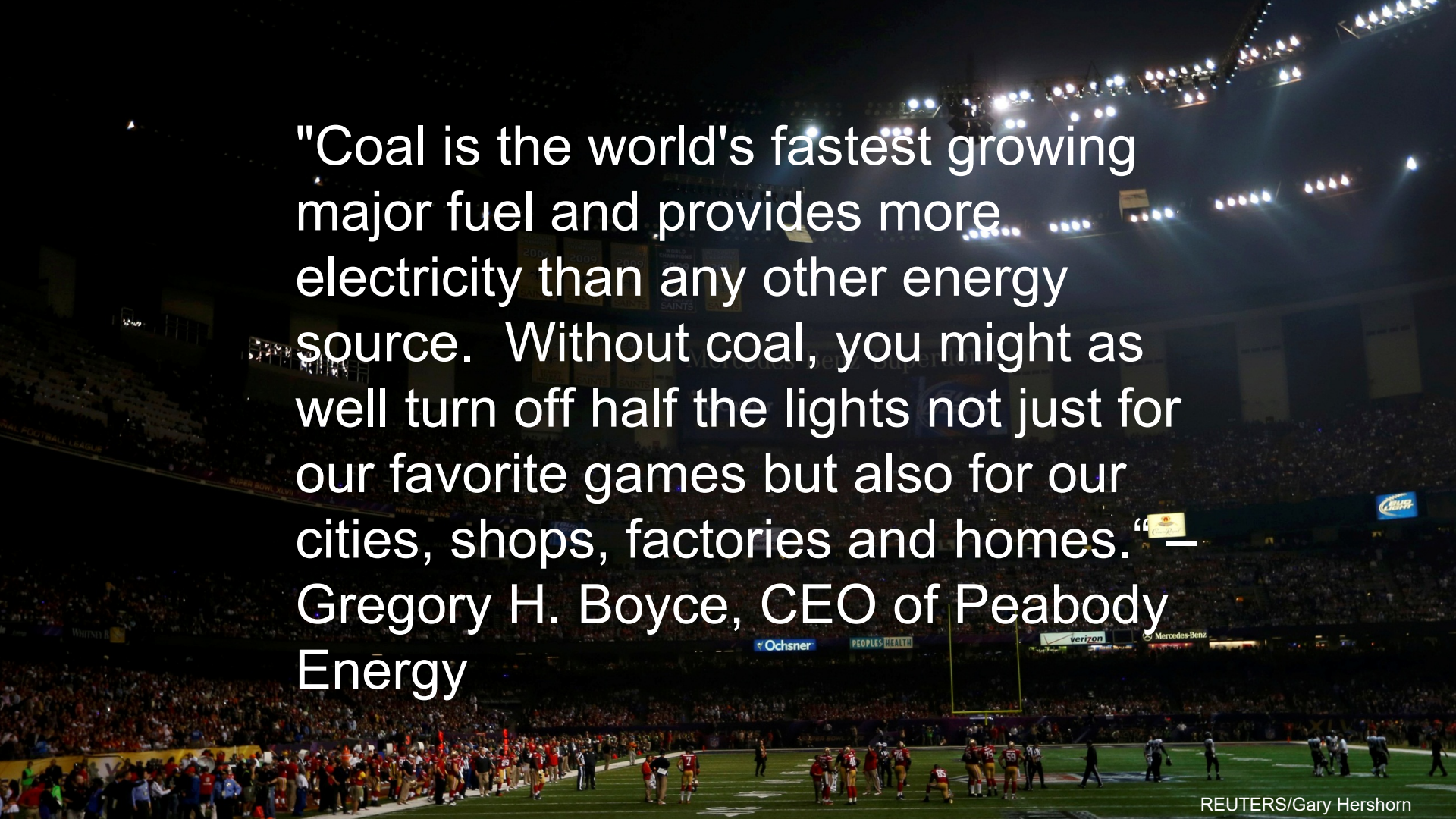
Graduate Certificates

- Computer & Systems Security
- Engineering Management
- Stormwater Management

DOCTORAL DEGREES

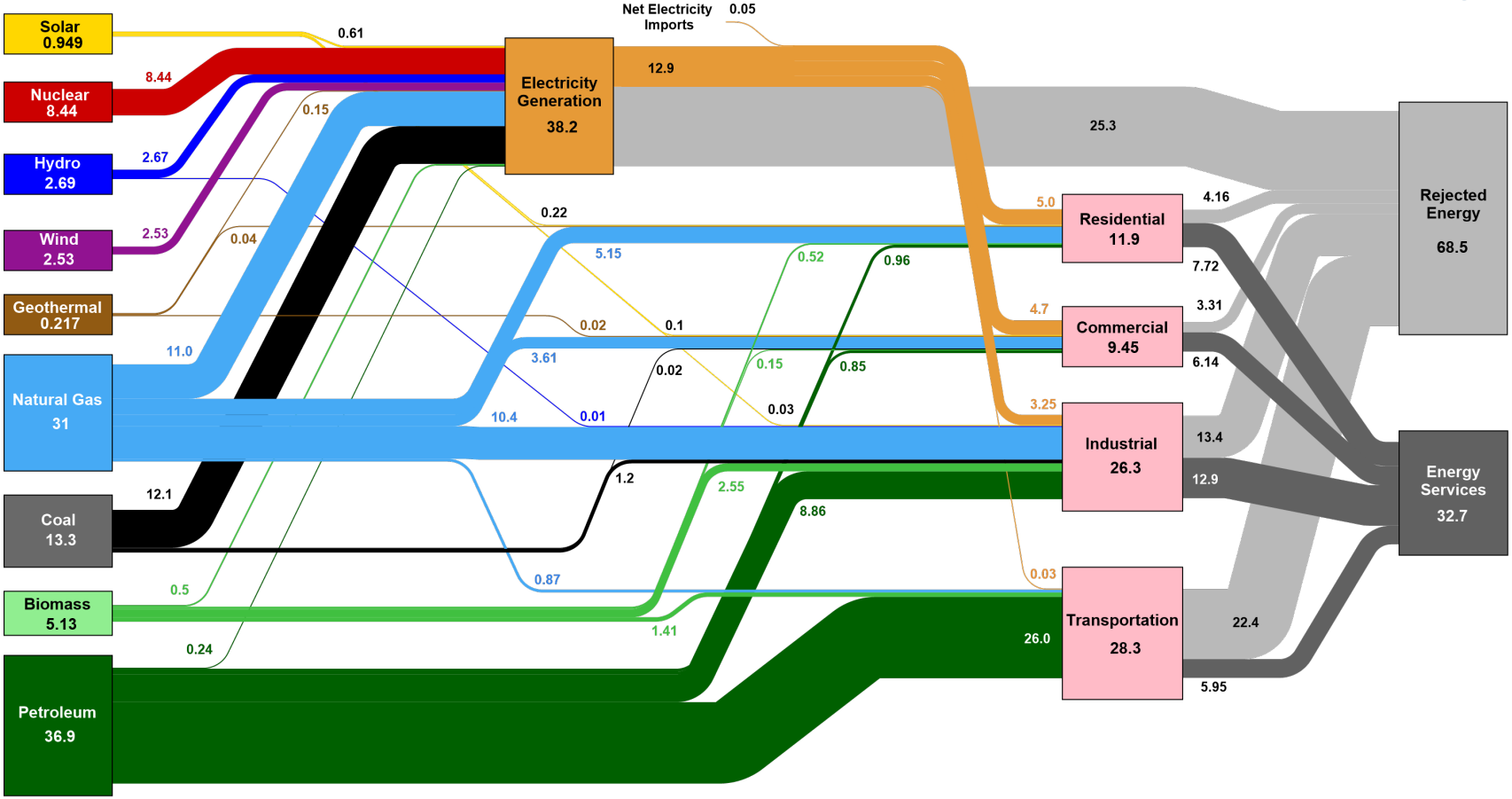
- PhD Bioengineering
- PhD Civil Engineering
- PhD Electrical Engineering
- PhD Environmental Engineering
- PhD Mechanical Engineering

