Climate Change and Clean Energy

Steve Blake, David Blessing, David Clive, Chelcie Liu, Gary Nelson, Doug Rodgers

Thursdays 6:30-8:30
January 13 through February 17, 2022
Jefferson County Library

The Plan for Six Sessions

- **Session 1. Understanding the scope of our challenge.**
  - In this session we will cover some aspects of climate change and energy production that you may not have thought about. We will discuss climate models and their predictions and some of the issues related to changing worldwide energy production methods. We will attempt to bound the scale of the problem.
- **Session 2. Understanding the electric grid and how to make CO2 free electricity**
  - In order to have electric cars, trucks and trains plus electric heating systems for our homes we will need to increase our capacity for electric generation. Our existing electric grid has evolved to include systems for generation and distribution, but storage of electric power is extremely limited. We will discuss how the electric grid functions and what changes will be needed to make it CO2 free.
- **Session 3. Renewables are necessary but not sufficient**
  - We have all heard that to stop global warming we need to replace fossil fuels with renewables. In this session we will talk about the advantages and limits of renewables, technologies for energy storage and carbon capture.
- **Session 4. How do nuclear reactors fit our need for electricity production?**
  - Unlike solar and wind, nuclear power plants produce electricity 24/7. In this session we will discuss nuclear power advantages and disadvantages, safety issues and current status. France and Germany have taken very different approaches to the use of nuclear power. We will discuss some of those differences and why we think nuclear power is necessary.
- **Session 5. Bringing clean energy to everyone**
  - Our use of energy varies around the world from the electricity we depend on to those who collect and burn wood for all their energy needs. A sustainable world needs to have clean energy for everyone, but how can that happen? The UN Sustainable Development Goal 7 promises this outcome.
  - What will be the role of microgrids for developing countries? Will microreactors play a role?
- **Session 6. Wrap up.**
  - We will reserve this session for further discussion of any areas that the class would like to explore.

Goals and Non-goals

Goals as axioms

- Accept IPCC climate perspective
- Electrification of world economy required
- UN SDG 7 ➔ juice for all*
  – Assume clean energy for all is #1
- Provide realistic Scope of the problem
- Offer our perspectives on best, low risk path to ***zero emissions by 2050***
  – Technologies **are not** zero emission goals
- Investigate ways to reduce CO_2 in air and oceans
  – Innovation Beyond Zero

Non-goals

- Debate the veracity of climate models
- React to apocalyptic claims

Climate problem Review

* SDG = Sustainable Development Goal (United Nations)

UN Sustainable Goal Number 7

7 AFFORDABLE AND CLEAN ENERGY

Ensure access to affordable, reliable, sustainable and modern energy for all

ABUNDANT

CLEAN

9.7 GigaPeople by 2050
10.9 GP by 2100

Scope of the Problem

- Plenty of POST DOOM rhetoric in the cybersphere
  - We're doomed and if you don't believe it, you're in denial
  - No such thing as a techno-fix
  - Possibly helpful to *Prepare for the Worst*
- But, we are in denial that a techno-fix is impossible
  - Achieving Net Zero Emissions by 2050 is plausible
  - World financial institutions are on board
    - https://www.unepfi.org/banking/bankingprinciples/
    - https://www.forbes.com/sites/davidcarlin/2021/02/20/the-case-for-fossil-fuel-divestment/?sh=3f8a01ac76d2
    - https://www.goldmansachs.com/media-relations/press-releases/2021/2021-tcfd-decarbonization-targets.html
    - https://kpcb.com/ggf Kleiner Perkins Green Growth Fund


Net-Zero Banking Alliance
Industry-led, UN-convened

DOWNLOAD

Net Zero Banking Alliance

The [Commitment Statement] is a pre-requisite for joining the Net-Zero Banking Alliance, and is signed by a bank's CEO. All banks that have signed the commitment will:

- **Transition** the operational and attributable GHG emissions from their lending and investment portfolios to align with pathways to net-zero by 2050 or sooner.
- **Within 18 months** of joining, set 2030 targets (or sooner) and a 2050 target, with intermediary targets to be set every 5 years from 2030 onwards.
- **Banks' first 2030 targets** will focus on priority sectors where the bank can have the most significant impact, ie. the most GHG-intensive sectors within their portfolios, with further sector targets to be set within 36 months.
- **Annually publish** absolute emissions and emissions intensity in line with best practice and within a year of setting targets, disclose progress against a board-level reviewed transition strategy setting out proposed actions and climate-related sectoral policies.
- **Take a robust approach** to the role of offsets in transition plans.

Latest Membership Stats

98	39	US$ 66trn	43%
Banks	*Countries*	*Total Assets*	*of global banking assets*

Source: Member banks, UNEP Finance Initiative, FSB Global Monitoring Report 2020

Region: All | Country: USA | Founding signatory: Yes | Search

Results for: *North America, USA, Net Zero Banking Alliance*

Bank	Country	Date signed
Amalgamated Bank	USA	Apr 21
Bank of America	USA	Apr 21
Citi	USA	Apr 21
J.P. Morgan Chase & Co.	USA	Oct 21
Morgan Stanley	USA	Apr 21
The Goldman Sachs Group, Inc.	USA	Oct 21
Wells Fargo & Company	USA	Oct 21

Arctic refuge lease sale goes bust, as major oil companies skip out

By

Tegan Hanlon & Nathaniel Herz, Alaska Public Media -

January 6, 2021

- One of the Trump administration's biggest energy initiatives suffered a stunning setback Wednesday, as a decades-long push to drill for oil in Alaska's Arctic National Wildlife Refuge ended with a lease sale that attracted just three bidders — one of which was the state of Alaska itself.
- Alaska's state-owned economic development corporation was the only bidder on nine of the tracts offered for lease in the northernmost swath of the refuge, known as the coastal plain. Two small companies also each picked up a single parcel.
- Half of the offered leases drew no bids at all.
- "They held the lease in ANWR — that is history-making. That will be recorded in the history books and people will talk about it," said Larry Persily, a longtime observer of the oil and gas industry in Alaska. "But no one showed up."
- https://www.alaskapublic.org/2021/01/06/long-awaited-arctic-refuge-oil-lease-sale-attracts-little-interest/

Necessary Conditions are Emerging

- Net Zero by 2050 is spreading like a virus
- Fossil Fuel Divestment is spreading
- Clean Energy Techno-fix is plausible
  - Sufficient conditions are still necessary
  - Obstacles still exist
    - Geo-politics
    - Vested interests
    - Cost
    - Need support from Environmental Wisdom

Techno-fix feasible?

