

# **Mitigating & Adapting to Climate change: Extreme Weather Events, a Worldwide Energy Revolution and Geoengineering options**

**Week 6: May 1<sup>st</sup> , 2017**

**Part A: Nuclear Power (fission and fusion)**

**Part B: Storage and Grid Options**

**Paul Belanger, Ph.D.**

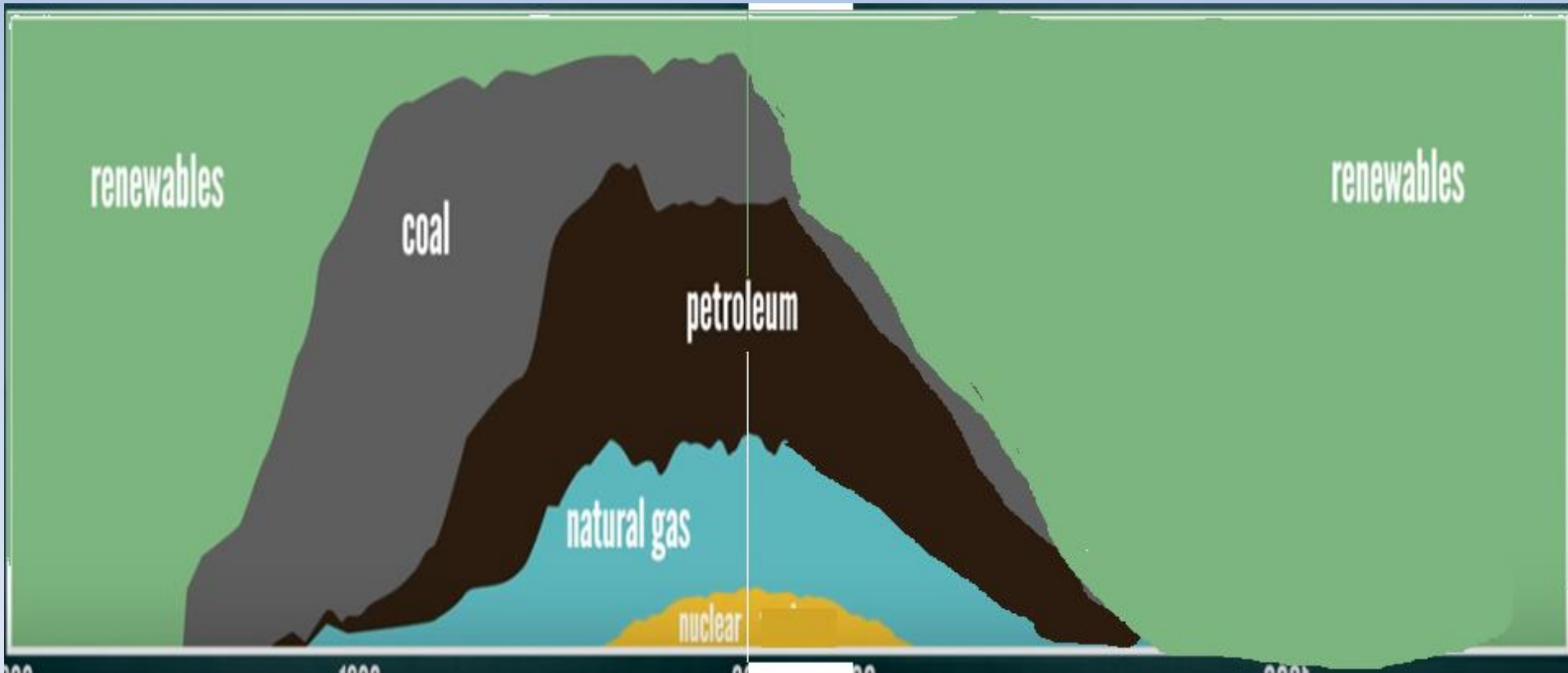
# PART B: A Changing Power System

## Storage vs. the Grid

### Small or Large

- Power Source Options in Decarbonization
- Baseload Power or Not
- Storage vs. the Grid