College of Engineering


"Coal is the world's fastest growing major fuel and provides more electricity than any other energy source. Without coal, you might as well turn off half the lights not just for our favorite games but also for our cities, shops, factories and homes." – Gregory H. Boyce, CEO of Peabody Energy
Ochsner
PEOPLES HEALTH
verizon
Mercedes-Benz
REUTERS/Gary Hershorn

Estimated U.S. Energy Consumption in 2018: 101.2 Quads

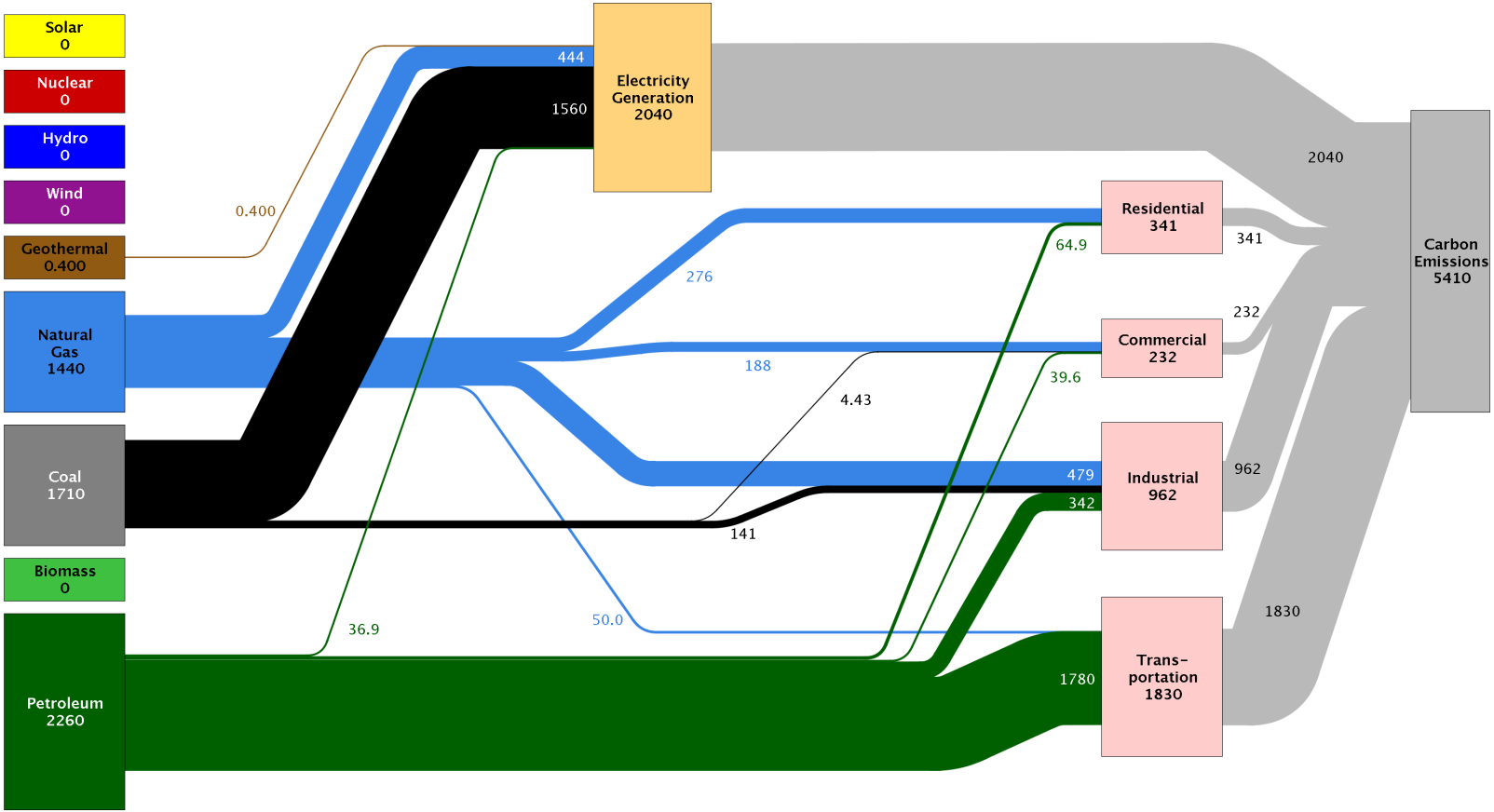
Lawrence Livermore National Laboratory



Source: LLNL March, 2019. Data is based on DOE/EIA MER (2018). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

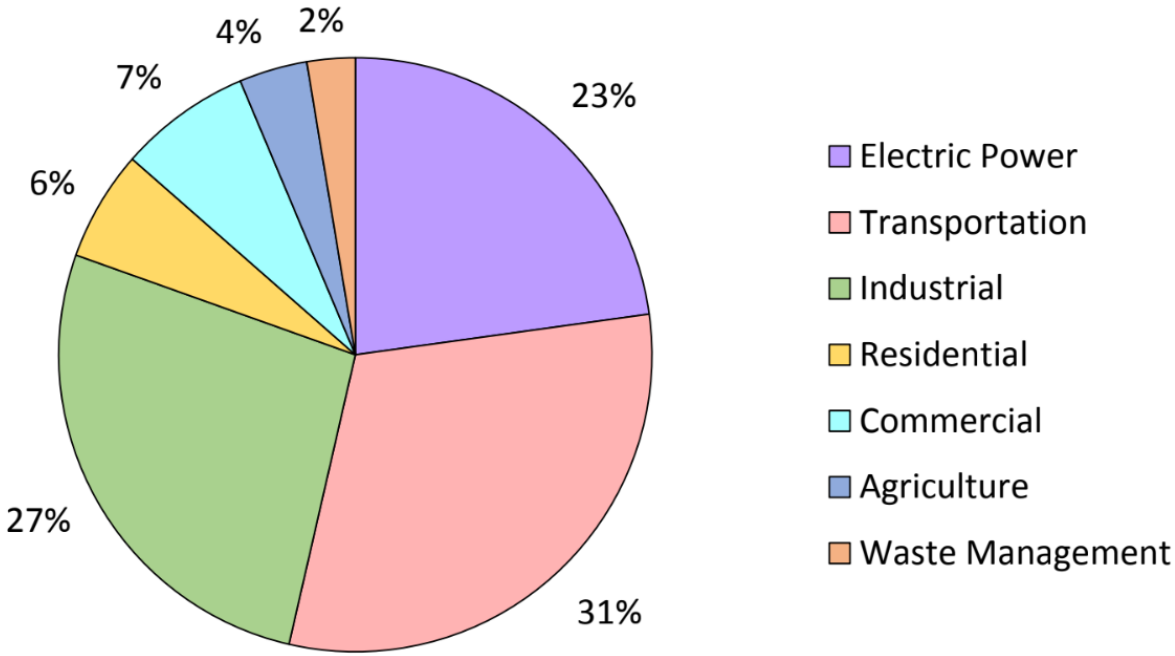
Estimated U.S. Carbon Emissions in 2014: ~5,410 Million Metric Tons