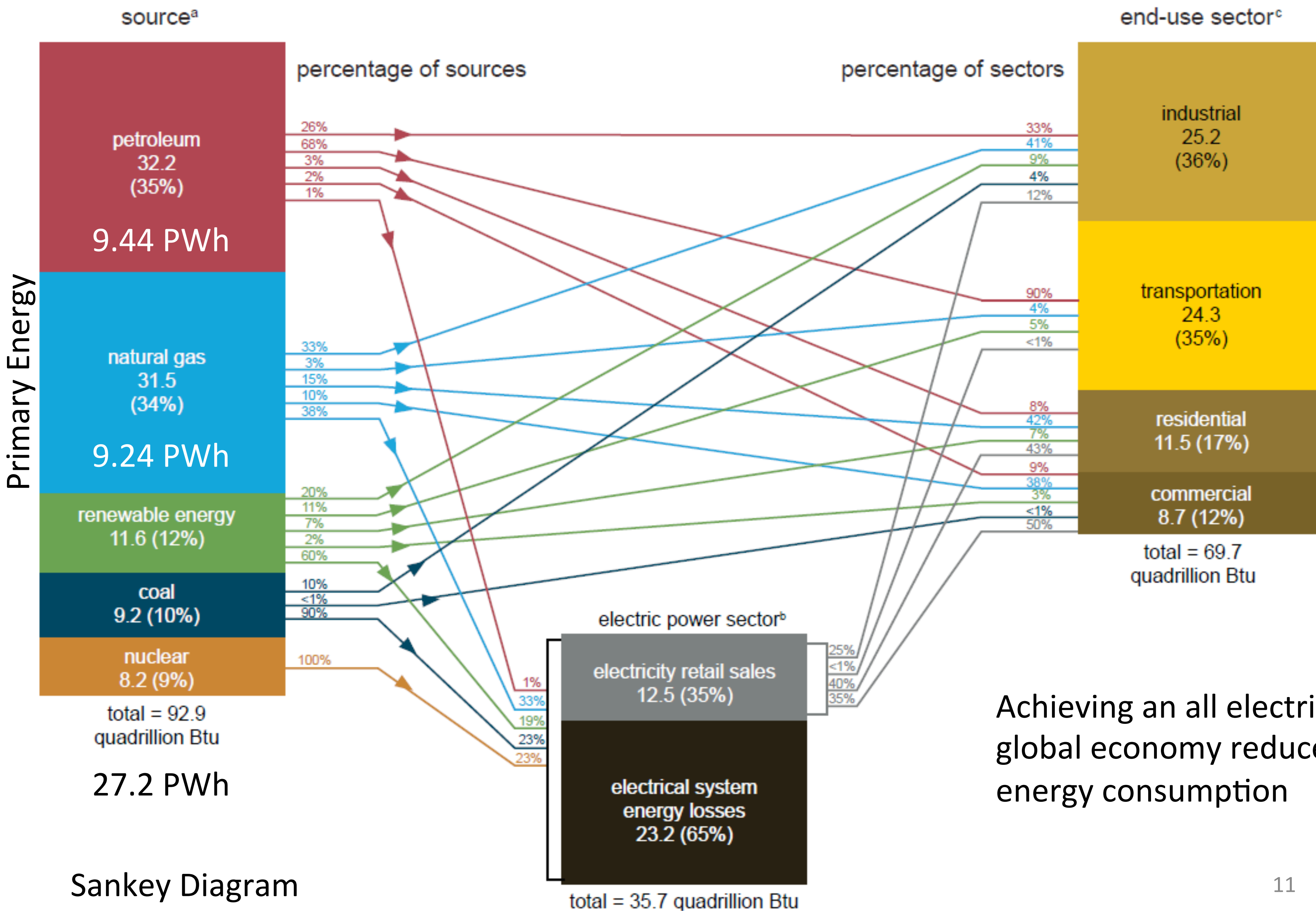
Framework for Discussion

- Energy = Power x Time
  - Watt Hours = Watts x hours
- Will convert all numbers to WATTS
  - Example: Your solar panels have 5 kW
    - kW ➔ kiloWatts ➔ watts x 1000 (10^3)
      - Your energy bill from PUD is in $/kWh
    - MW ➔ MegaWatts ➔ kW x 1000 (10^6)
    - GW ➔ GigaWatts ➔ MW x 1000 (10^9)
    - TW ➔ TeraWatts ➔ GW x 1000 (10^{12})
    - PW ➔ PetaWatts ➔ TW x 1000 (10^{15})
- Energy also expressed in BTUs
  - QUAD = quadrillion (10^{15}) BTUs
    - 3.41 QUAD = 1 PetaWattHour