# PROJECTIONS: Renewables to Coal-Petroleum-Natural Gas-Nuclear -- Back to Renewables & Nuclear Sources



## Fossil fuels: global production, 1800–2200

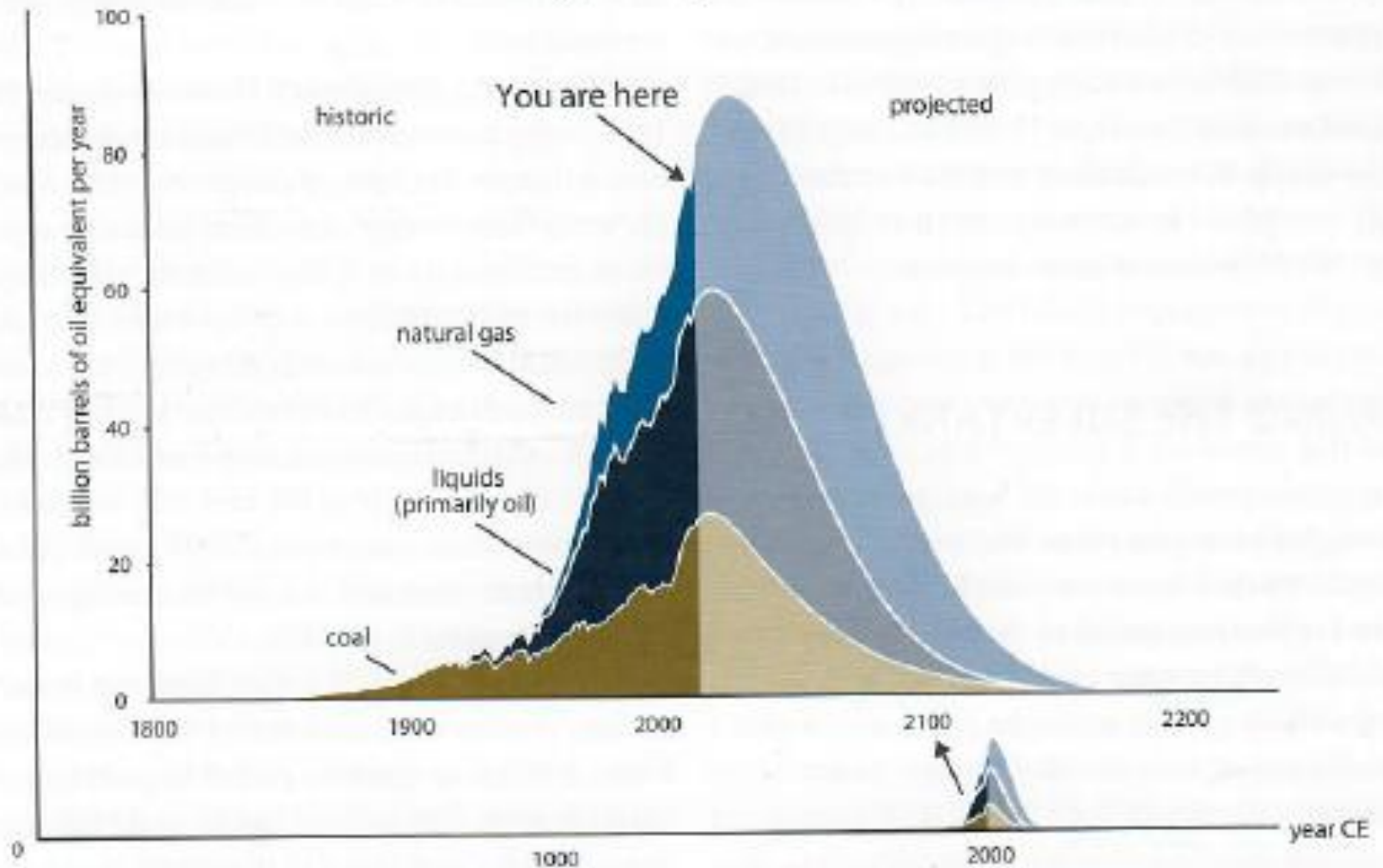


FIG. 1-3. This graph plots the actual global output of the three major classes of hydrocarbons through 2009, then projects the remaining amounts of each believed likely to be recovered if there are no aboveground constraints.<sup>27</sup> The historic data are accurate but the smoothed illustrative projections are quite approximate, reflecting leading resource experts' knowledge in early 2011 but subject to many uncertainties. The projections include unconventional resources such as shale gas, heavy oil, tar sands, and shale oil, but not methane hydrates, potential Arctic and Antarctic resources, or Alaskan North Slope and central Siberian coal.