Lawrence Livermore National Laboratory



Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2015. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon emissions are attributed to their physical source, and are not allocated to end use for electricity consumption in the residential, commercial, industrial and transportation sectors. Petroleum consumption in the electric power sector includes the non-renewable portion of municipal solid waste. Combustion of biologically derived fuels is assumed to have zero net carbon emissions – the lifecycle emissions associated with producing biofuels are included in commercial and industrial emissions. Totals may not equal sum of components due to independent rounding errors. LLNL-MI-410527

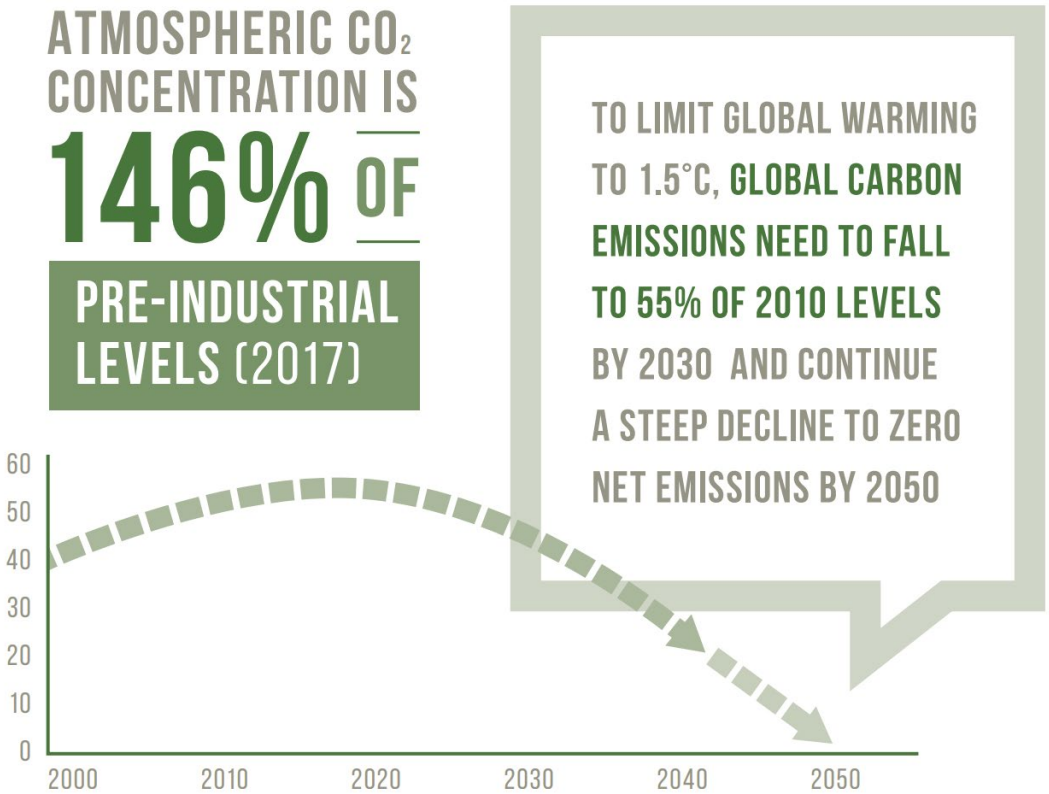
Breakdown of gross GHG Emissions in DE By Sector



From *Delaware's 2016 Greenhouse Gas Emissions Inventory*

College of Engineering

The time for action is now



College of Engineering

https://www.un.org/sustainabledevelopment/climate-change/

Challenges to 100% Renewable Energy

#1: Resource Size

#2: Cost

#3: Intermittency of Renewable Generation

#4: Policy and Market Barriers

College of Engineering

Challenges to 100% Renewable Energy

#1: Resource Size

#2: Cost

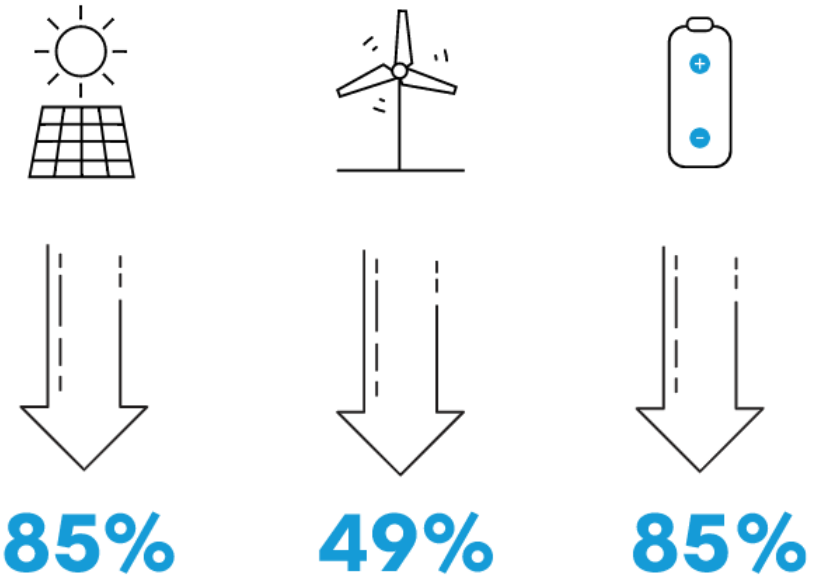
#3: Intermittency of Renewable Generation

#4: Policy and Market Barriers

College of Engineering

Technology cost declines since 2010

(Source: BloombergNEF)