Our Universe is about 13.7 GigaYears Old

U.S. energy consumption by source and sector, 2020

quadrillion British thermal units (Btu) 3.41 QUAD = 1 PetaWh

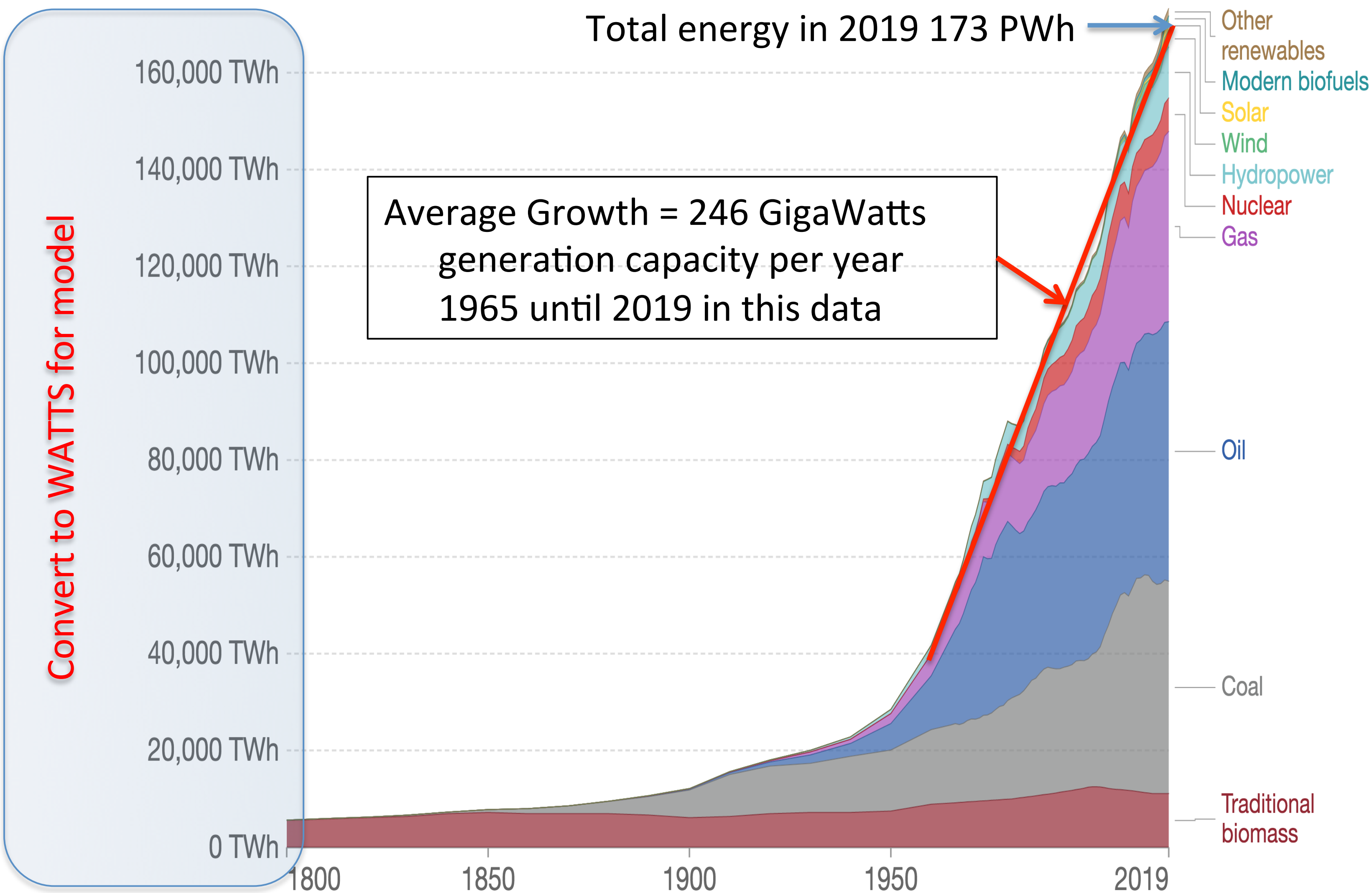


Achieving an all electric global economy reduces energy consumption

Sankey Diagram

Global primary energy consumption by source

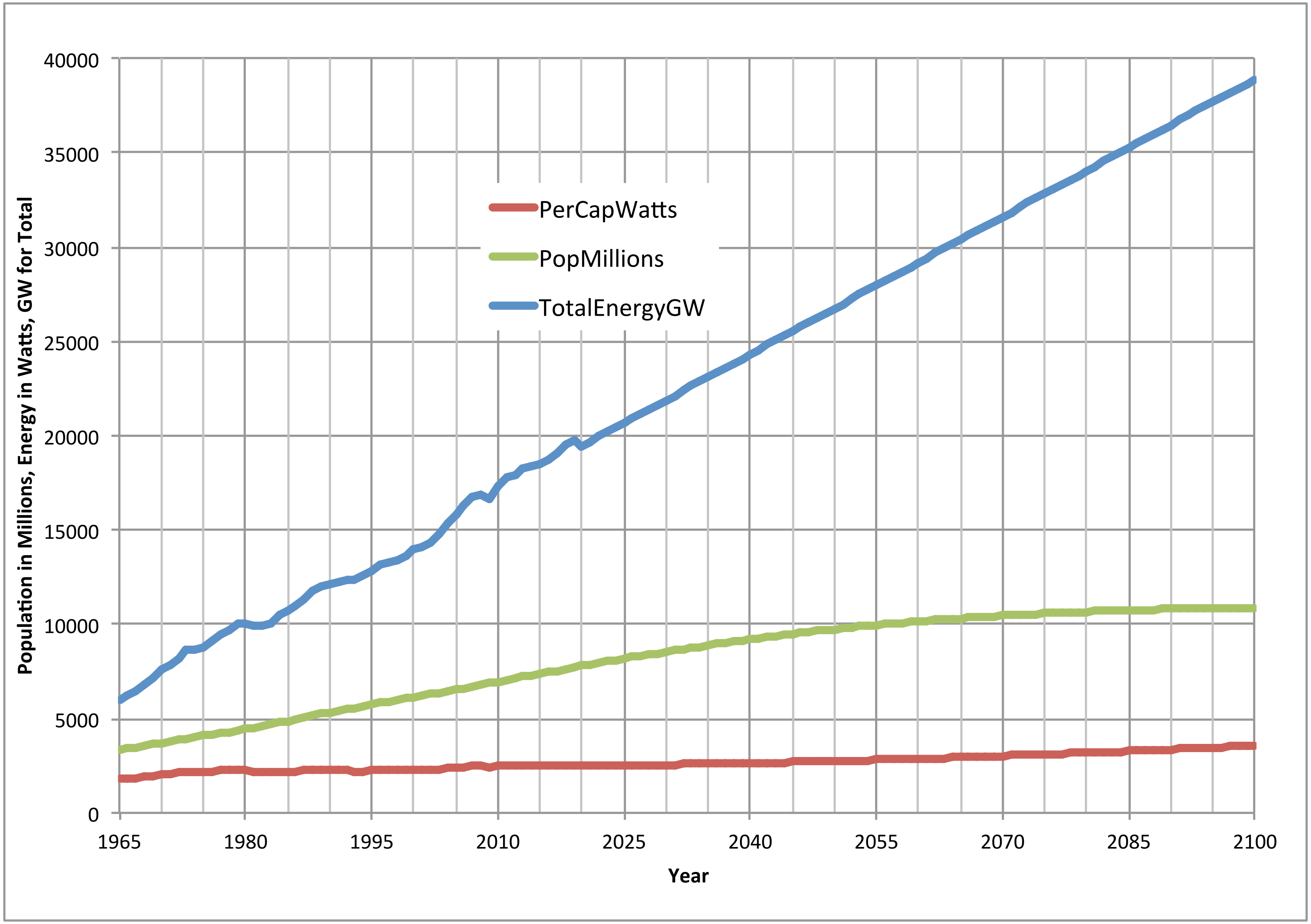
Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.