## Costs of oil dependence to the U.S. economy, 1970-2008

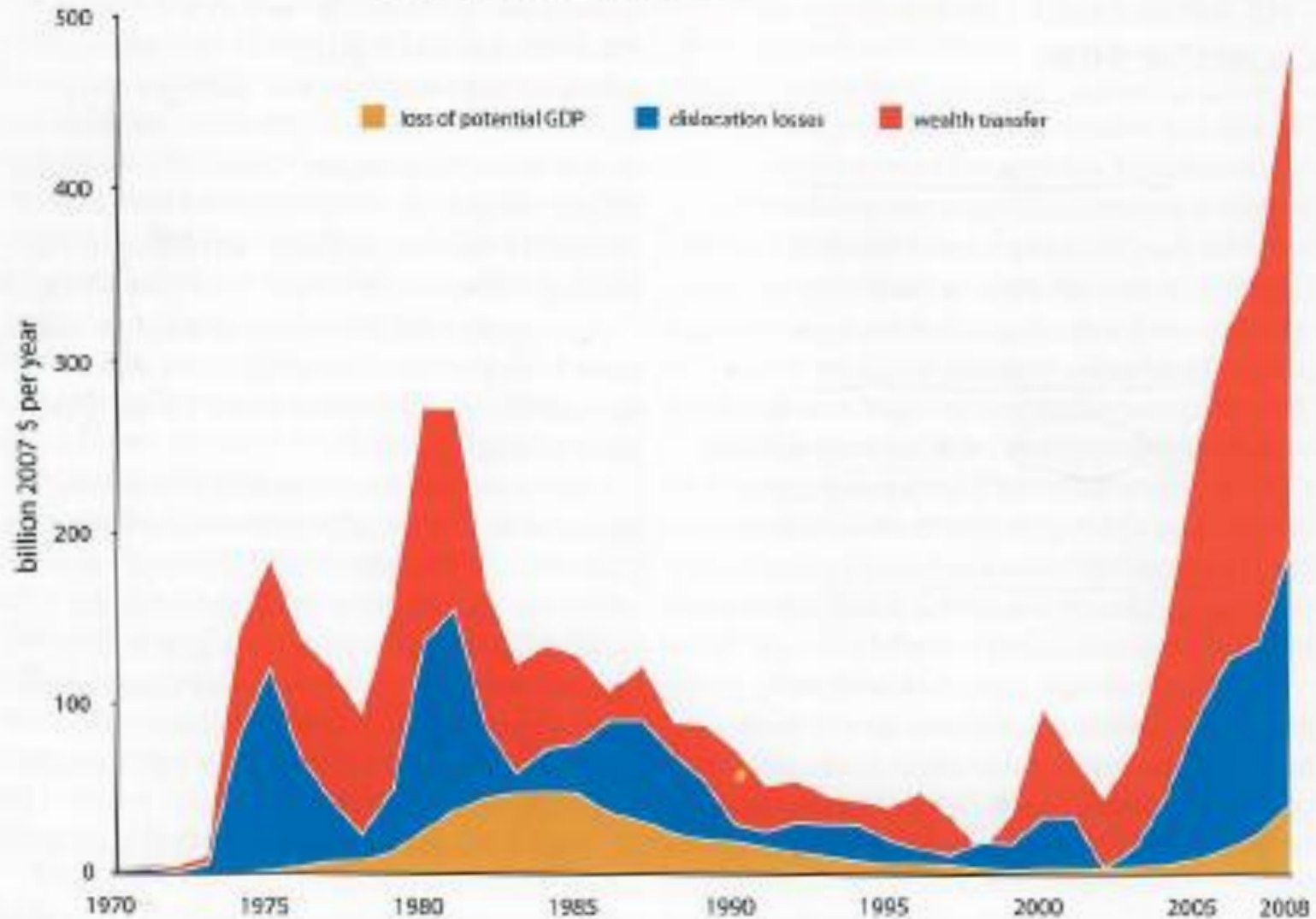
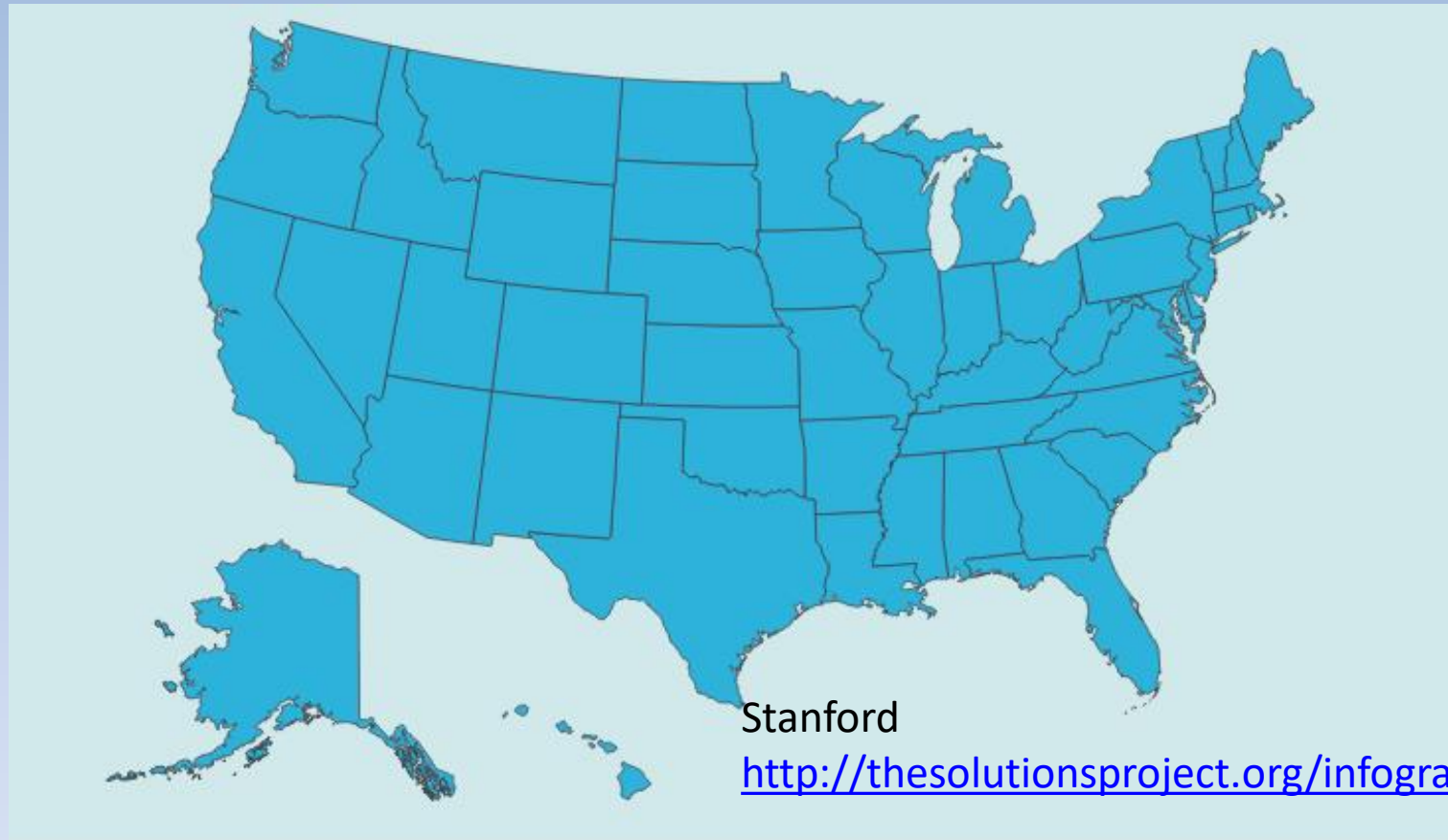


FIG. 1-2. Estimated direct costs of oil dependence to the United States, 1970-2008<sup>10</sup>

