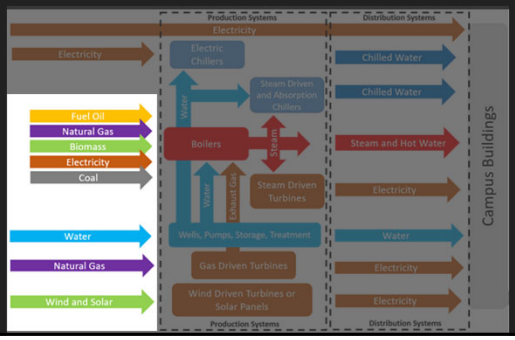
FUELS & ENERGY RESOURCES

January 2024

SUZANNE KITTEN
SHERRI JETT

1

FUELS & ENERGY RESOURCES



2

CHANGING ENERGY LANDSCAPE

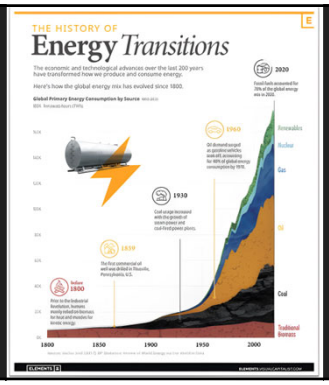
Resource	Government	Institution Goals
• Availability • Cost • Risk	• Policies • Incentives	• Carbon emissions • Renewable energy

What energy resources make the most sense for your campus?

3

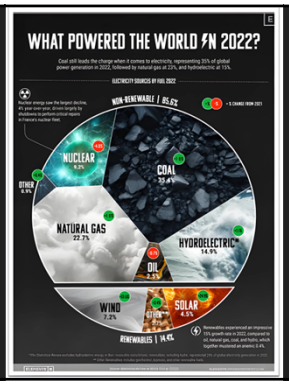
3

GLOBAL HISTORY



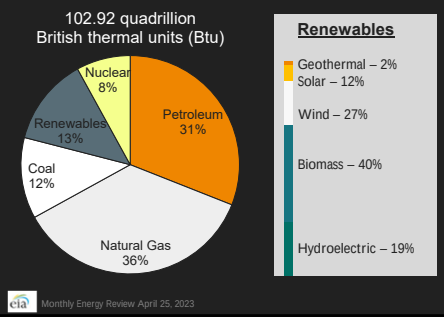
4

GLOBAL SNAPSHOT



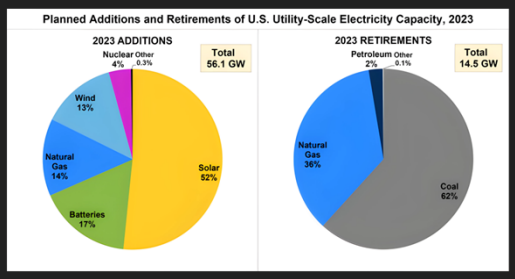
5

U.S. ENERGY PRODUCTION



6

U.S. ENERGY CAPACITY CHANGES



7

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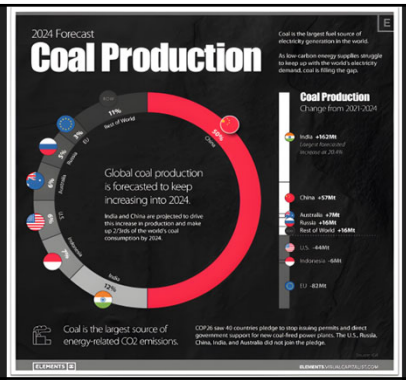
COAL

8

8

GLOBAL



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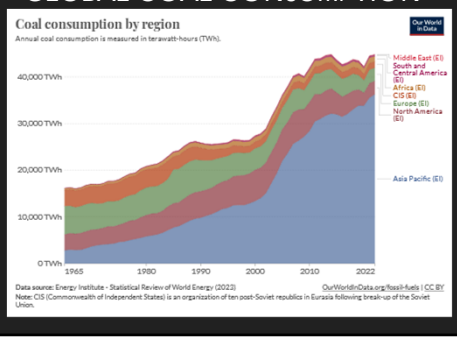
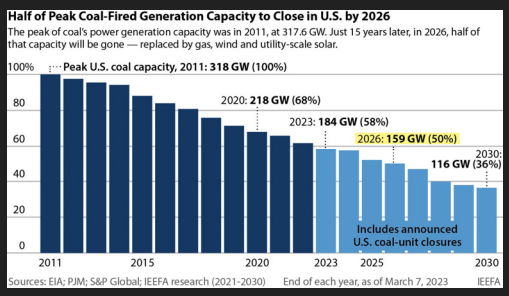
GLOBAL COAL CONSUMPTION