College of Engineering

Challenges to 100% Renewable Energy

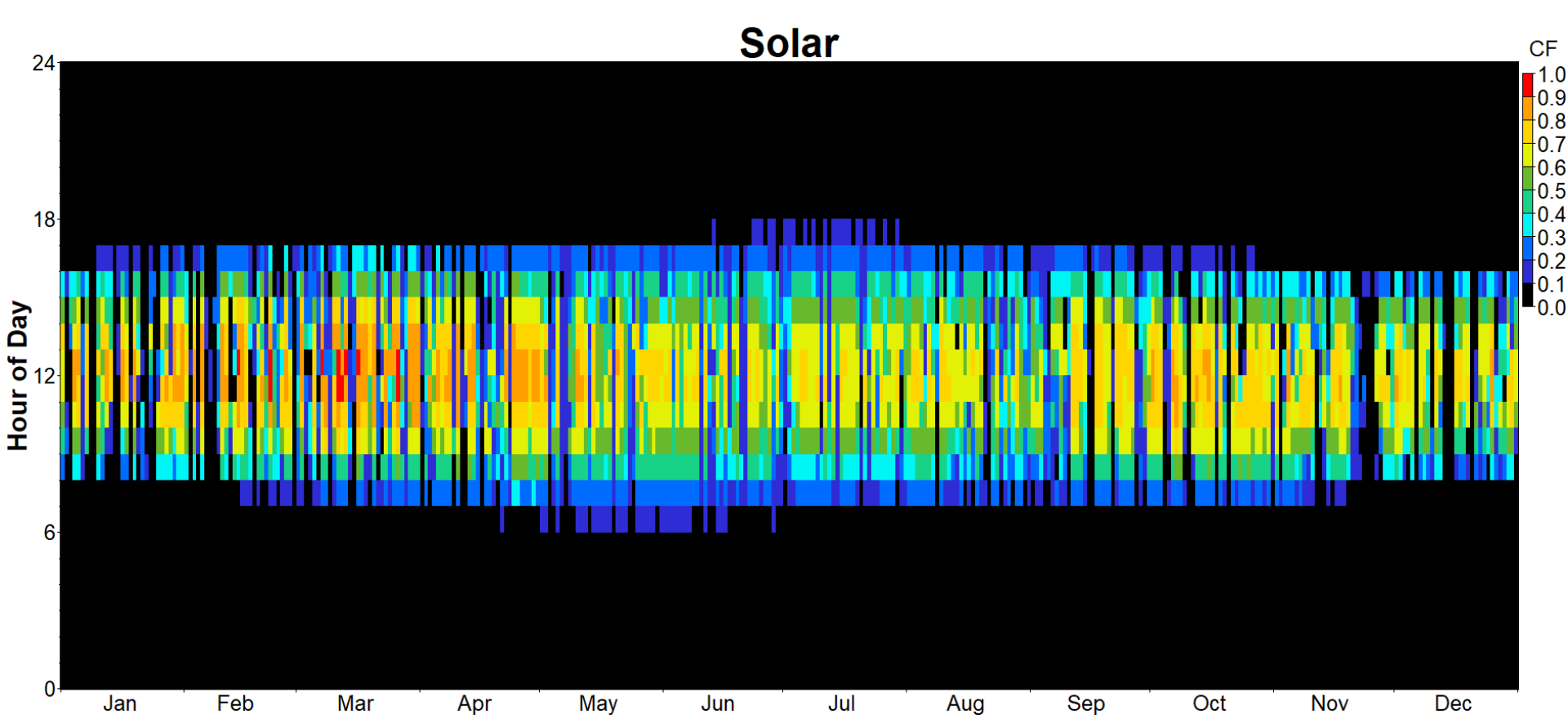
#1: Resource Size

#2: Cost

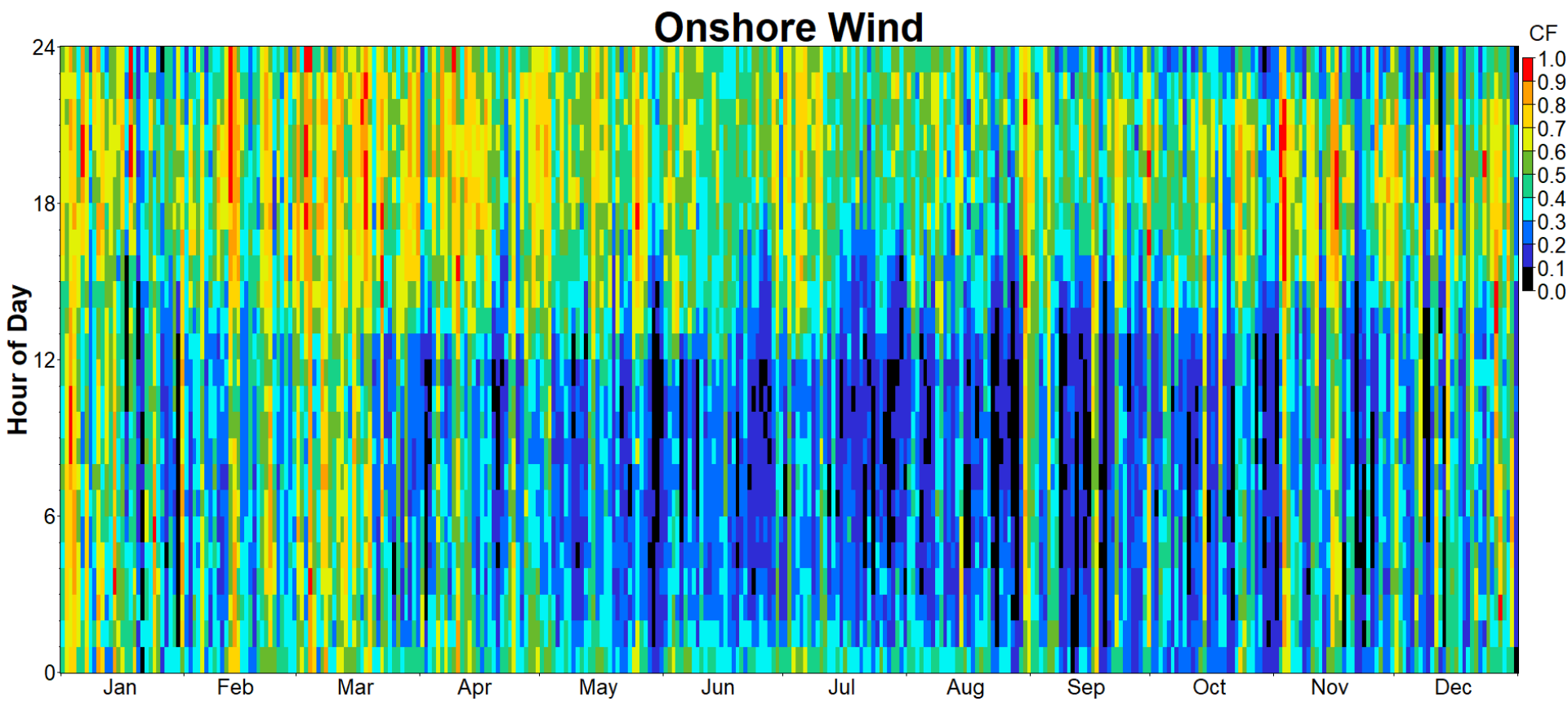
#3: Intermittency of Renewable Generation