# The Solutions Project

- **100% RENEWABLE ENERGY VISION**



Stanford

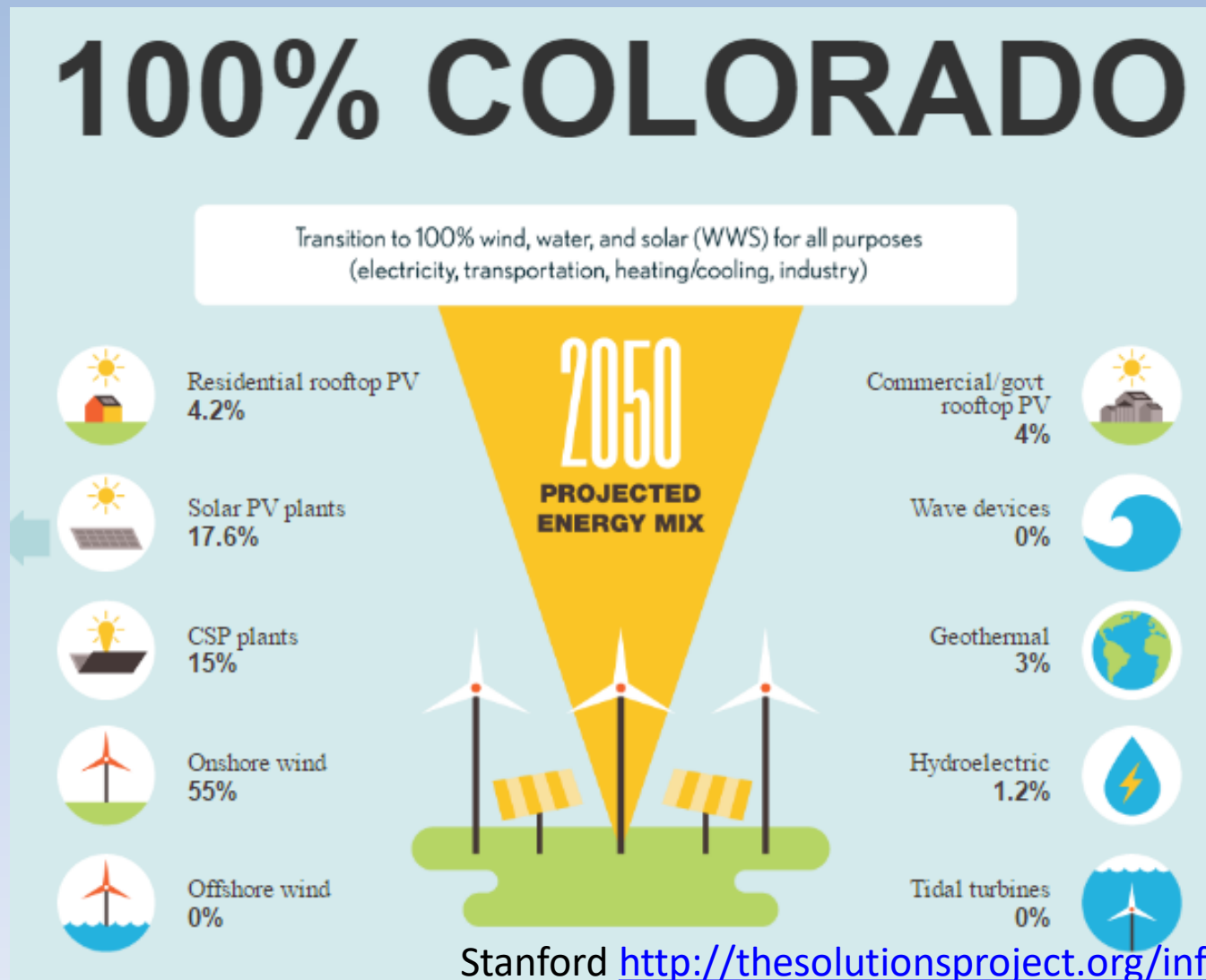
<http://thesolutionsproject.org/infographic/>

## MAP KEY:



# The Solutions Project

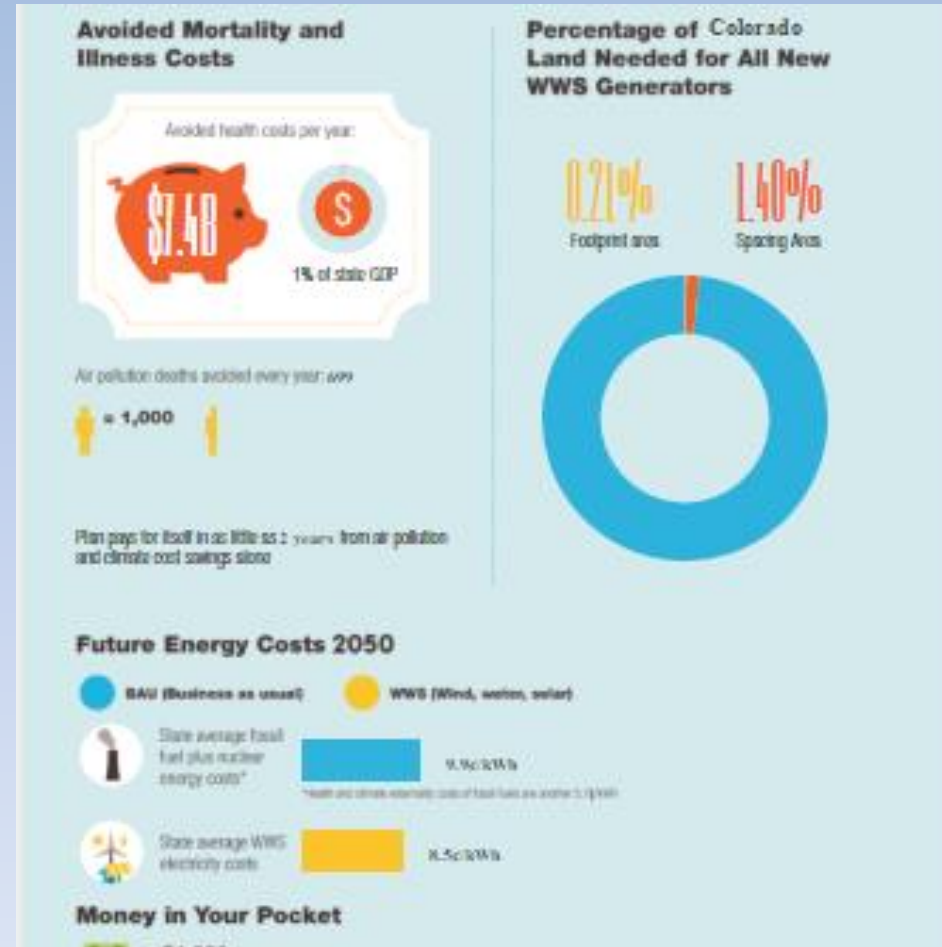
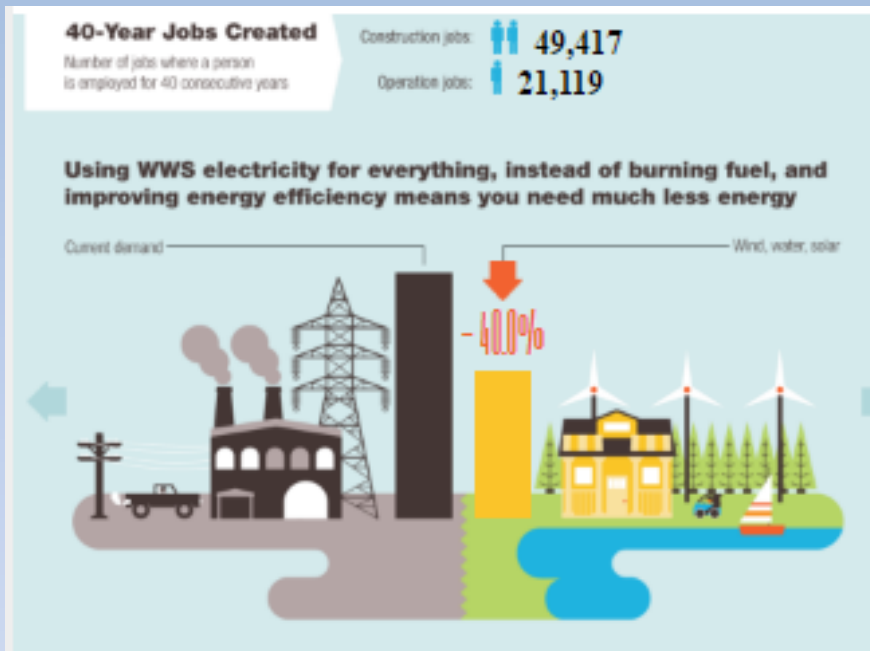
- **100% RENEWABLE ENERGY VISION**