10

10

U.S. COAL GENERATION CAPACITY



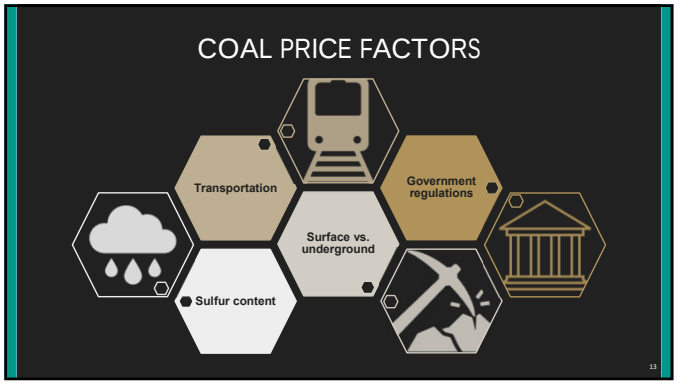
11

11

WHERE ARE THE U.S. COAL BASINS?

12

12


COAL PRICE FACTORS
Transportation
Government regulations
Surface vs. underground
Sulfur content
13

13

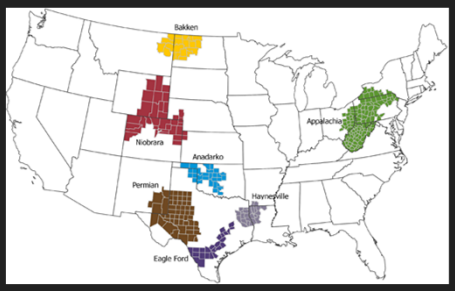

NATURAL GAS
Cleaner to burn – half as much CO2 as coal
More efficient – 10% energy lost
60 – year supply at current rates
Difficult to transport
Can be polluting, dangerous when extracted
Methane bed drilling pollutes
14

14


GLOBAL
THE LARGEST
PRODUCERS OF NATURAL GAS
U.S.
934.2
RUSSIA
701.7
CHINA
IRAN
REST OF THE WORLD
15

15

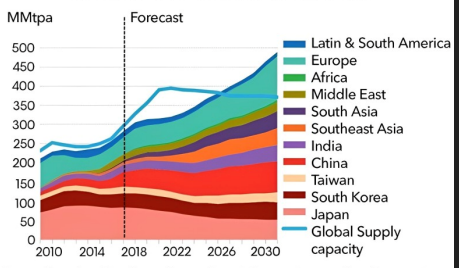
WHERE IS THE U.S. NATURAL GAS?



16

16

Global LNG demand forecast

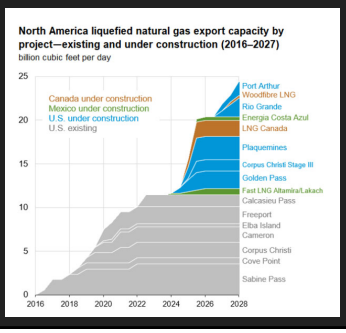


Source: Bloomberg New Energy Finance, Poten & Partners, Customs. Note: Re-exporting countries are excluded. South Asia includes Pakistan, Bangladesh etc.

17

17

NORTH AMERICAN LNG EXPORTS



18

18

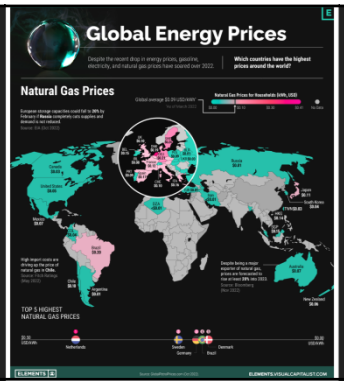
NATURAL GAS PRICE FACTORS

- Distance from wells
- Pipeline proximity and capacity
- Demand profile
- Local costs - distribution, taxes, other
- State regulations
- Competing suppliers

19

19

GLOBAL



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20

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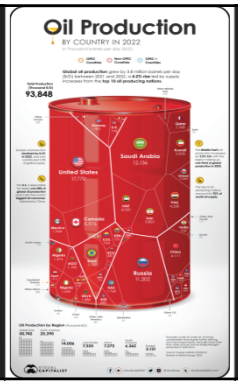
GLOBAL