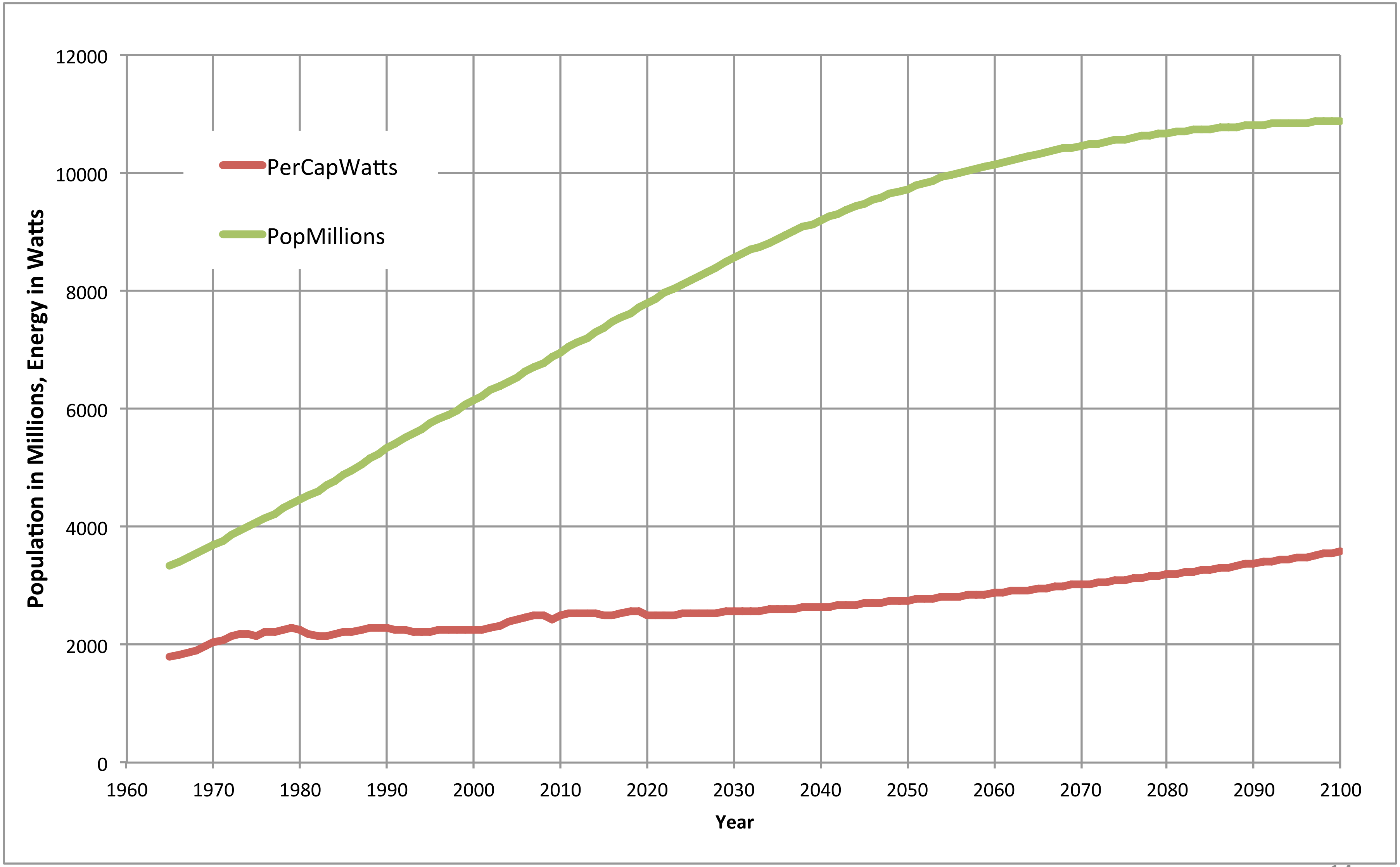
Source: Vaclav Smil (2017) & BP Statistical Review of World Energy