# The Solutions Project

- 100% RENEWABLE ENERGY VISION



VISIT [THE SOLUTIONS PROJECT.ORG](http://thesolutionsproject.org)  
TO LEARN MORE AND [100.ORG](http://100.org) TO JOIN THE MOVEMENT



# A Changing Power System

- CRES YouTube: Many videos on this and related topics
  - <https://www.youtube.com/channel/UCr81EUb2qVJVfmmlJIMxEHVw/videos>
- Thank Martin Voelker for his wonderful work doing this – free!

# J-CRES Meeting last week: K.K. DuVivier

## A. Net Zero Carbon Buildings



$\frac{1}{4}$  Electricity Plug-load

**1. SOLAR PV + STORAGE**

$\frac{1}{4}$  Domestic Hot Water

$\frac{1}{2}$  Space Heating

**II. DG THERMAL—HOT WATER  
& SPACE CONDITIONING**

# Why not distributed wind or hydro?

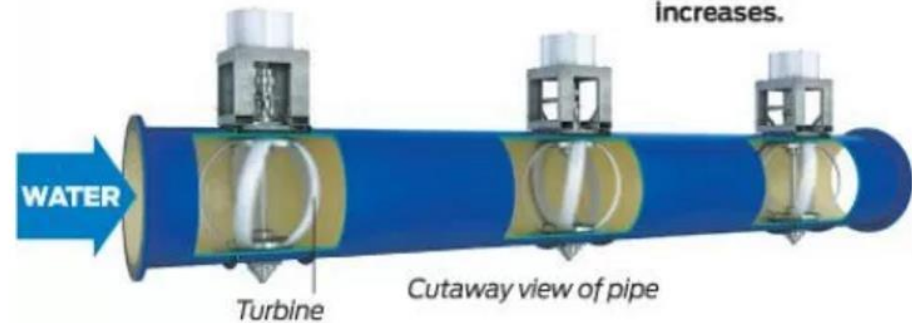
Nov 2016 report from NREL concludes that resource potential for distributed wind exceeds the total US electricity demand, but only 934 MW of capacity.



## Energy from a pipeline

LucidEnergy's Lucidpipe allows electricity to be generated from water that is already flowing through pipelines. Here is a brief outline of how the technology works:

- 1** Water flows through the pipe in either direction.
- 2** The water spins the hydrodynamic turbine.
- 3** As water velocity increases, power production increases.



Source: LucidEnergy

San Antonio Express-News

<http://www.gamengadgets.com/water-pipes-will-generate-electricity-for-portland/>

<https://cleantechnica.com/2014/12/29/bipartisan-group-senators-pushing-distributed-wind-heres-matters/>

## B. Solar + Storage (the next killer app)

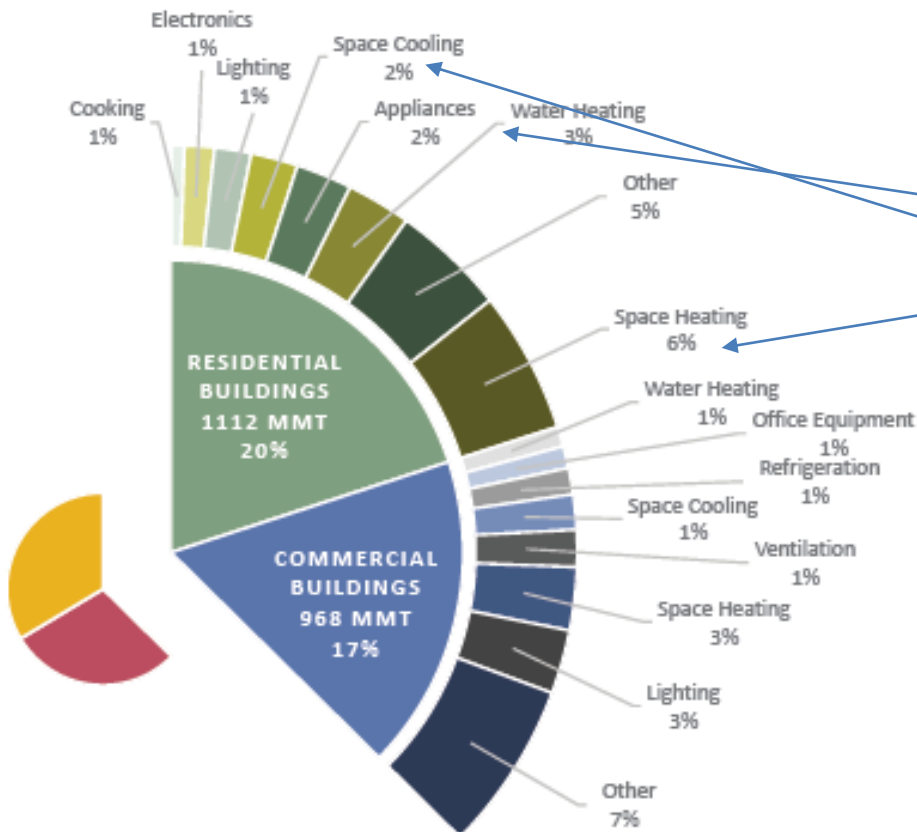
- US solar capacity tripled to 32 gigawatts (end of 2016), up from 10 gigawatts in 2013.
- US total technical potential for 1,118 GW of rooftop solar PV, which could generate 1,432 TWh of annual energy generation (2016).
- By the first half of 2015, the US had only installed about 1% of the technical potential.
- Only 26% of rooftop area of small buildings is optimal for PV, but has the greatest potential—731 GW or 65% of the technical potential.