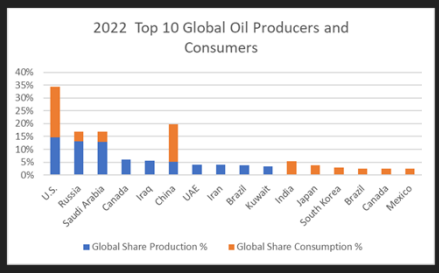


22

22

GLOBAL

OIL PRODUCTION & CONSUMPTION



23

23

OIL PRICE FACTORS

Crude oil price
- Politics
- Weather
- Production Limits

Storage space

Delivery costs

Demand

24

24

FUEL MARKET VOLATILITY & RISK

- Commodity Markets
  - Coal
  - Natural Gas
  - Crude Oil
- Transportation and Storage
  - Increases volatility and risk
- Procurement/Contracting Process
  - Take or pay requirements
  - Balancing issues

25

25

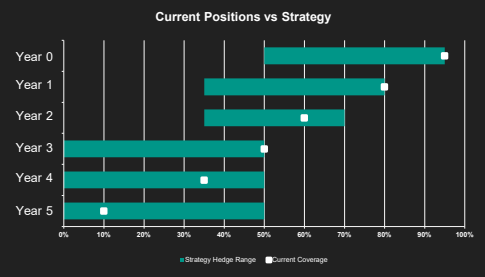
FUEL RISK MANAGEMENT

- Hedging or Futures Options
- Ability to Switch Fuels
- Demand Management/Peak Shaving
- Thermal Energy Storage
- Combined Heat & Power
- Customer Incentives
- Renewables

26

26

FUEL RISK STRATEGY EXAMPLE

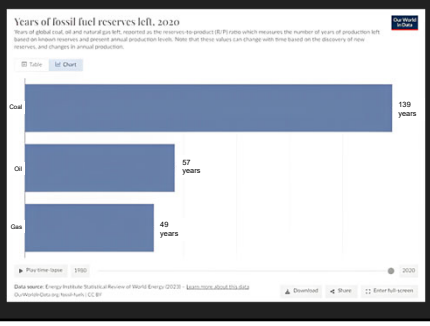


27

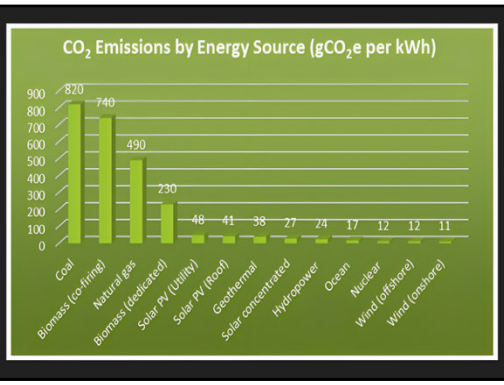
27

WHEN WILL FOSSIL FUEL RUN OUT?

GLOBAL

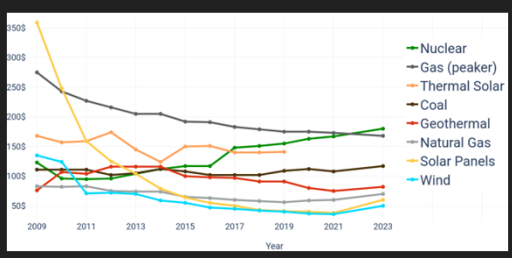


28



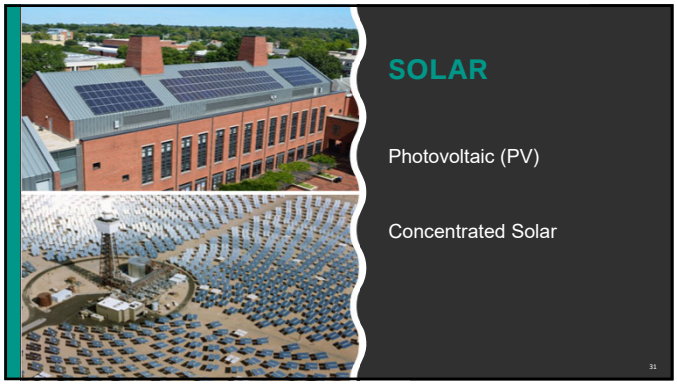
29

LEVELIZED COST OF ENERGY $/MWh

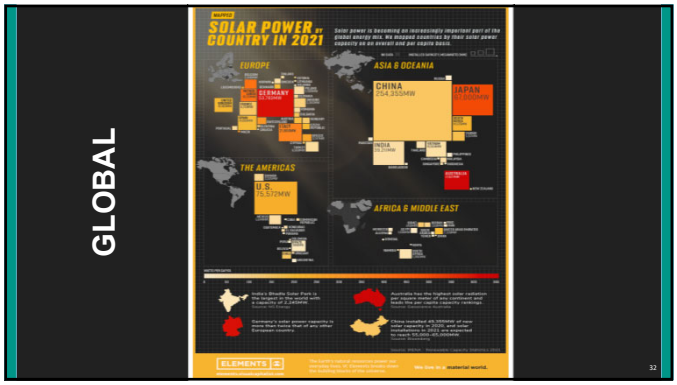


Average unsubsidized levelized cost of energy.
Data source is Lazard.