#4: Policy and Market Barriers

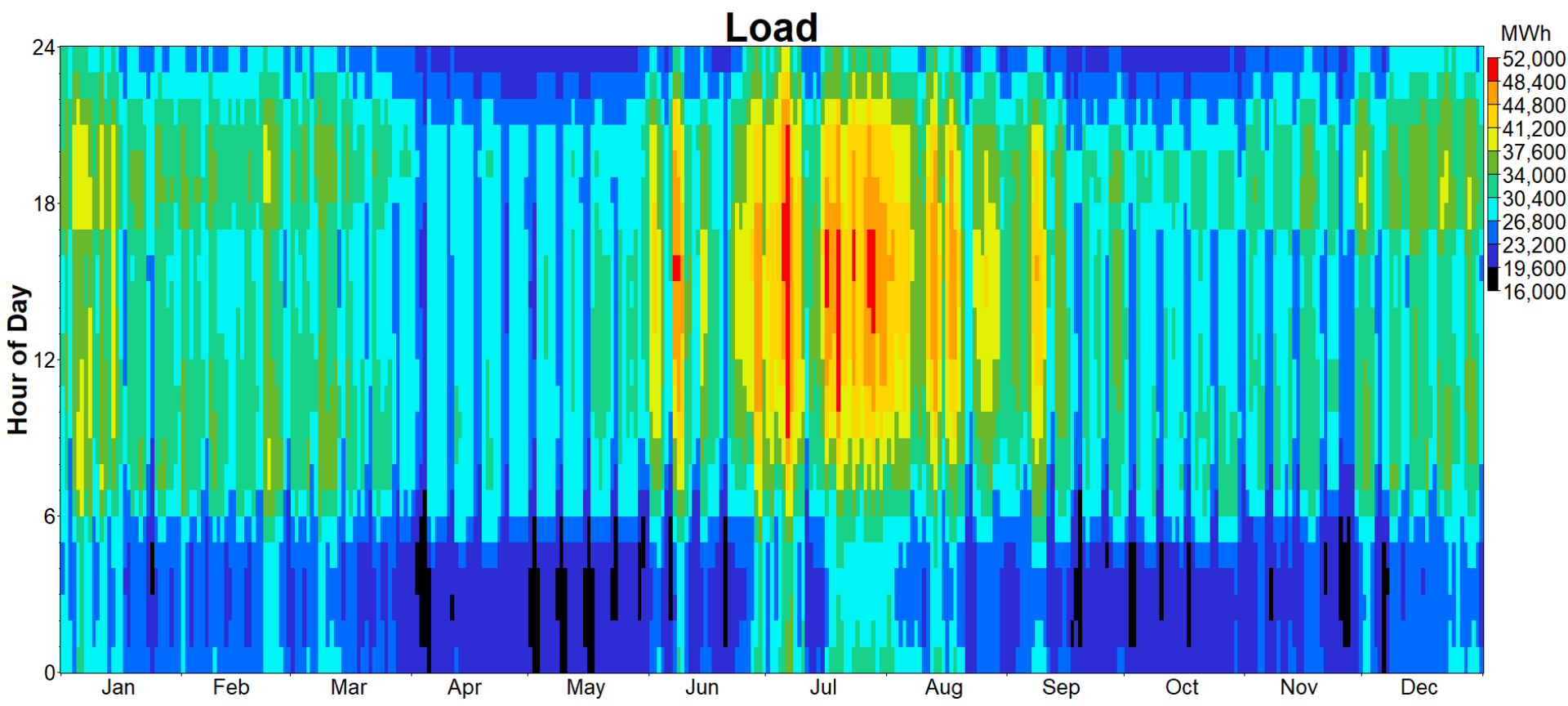
College of Engineering



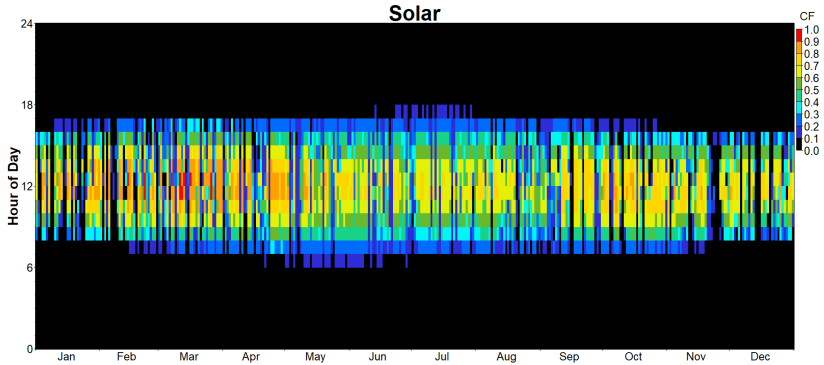
College of Engineering

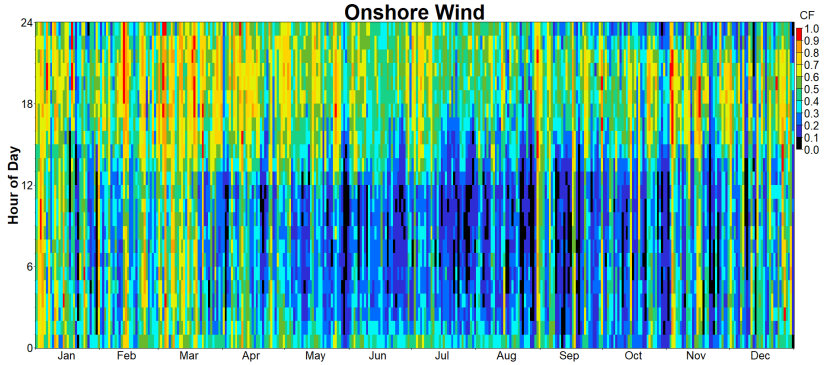


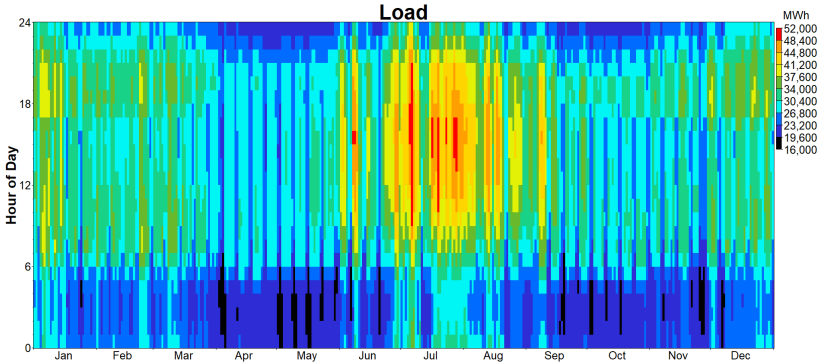
College of Engineering



College of Engineering







College of Engineering

Challenges to 100% Renewable Energy

#1: Resource Size

#2: Cost

#3: Intermittency of Renewable Generation

#4: Policy and Market Barriers

College of Engineering

Some Current Delaware Policies/Programs -DNREC

The Delaware Energy Efficiency Advisory Council

The Energy Efficiency Advisory Council develops and deploys energy efficiency programs and financing mechanisms offered by Delaware energy providers.