<http://www.cpr.org/news/gallery/slideshow-kk-duvivier-and-lance-wrights-home-solar-settlement>

# C. Distributed Thermal Resources

**FIGURE 4.13: CO<sub>2</sub> EMISSIONS BY END USE: BUILDINGS**



**37% of CO<sub>2</sub> emissions from residential & commercial buildings combined.**

**Largest contributors are:**

- 1) Water Heating and**
- 2) Space Heating and Cooling**

**About ½ of US floor space is currently heated with systems that burn fossil fuels.**

**Energy Efficiency is one solution, but another is increased electrification.**

[https://www.whitehouse.gov/sites/default/files/docs/mid\\_century\\_strategy\\_report-final.pdf](https://www.whitehouse.gov/sites/default/files/docs/mid_century_strategy_report-final.pdf)  
at 59

# Storage options

- [https://en.wikipedia.org/wiki/Energy\\_storage](https://en.wikipedia.org/wiki/Energy_storage)
- [2Methods](#)
  - [2.1Outline](#)
  - [2.2Mechanical storage](#)
  - [2.3Thermal storage](#)
  - [2.4Electrochemical](#)
  - [2.5Other chemical](#)
  - [2.6Electrical methods](#)
  - [2.7Interseasonal thermal storage](#)

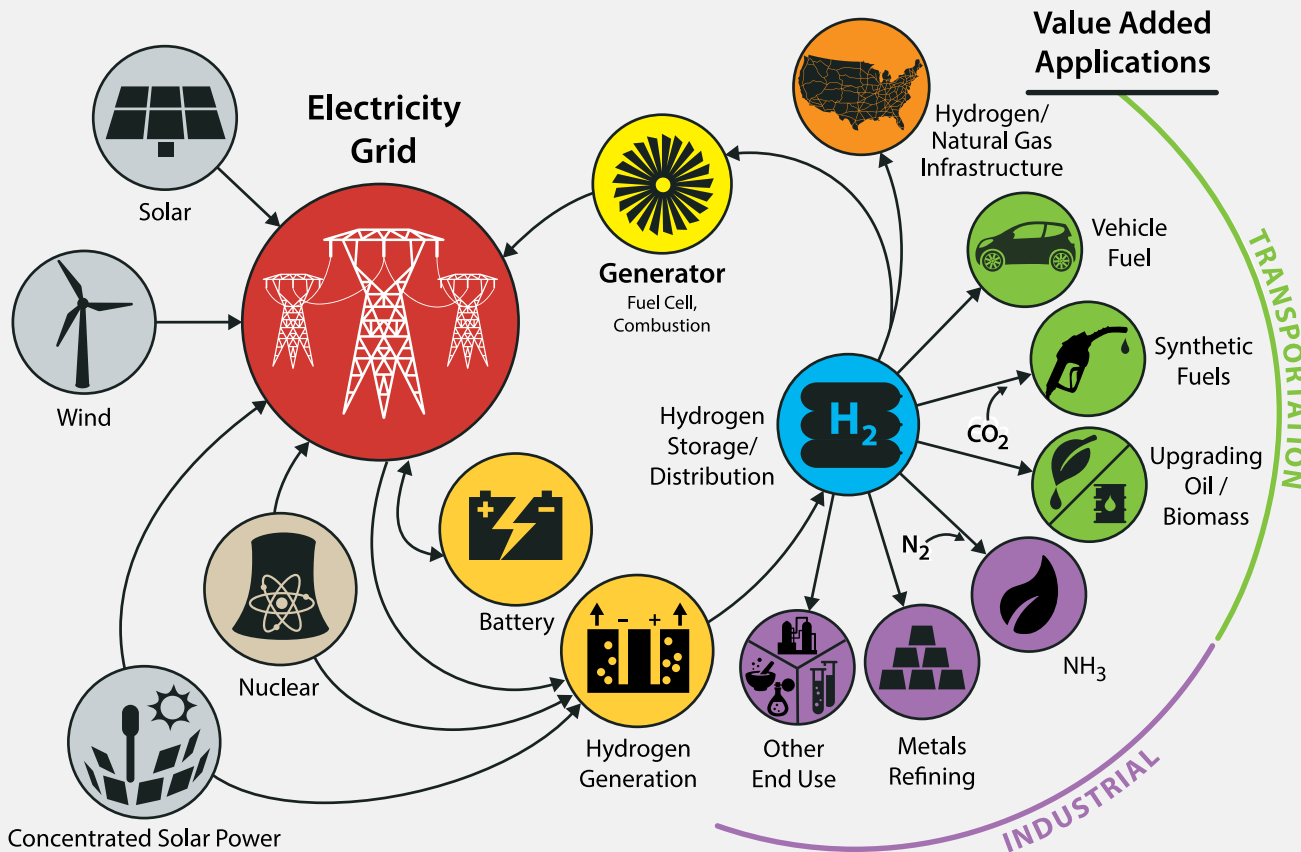


# BACKUP OR GRID

- Balanced power is necessary: not too much, not too little
- SOLUTION – EITHER
  - Backup:
    - Battery,
    - Compressed Air,
    - Re-pumped Hydro,
    - H<sub>2</sub> (this can be 2-way for excess power or needed power)
    - Rubber Bands, etc.
  - Grid

# Future Energy System – Commodity H<sub>2</sub>

## Future H<sub>2</sub> at Scale Energy System



### WHY HYDROGEN?

- Hydrogen is an ideal clean energy carrier—connecting diverse energy sources to diverse applications
- It can play a unique and critical role in addressing many of the energy sector's greatest challenges

### TODAY'S ENERGY SYSTEM

- Renewable energy—particularly wind and solar—offer great promise but have challenges associated with variable and concurrent generation
- Options to achieve deep decarbonization while meeting society's multi-sector energy demands are limited, particularly in the industrial and transportation sectors