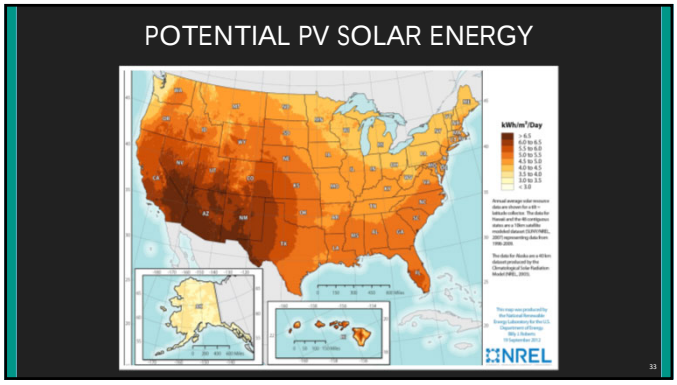
30


SOLAR
Photovoltaic (PV)
Concentrated Solar
31

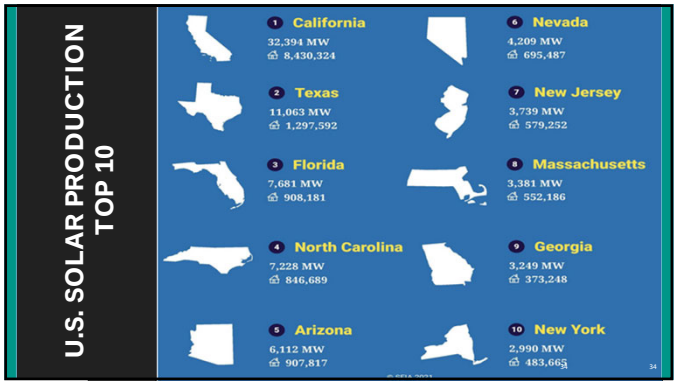
31


GLOBAL
SOLAR POWER BY COUNTRY IN 2021
EUROPE
GERMANY
ASIA & OCEANIA
CHINA
254.355MW
JAPAN
INDIA
THE AMERICAS
U.S.
75.572MW
AFRICA & MIDDLE EAST
ELEMENTS
32

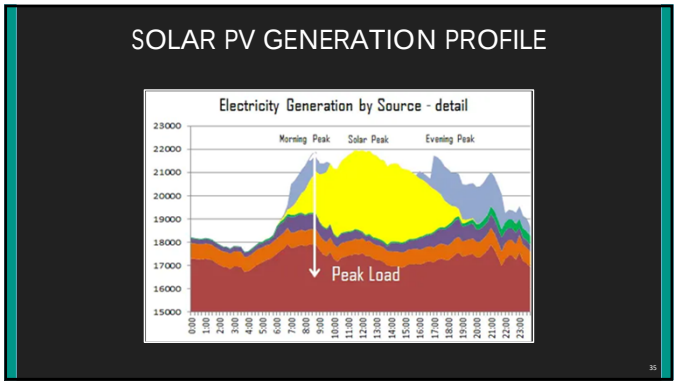
32


POTENTIAL PV SOLAR ENERGY
kWh/m²/Day
NREL
33

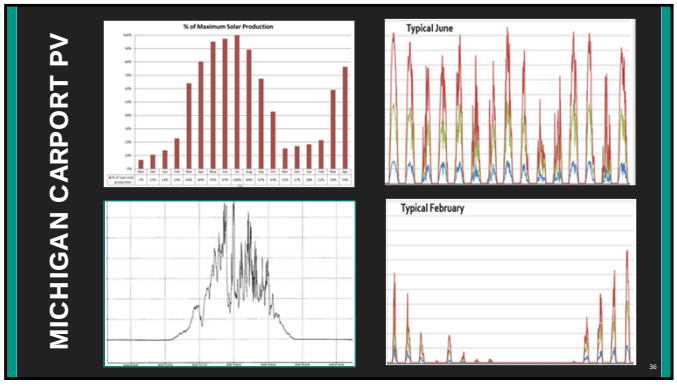
33


U.S. SOLAR PRODUCTION TOP 10
1 California
32,394 MW
8,430,324
2 Texas
11,063 MW
1,297,592
3 Florida
7,681 MW
908,181
4 North Carolina
7,228 MW
846,689
5 Arizona
6,112 MW
907,817
6 Nevada
4,209 MW
695,487
7 New Jersey
3,739 MW
579,252
8 Massachusetts
3,381 MW
552,186
9 Georgia
3,249 MW
373,248
10 New York
2,990 MW
483,665
34