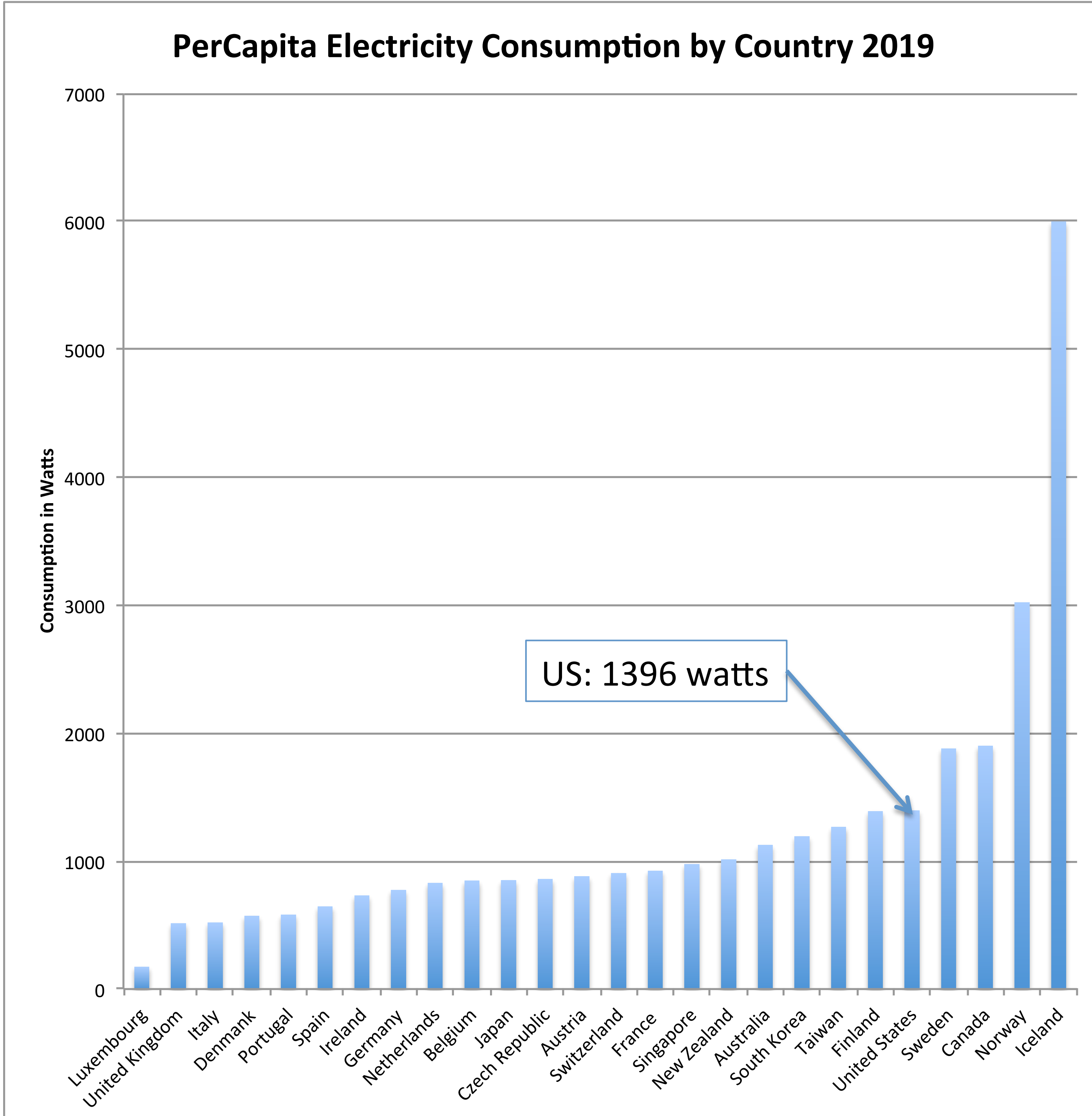
OurWorldInData.org/energy • CC BY

Extrapolate 246 GW/yr to 2100



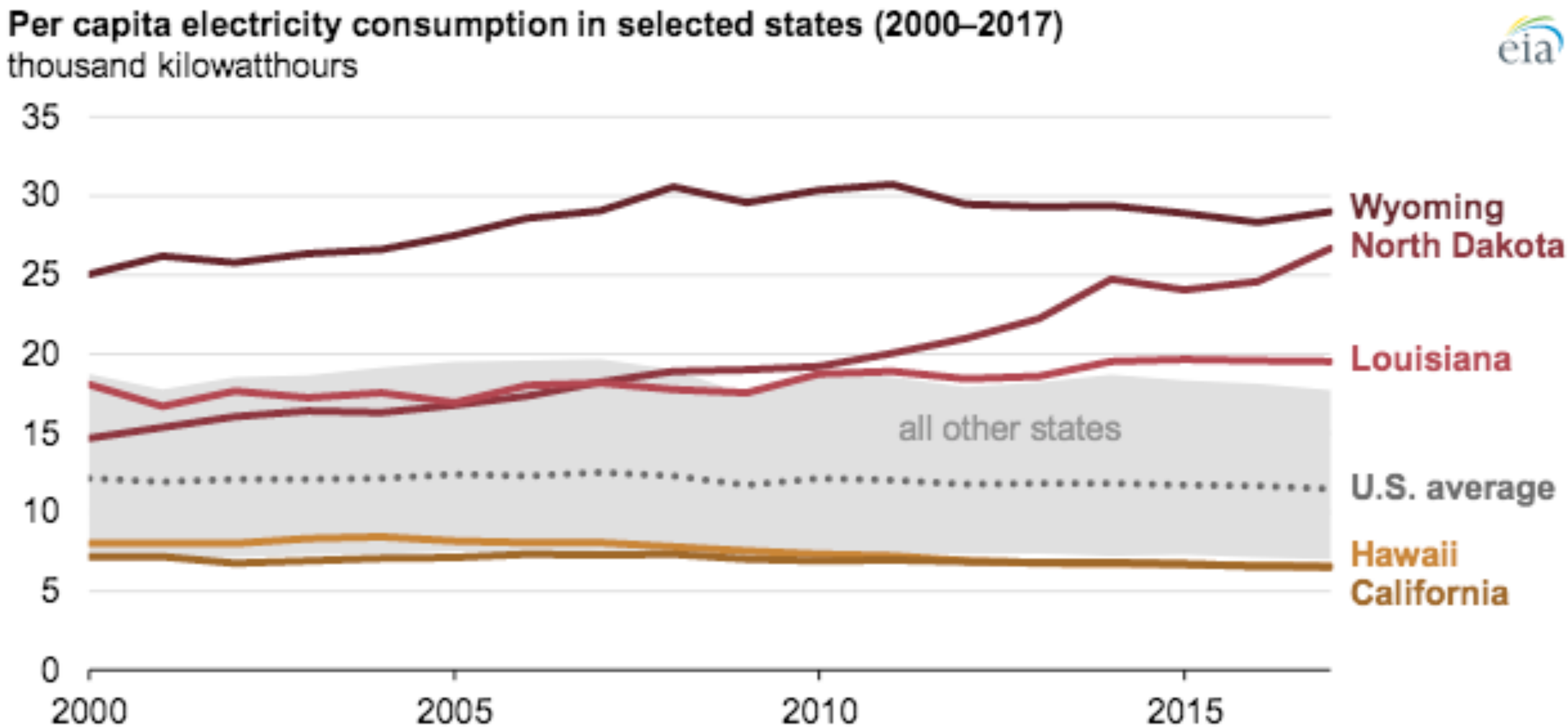
PerCapita Energy Projection





PerCapita Electricity Consumption by Country 2019
Consumption in Watts
7000
6000
5000
4000
3000
2000
1000
0
US: 1396 watts
Luxembourg
United Kingdom
Italy
Denmark
Portugal
Spain
Ireland
Germany
Netherlands
Belgium
Japan
Czech Republic
Austria
Switzerland
France
Singapore
New Zealand
Australia
South Korea
Taiwan
Finland
United States