### FUTURE H<sub>2</sub> AT SCALE ENERGY SYSTEM

- Connects low-carbon energy sources to all of the energy sectors
- Uses carbon-free, renewable inputs to service all of society's energy needs, in particular the difficult to decarbonize sectors of industry and transportation
- Does not compete with other options—rather, it enables increased renewable penetration
- Can decrease 45% of all U.S. carbon emissions by 2050

# Ken Regelson videos

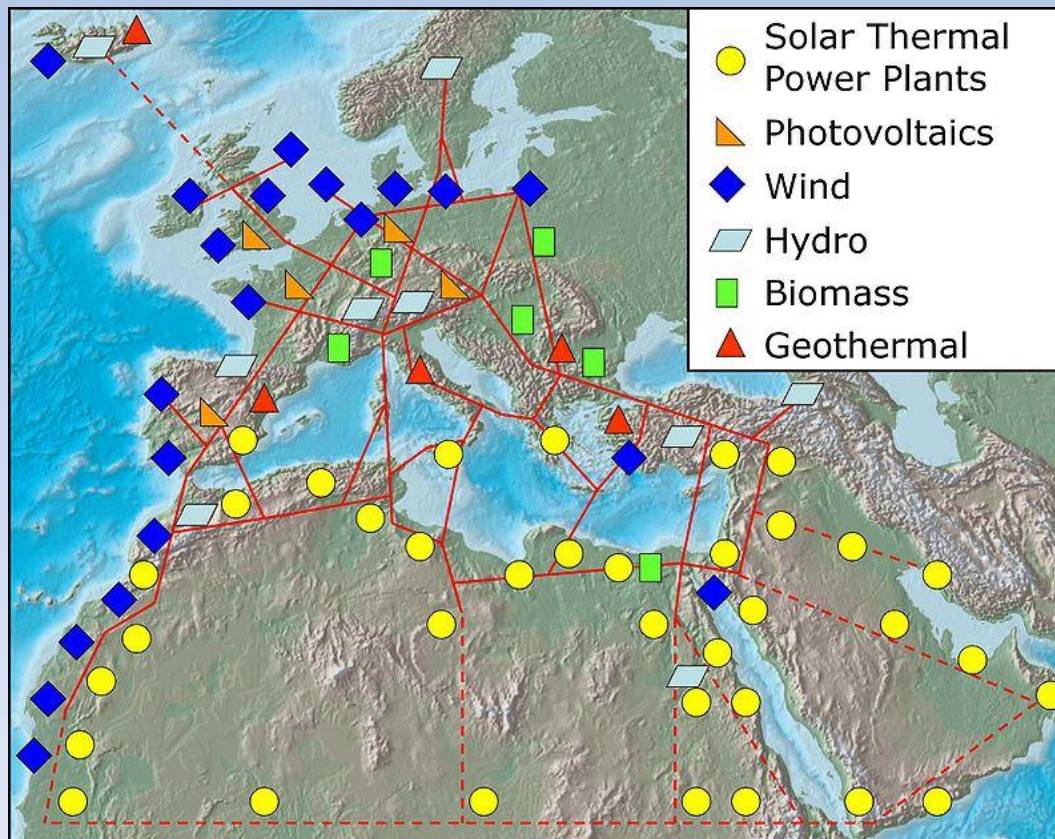
- CRES YouTube: Many videos on
  - <https://www.youtube.com/channel/UCr81EUb2qVJVfmmIJMxEHVw/videos>
- Energy Should Be web page: <http://energysouldbe.org/>
  - Why Storage is Key for a Renewable Energy Future: [https://www.youtube.com/watch?v=Yc\\_hULwykvQ&t=14s](https://www.youtube.com/watch?v=Yc_hULwykvQ&t=14s)
  - To Allow Lots of Renewables, Baseload Coal & Nuclear Must Go: <https://youtu.be/deWtgpheDJM>
  - Etc.

# Grid: Big or Small?

- A case for small?
- <http://www.wbur.org/bostonomix/2017/04/19/microgrid-joint-base-cape-cod>

# Grid: Big or Small?

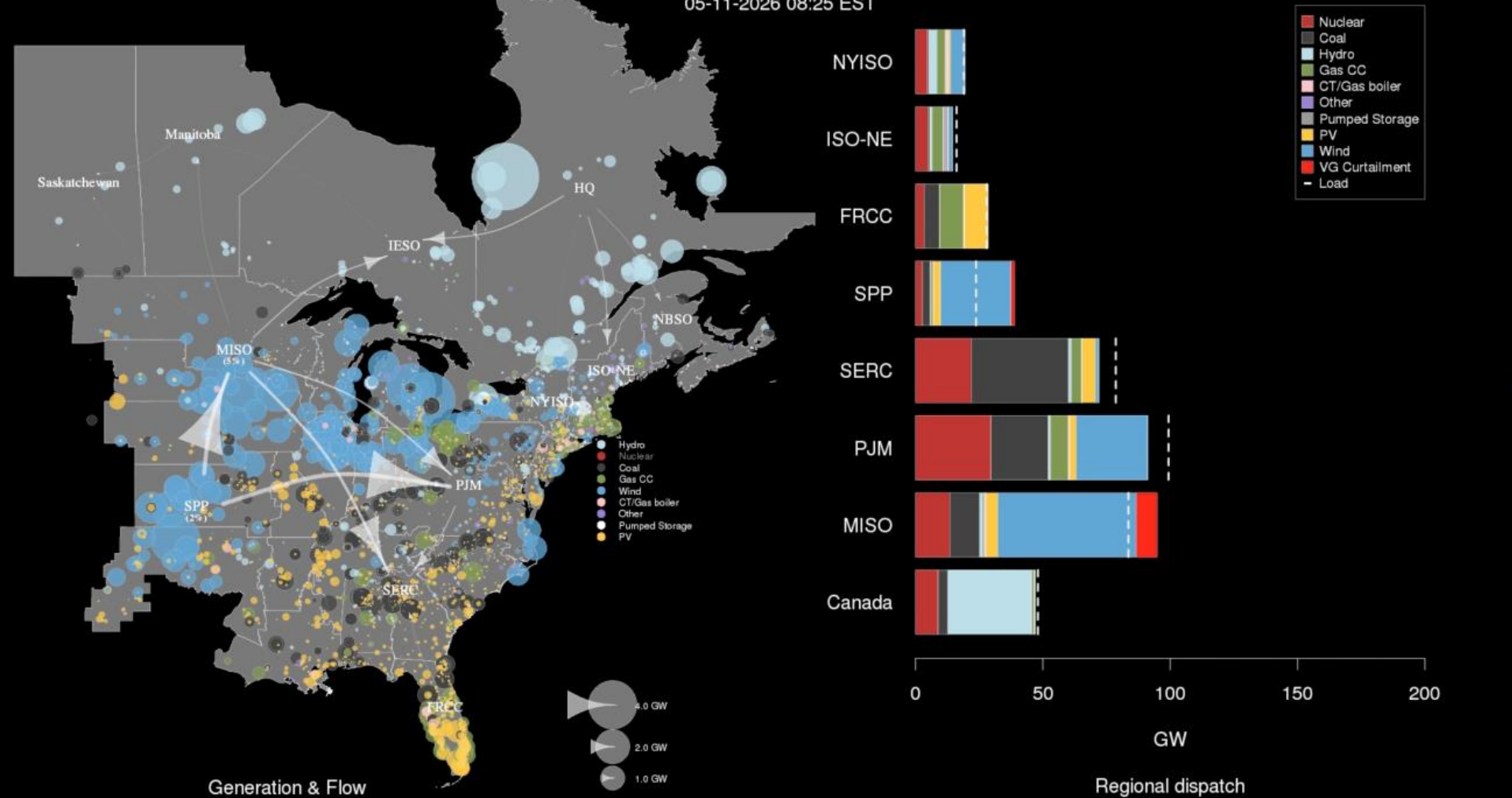
- Case for super-grid: [https://en.wikipedia.org/wiki/Super\\_grid](https://en.wikipedia.org/wiki/Super_grid)