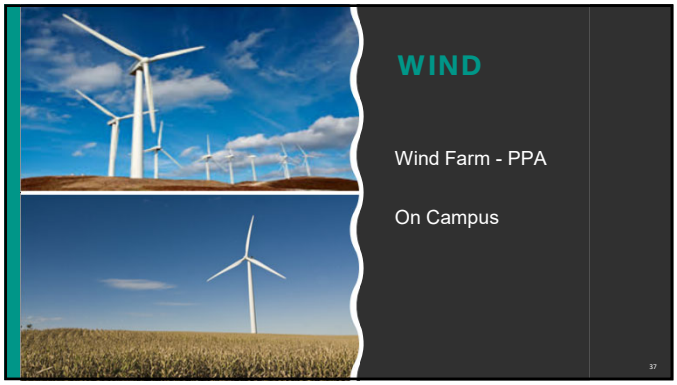
34


SOLAR PV GENERATION PROFILE
Electricity Generation by Source - detail
Morning Peak
Solar Peak
Evening Peak
Peak Load
35

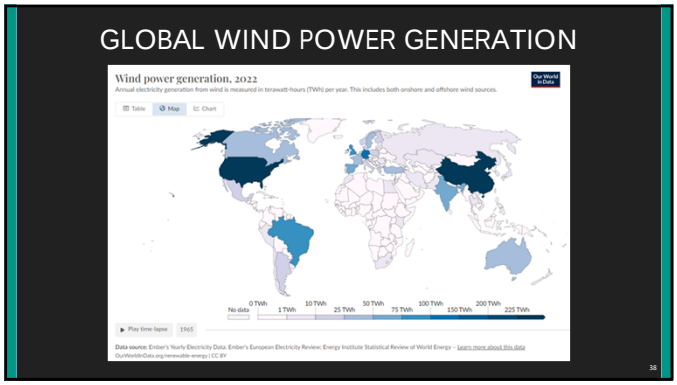
35


MICHIGAN CARPORT PV
% of Maximum Solar Production
Typical June
Typical February
36

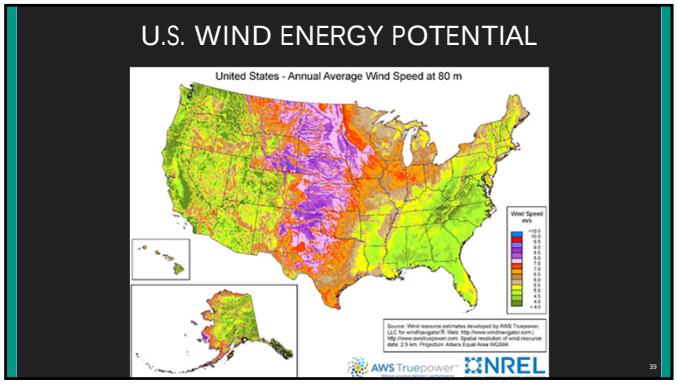
36


WIND
Wind Farm - PPA
On Campus
37

37

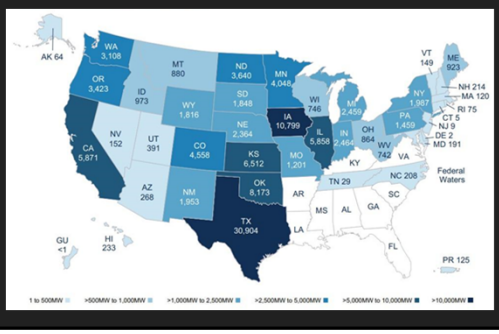

GLOBAL WIND POWER GENERATION
Wind power generation, 2022
Annual electricity generation from wind is measured in terawatt-hours (TWh) per year. This includes both onshore and offshore wind sources.
Our World in Data
Table
Map
Chart
0 TWh
No data
1 TWh
10 TWh
25 TWh
50 TWh
75 TWh
100 TWh
150 TWh
200 TWh
225 TWh
Play time-lapse
1965
Data source: Ember's Yearly Electricity Data; Ember's European Electricity Review; Energy Institute Statistical Review of World Energy - Learn more about this data
OurWorldInData.org/renewable-energy | CC-BY
38