Sweden
Canada
Norway
Iceland

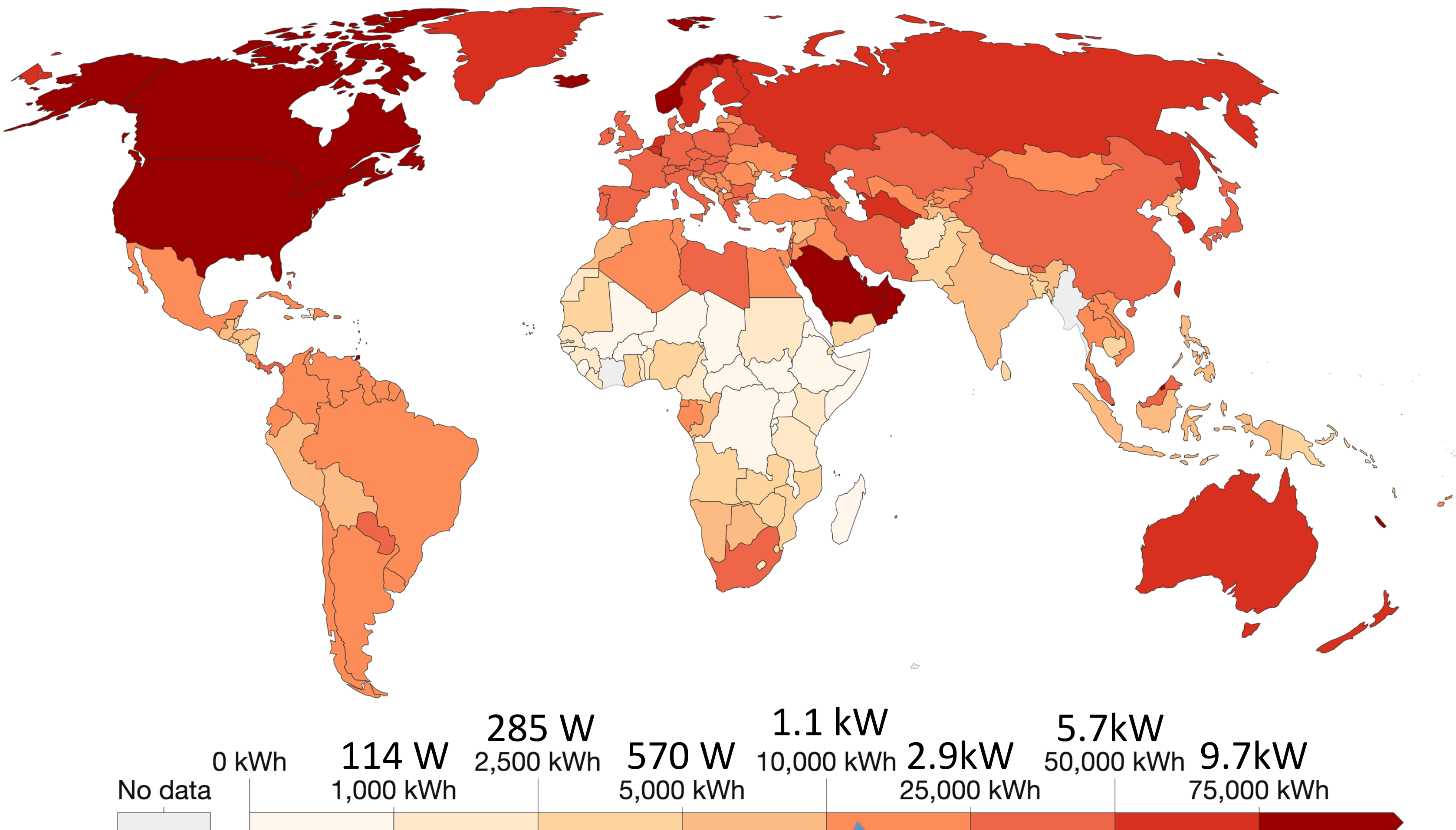
Yet another view of PerCapita energy



12.2 MWh/year ➔ 1396 Watts

Energy use per person, 2019

Energy use not only includes electricity, but also other areas of consumption including transport, heating and cooking.



Source: Our World in Data based on BP & Shift Data Portal

Note: Energy refers to primary energy – the energy input before the transformation to forms of energy for end-use (such as electricity or petrol for transport).