# Click on next slide for simulation

## Eastern Renewable Generation Integration Study (ITx30)

05-11-2026 08:25 EST





Click on slide for ERGIS Visualization



## **EASTERN RENEWABLE GENERATION INTEGRATION STUDY**

GENERATION, REGIONAL FLOWS, & DISPATCH  
ITx30

MAY 11 - MAY 13, 2026  
HIGH VARIABLE GENERATION

# We'd like the role of Government BUT IT DOES NOT LOOK PROMISING RIGHT NOW?

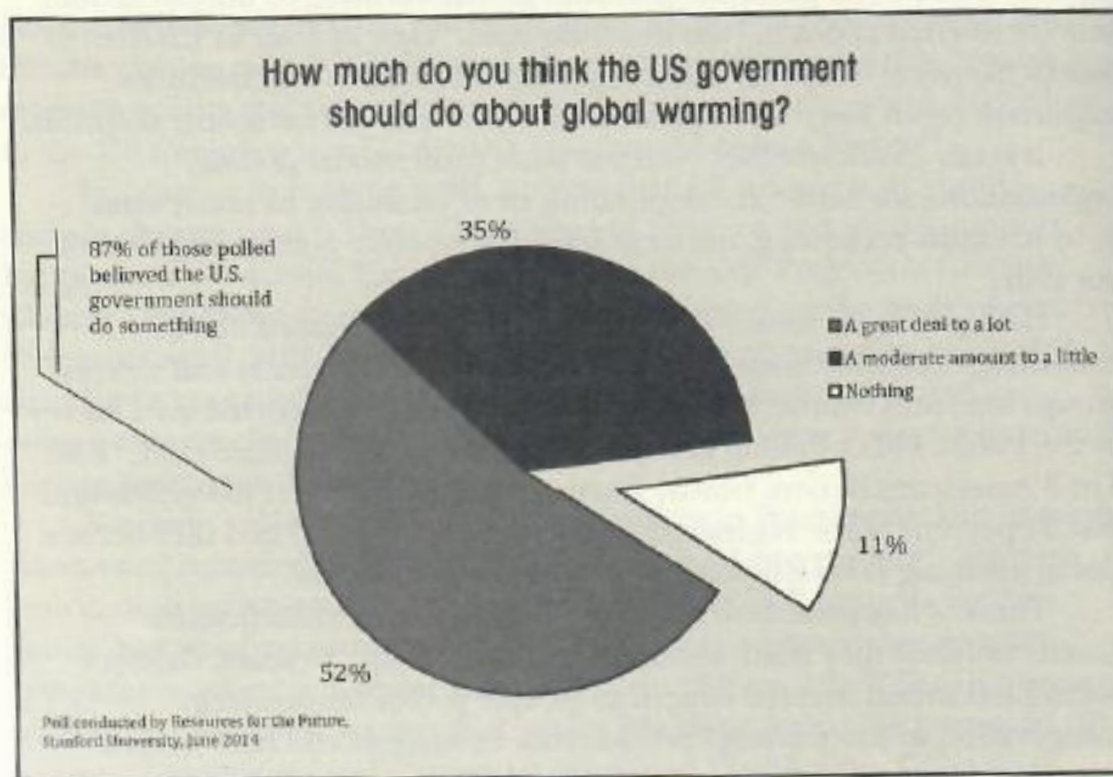


Figure 6.2

THAT'S WHY WEEK 8 WE WILL DEAL  
WITH GEOENGINEERING OPTIONS  
WITH FOCUS ON:

WITH PERSONAL SOLUTIONS AND  
SEQUESTRATION – PARTICULARLY  
BIOFUELS AND BIOCHAR

# What if?



REMINDER: WEEK 7, MAY 8<sup>TH</sup>,  
NREL TOUR – BE AT Learning center  
12:45 p.m.

- **NREL Education Center:** 15013 Denver West Parkway Golden, CO 80401
- Google maps  
<https://www.google.com/maps/dir//15013+Denver+W+Pkwy,+Golden,+CO+80401/@39.7408398,-105.1729051,16z/data=!3m1!4b1!4m8!4m7!1m0!1m5!1m1!1s0x876b84596aab36ab:0x5eac346d18c1fbe5!2m2!1d-105.1685277!2d39.7408399?hl=en>