38


U.S. WIND ENERGY POTENTIAL
United States - Annual Average Wind Speed at 80 m
Wind Speed
m/s
AWS Truepower
NREL
39

39

U.S. INSTALLED WIND ENERGY



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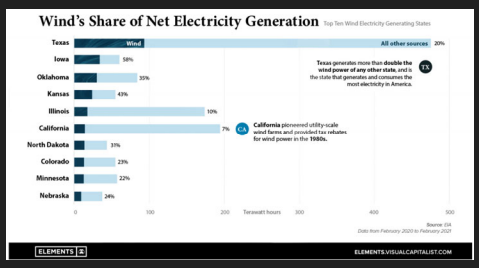
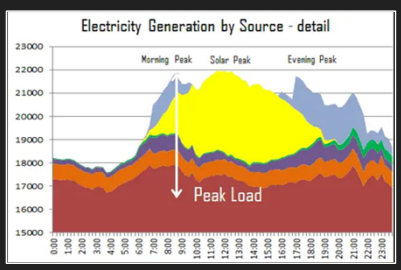
U.S. TOP WIND GENERATING STATES



41

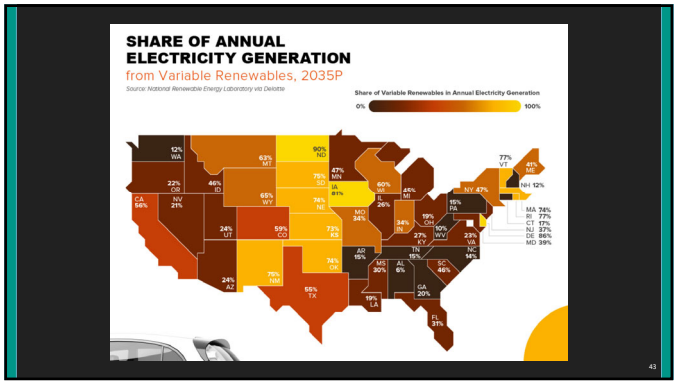
41

WIND GENERATION PROFILE

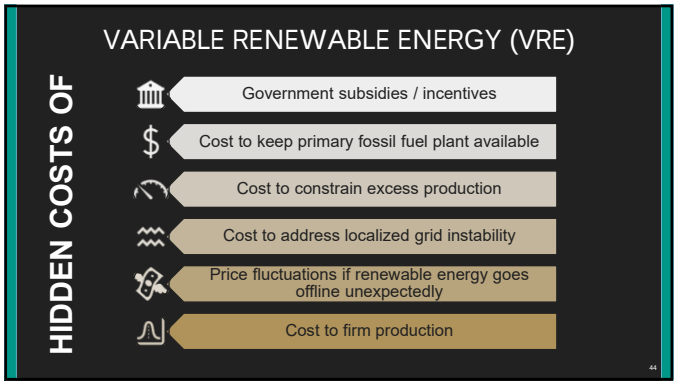


42

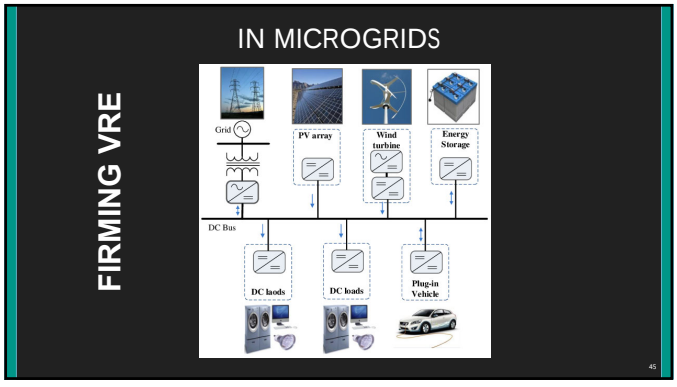
42


SHARE OF ANNUAL
ELECTRICITY GENERATION
from Variable Renewables, 2035P
Source: National Renewable Energy Laboratory via Deloitte
Share of Variable Renewables in Annual Electricity Generation
0%
100%
12% WA
63% MT
90% ND
47% MN
75% SD
IA 61%
22% OR
46% ID
65% WY
74% NE
90% WI
MI
46%
NY 47%
77% VT
41% MD
NH 12%
CA 56%
NV 21%
24% UT
59% CO
73% KS
MO 34%
34% IN
15% PA
19% OH
10% WV
27% KY
23% VA
NC 14%
TN 15%
AR 15%
MS 30%
AL 6%
SC 46%
24% AZ
75% NM
74% OK
55% TX
19% LA
GA 20%
FL 31%
MA 74%
RI 77%
CT 17%
NJ 37%
DE 86%
MD 39%
43