The Delaware Energy Efficiency Investment Fund

The Energy Efficiency Investment Fund helps commercial and industrial customers replace aging, inefficient energy equipment and systems.

Model Building Energy Codes

Delaware provides model energy conservation standards for local government building and plumbing rules and regulations.

Renewable Energy Assistance

The Green Energy Program provides rebates for residential and small scale renewable energy systems.

Renewable Energy Portfolio Standards

Delaware utilities must get an increasing percentage of their electricity from renewable resources.

Offshore Wind Working Group

An Offshore Wind Working Group explored opportunities and issues for Delaware in developing offshore wind.

Plus:

RGGI

Clean Vehicle Rebate

+More

College of Engineering

Some Current Delaware Policies/Programs - SEU

RESIDENTIAL

ENERGIZE DELAWARE PROGRAMS

Home Performance with ENERGY STAR®
Affordable Multifamily Housing
Pre-Weatherization Program
ZeMod
Residential Solar Loans
Solar Renewable Energy Credits

OTHER PROGRAMS

Weatherization Assistance
Green Energy Program

PUBLIC & NONPROFIT

ENERGIZE DELAWARE PROGRAMS

Delaware Property Assessed Clean Energy (D-PACE)
Low Interest Commercial Loan Program
Performance Contracting Program
Energy Efficiency Investment Fund
Energy Assessment Program
Faith Efficiencies
Pathways to Green Schools
Solar Renewable Energy Credits

FARM

ENERGIZE DELAWARE PROGRAMS

Delaware Property Assessed Clean Energy (D-PACE)
Farm Program
Low Interest Commercial Loan Program
Solar Renewable Energy Credits

BUSINESS

ENERGIZE DELAWARE PROGRAMS

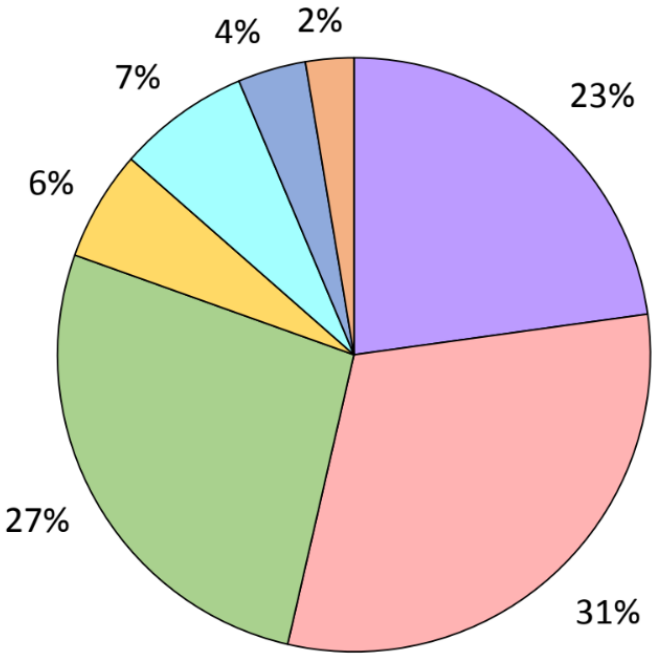
Delaware Property Assessed Clean Energy (D-PACE)
Low Interest Commercial Loan Program
Affordable Multifamily Housing
Solar Renewable Energy Credits

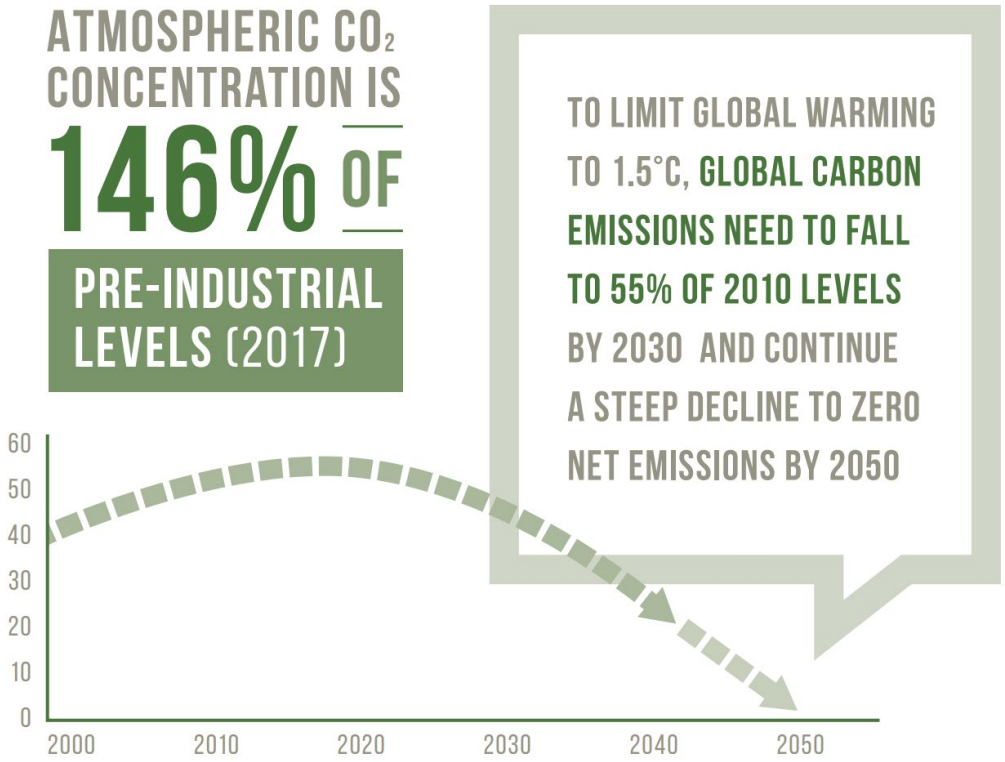
Some Current Delaware Policies/Programs - Federal

So many…

College of Engineering

Remember…





https://www.un.org/sustainabledevelopment/wp-content/uploads/2019/07/E_Infographic_13.pdf