43


HIDDEN COSTS OF
VARIABLE RENEWABLE ENERGY (VRE)
Government subsidies / incentives
Cost to keep primary fossil fuel plant available
Cost to constrain excess production
Cost to address localized grid instability
Price fluctuations if renewable energy goes offline unexpectedly
Cost to firm production
44

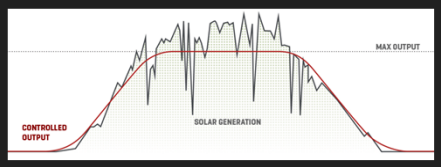
44


FIRMING VRE
IN MICROGRIDS
Grid
PV array
Wind turbine
Energy Storage
DC Bus
DC loads
DC loads
Plug-in Vehicle
45

45

FIRMING SOLAR PV

USING BATTERY ENERGY STORAGE



46

46

NUCLEAR

Why ISN'T nuclear energy considered renewable?

- Nuclear fuels, such as uranium, are not considered renewable as they are a finite material mined from the ground and can only be found in certain locations.

Why IS nuclear energy considered clean?

- It produces zero carbon emissions and doesn't produce other noxious greenhouse gases through its operation.

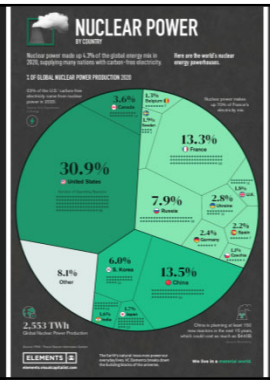
Uranium is the main fuel for nuclear reactors.

Uranium is mined and goes through refining and enrichment to make the fuel for a nuclear reactor.

47

47

GLOBAL

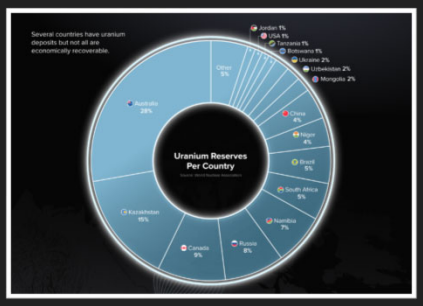


48

48

GLOBAL

WHERE IS THE URANIUM?



49

49

FUEL ENERGY DENSITY

About the size of a gummy bear

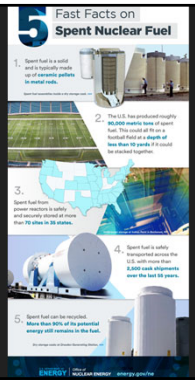
1 uranium fuel pellet =

- 1 ton of coal
- 17,000 cubic feet of natural gas
- 5,000 pounds of wood
- 149 gallons of oil