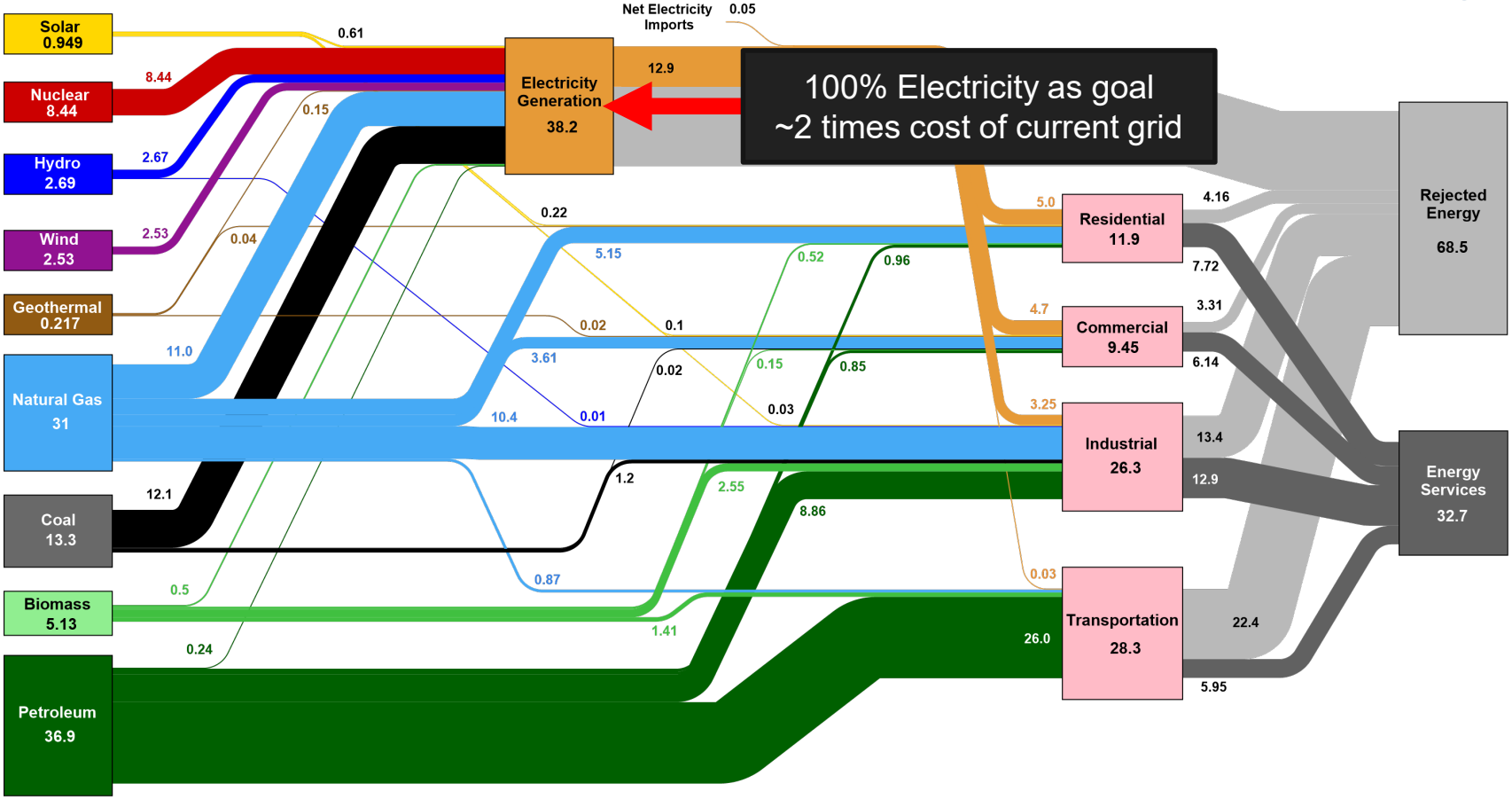
College of Engineering

In order to transition away from fossil fuels quickly and cost effectively, we need policies and our thinking to address the energy system as a whole.

College of Engineering

Estimated U.S. Energy Consumption in 2018: 101.2 Quads

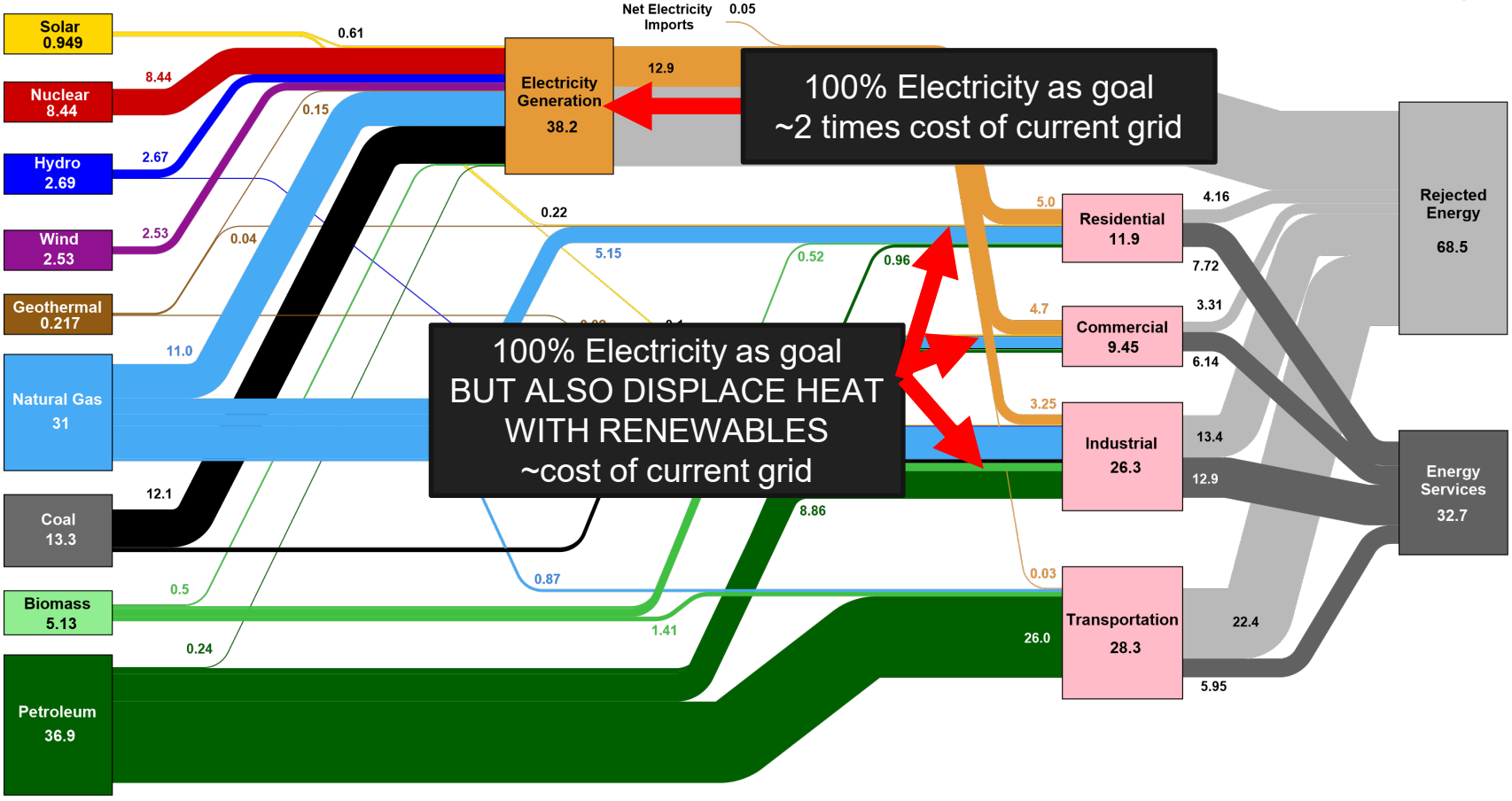
Lawrence Livermore National Laboratory



Cost results from: Budischak, C., Sewell, D., Thomson, H., Mach, L., & Veron, D. E. (2013). Cost-minimized combinations of wind power , solar power and electrochemical storage , powering the grid up to 99 . 9 % of the time. *Journal of Power Sources*, *225*, 60–74.