Source: Nuclear Energy Institute

50

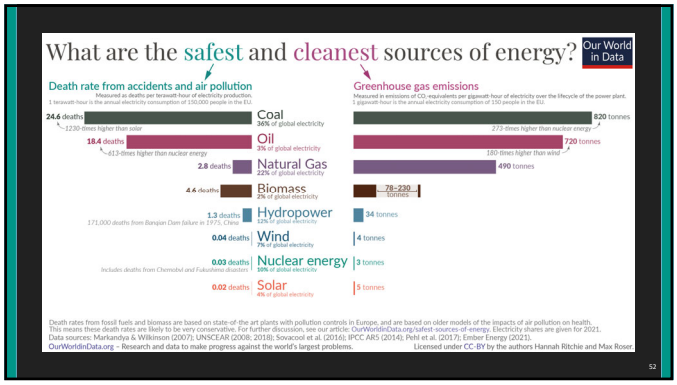
50



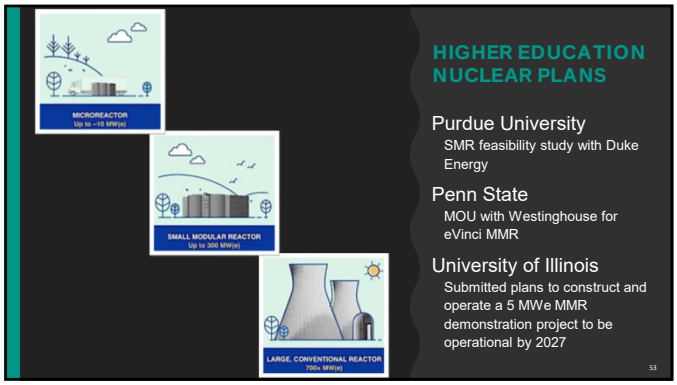
NUCLEAR WASTE

51

51


What are the safest and cleanest sources of energy?
Our World in Data
Death rate from accidents and air pollution
Measured as deaths per terawatt-hour of electricity production.
1 terawatt-hour is the annual electricity consumption of 150,000 people in the EU.
Greenhouse gas emissions
Measured in emissions of CO2-equivalents per gigawatt-hour of electricity over the lifecycle of the power plant.
1 gigawatt-hour is the annual electricity consumption of 150 people in the EU.
24.6 deaths
~1230 times higher than solar
Coal
36% of global electricity
820 tonnes
273 times higher than nuclear energy
18.4 deaths
~613 times higher than nuclear energy
Oil
3% of global electricity
720 tonnes
180 times higher than wind
2.8 deaths
Natural Gas
22% of global electricity
490 tonnes
4.4 deaths
Biomass
2% of global electricity
78–230 tonnes
1.3 deaths
171,000 deaths from Banqiao Dam failure in 1975, China
Hydropower
12% of global electricity
34 tonnes
0.04 deaths
Wind
7% of global electricity
4 tonnes
0.03 deaths
Includes deaths from Chernobyl and Fukushima disasters
Nuclear energy
10% of global electricity
3 tonnes
0.02 deaths
Solar
4% of global electricity
5 tonnes
Death rates from fossil fuels and biomass are based on state-of-the art plants with pollution controls in Europe, and are based on older models of the impacts of air pollution on health.
This means these death rates are likely to be very conservative. For further discussion, see our article: OurWorldinData.org/safest-sources-of-energy. Electricity shares are given for 2021.
Data sources: Markandya & Wilkinson (2007); UNSCEAR (2008; 2018); Sovacool et al. (2016); IPCC AR5 (2014); Pehl et al. (2017); Ember Energy (2021).
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Licensed under CC-BY by the authors Hannah Ritchie and Max Roser.
52

52


MICROREACTOR
Up to ~10 MW(e)
SMALL MODULAR REACTOR
Up to 300 MW(e)
LARGE, CONVENTIONAL REACTOR
700+ MW(e)
HIGHER EDUCATION NUCLEAR PLANS
Purdue University
SMR feasibility study with Duke Energy
Penn State
MOU with Westinghouse for eVinci MMR
University of Illinois
Submitted plans to construct and operate a 5 MWe MMR demonstration project to be operational by 2027
53

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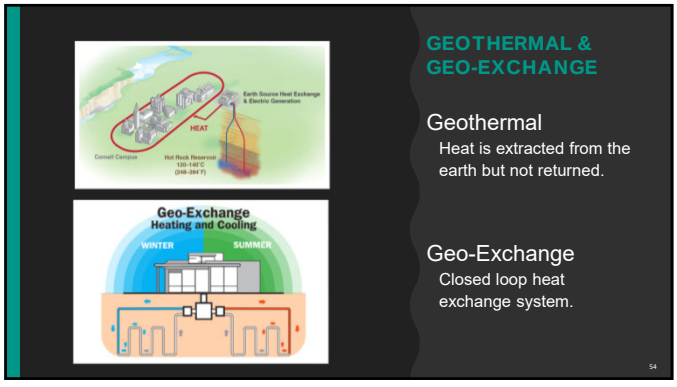
Earth Source Heat Exchange & Electric Generation
HEAT
Cornell Campus
Hot Rock Reservoir
120-140°C
(248-284°F)
Geo-Exchange
Heating and Cooling
WINTER
SUMMER
GEOTHERMAL & GEO-EXCHANGE
Geothermal
Heat is extracted from the earth but not returned.
Geo-Exchange
Closed loop heat exchange system.
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GEO-EXCHANGE

+	−
• Significantly reduces carbon emissions • Effective in many regions and climates • May qualify for incentives	• High up-front costs • More economic for new builds than retrofits • Geothermal heat pumps use electricity • Design is site dependent may be space constrained

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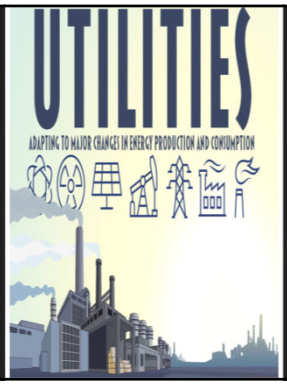

What fuels make the most sense for you?

Is your campus paying the best possible price for your fuel supply?

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QUESTIONS / COMMENTS

- Sign-in Sheet
- Evaluation Form

57

57