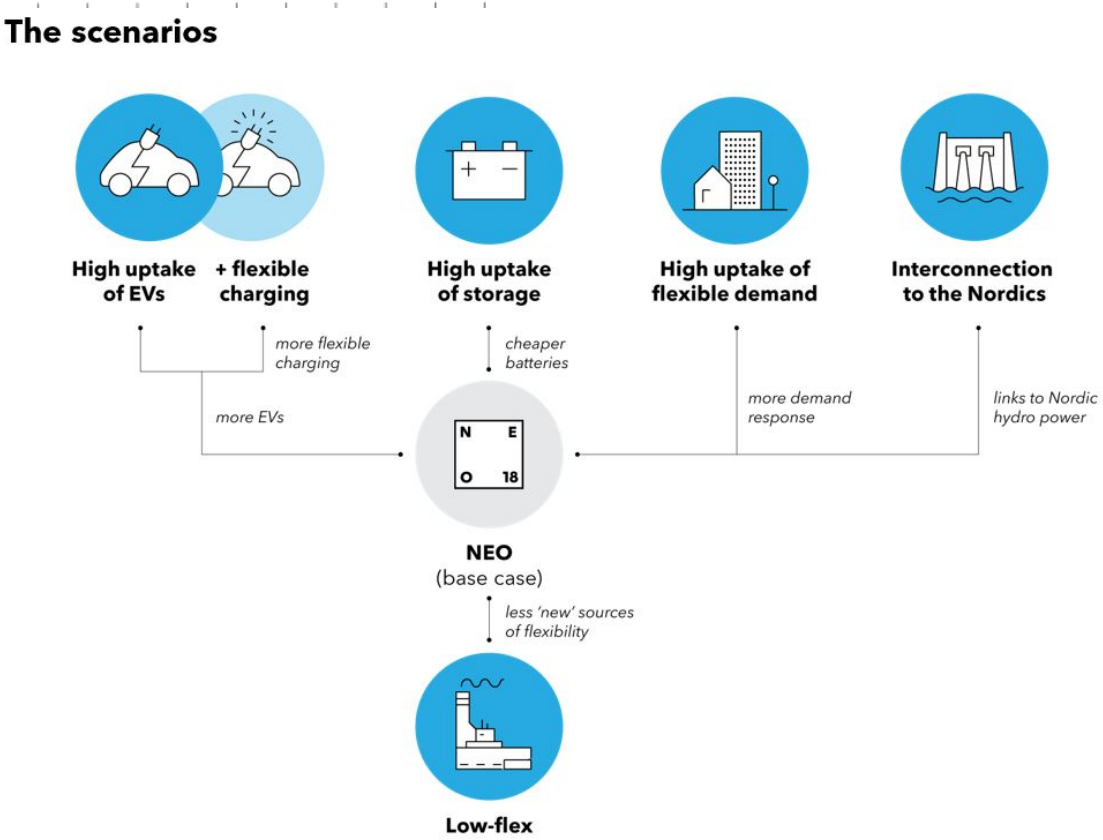
Estimated U.S. Energy Consumption in 2018: 101.2 Quads

Lawrence Livermore National Laboratory



Cost results from: Budischak, C., Sewell, D., Thomson, H., Mach, L., & Veron, D. E. (2013). Cost-minimized combinations of wind power , solar power and electrochemical storage , powering the grid up to 99 . 9 % of the time. *Journal of Power Sources*, *225*, 60–74.

Another Example



Source: BloombergNEF

College of Engineering

Table 2: Summary of scenario outcomes in 2040

Scenario	System cost	Emissions	Fossil capacity as share of peak demand	Renewable share of generation
NEO (base case)	48.6 EURm/TWh	109 MtCO2	56%	83%
Relative change vs NEO				
Low-flex	8%	-15%	19%	3%
High uptake of EVs	1%	-18%	-7%	2%
High uptake of EVs and flexible charging	-1%	-26%	-22%	4%
High uptake of storage	0%	-11%	-3%	3%
High uptake of flexible demand	0%	2%	-1%	0%
Interconnection to the Nordics	-2%	-11%	-4%	3%

Source: BloombergNEF. Note: Colour scales differ between columns, but in all cases green is desirable. Emissions for EV scenarios include a negative contribution from emissions displaced in the oil sector; net imports included in renewable share of generation.

https://data.bloomberglp.com/professional/sites/24/2018/11/Germany-Flexibility-Solutions-for-High-Renewable-Energy-Systems-2018-BNEF-Eaton-Statkraft.pdf

College of Engineering

Table 2: Summary of scenario outcomes in 2040

Scenario	System cost	Emissions	Fossil capacity as share of peak demand	Renewable share of generation
NEO (base case)	48.6 EURm/TWh	109 MtCO2	56%	83%
Relative change vs NEO				
Low-flex	8%	-15%	19%	3%
High uptake of EVs	1%	-18%	-7%	2%
High uptake of EVs and flexible charging	-1%	-26%	-22%	4%
High uptake of storage	0%	-11%	-3%	3%
High uptake of flexible demand	0%	2%	-1%	0%
Interconnection to the Nordics	-2%	-11%	-4%	3%

Source: BloombergNEF. Note: Colour scales differ between columns, but in all cases green is desirable. Emissions for EV scenarios include a negative contribution from emissions displaced in the oil sector; net imports included in renewable share of generation.

https://data.bloomberglp.com/professional/sites/24/2018/11/Germany-Flexibility-Solutions-for-High-Renewable-Energy-Systems-2018-BNEF-Eaton-Statkraft.pdf

College of Engineering

In order to transition away from fossil fuels quickly and cost effectively, we need policies and our thinking to address the energy system as a whole.

What policies do this?

College of Engineering

Example of Policy that Takes a Systems Approach

CHRIS COONS

Meet Chris | Services | News | Contact

News / Press Releases

Sens. Coons and Feinstein, Rep. Panetta introduce bill to price carbon pollution, invest in infrastructure, R&D, and working families

The Climate Action Rebate Act will help create jobs, spur innovation in clean energy, and reduce U.S. carbon emissions by 55% within a decade

JULY 25, 2019