US at 12MWh = 1.4 kW for electricity

UN Sustainable Goal Number 7

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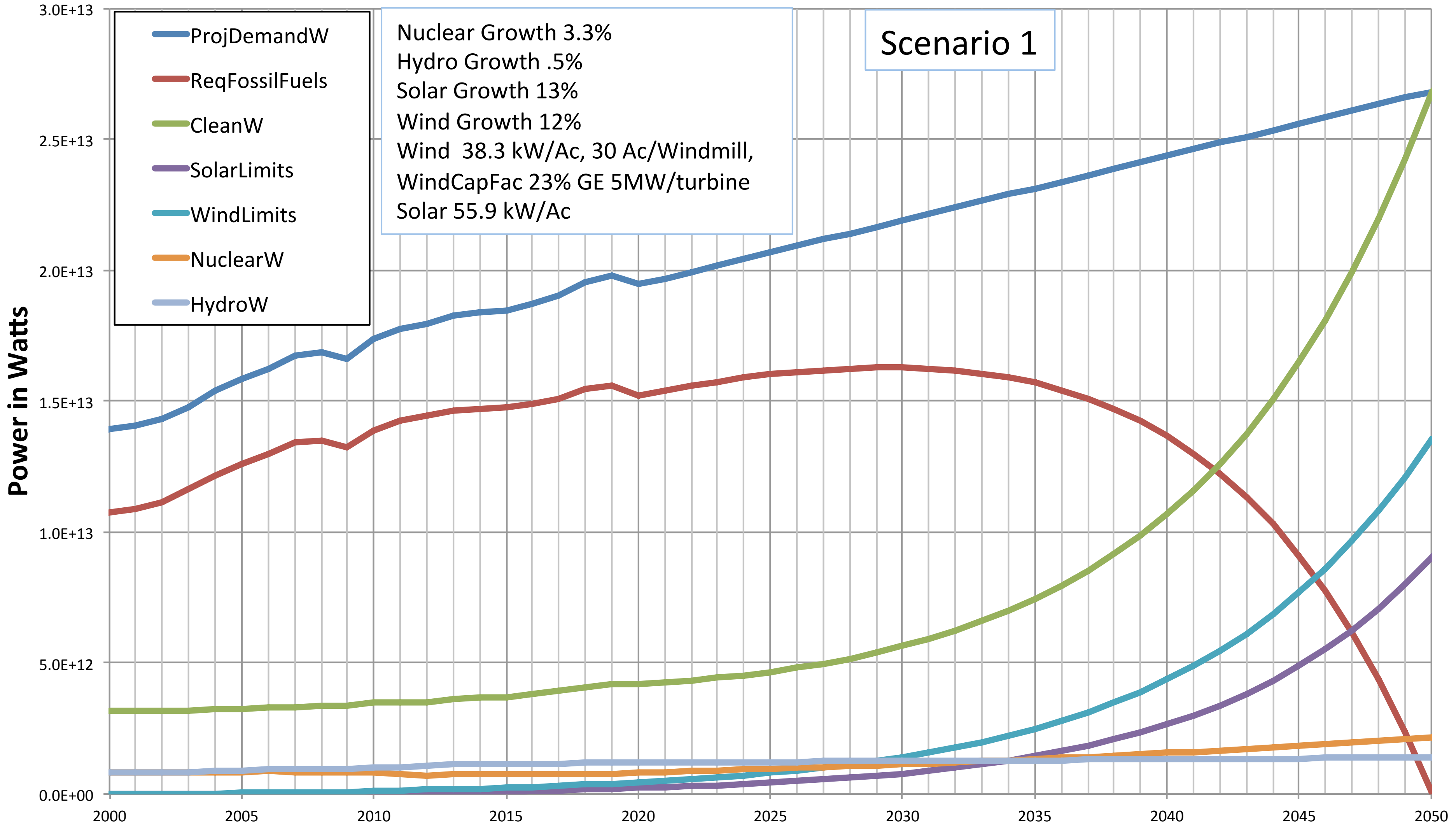
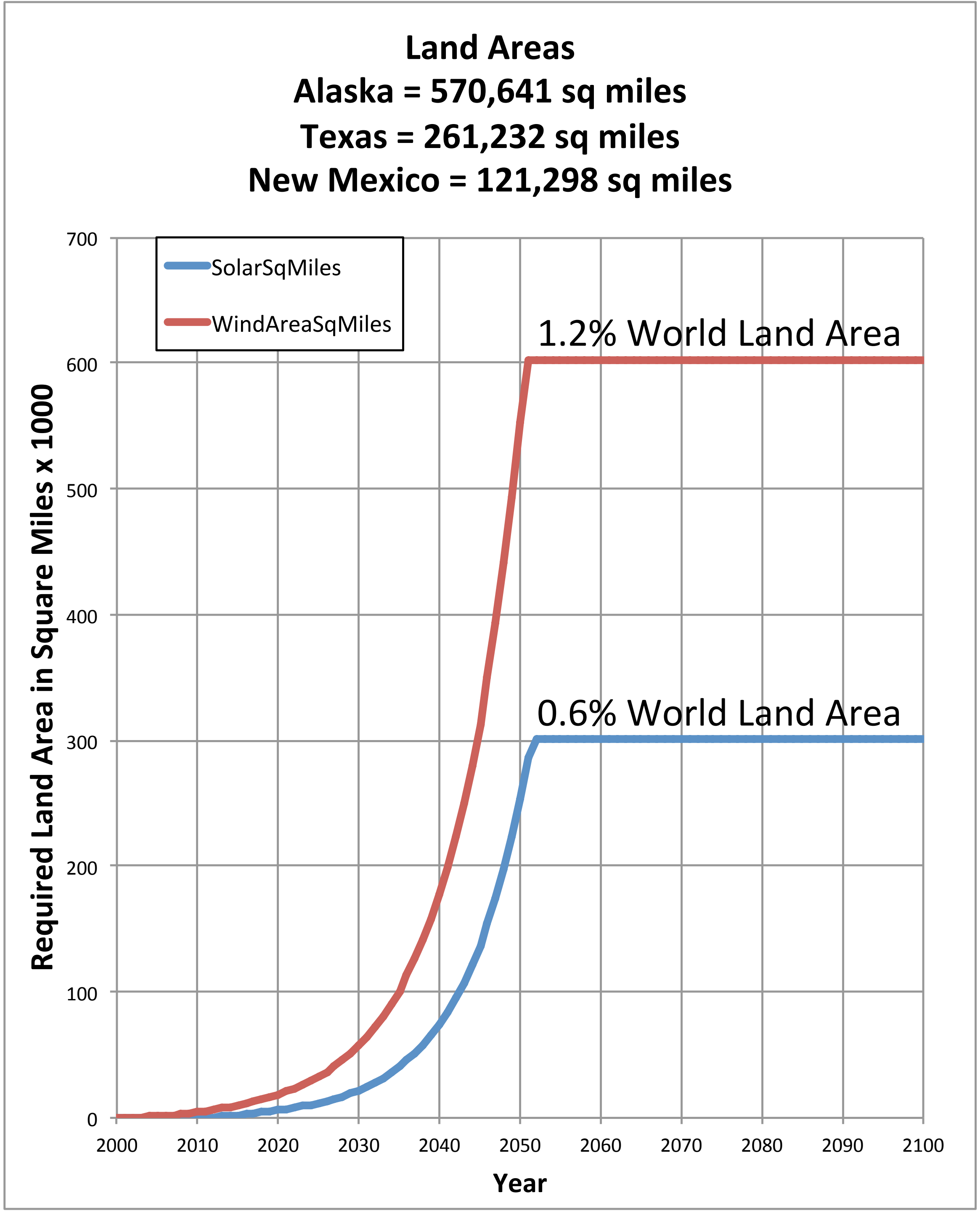
Plausible to Eliminate Fossil Fuels by 2050:

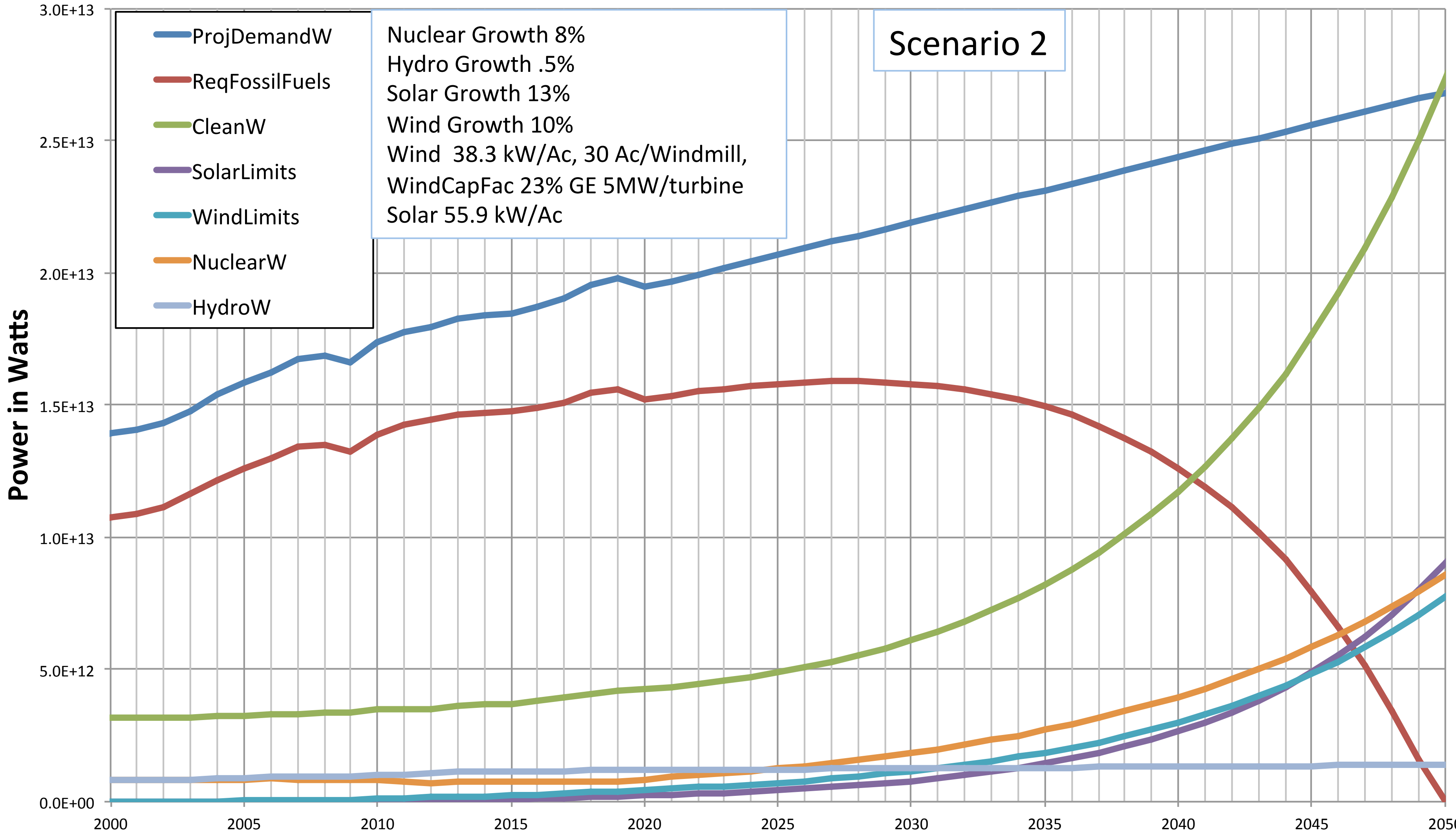


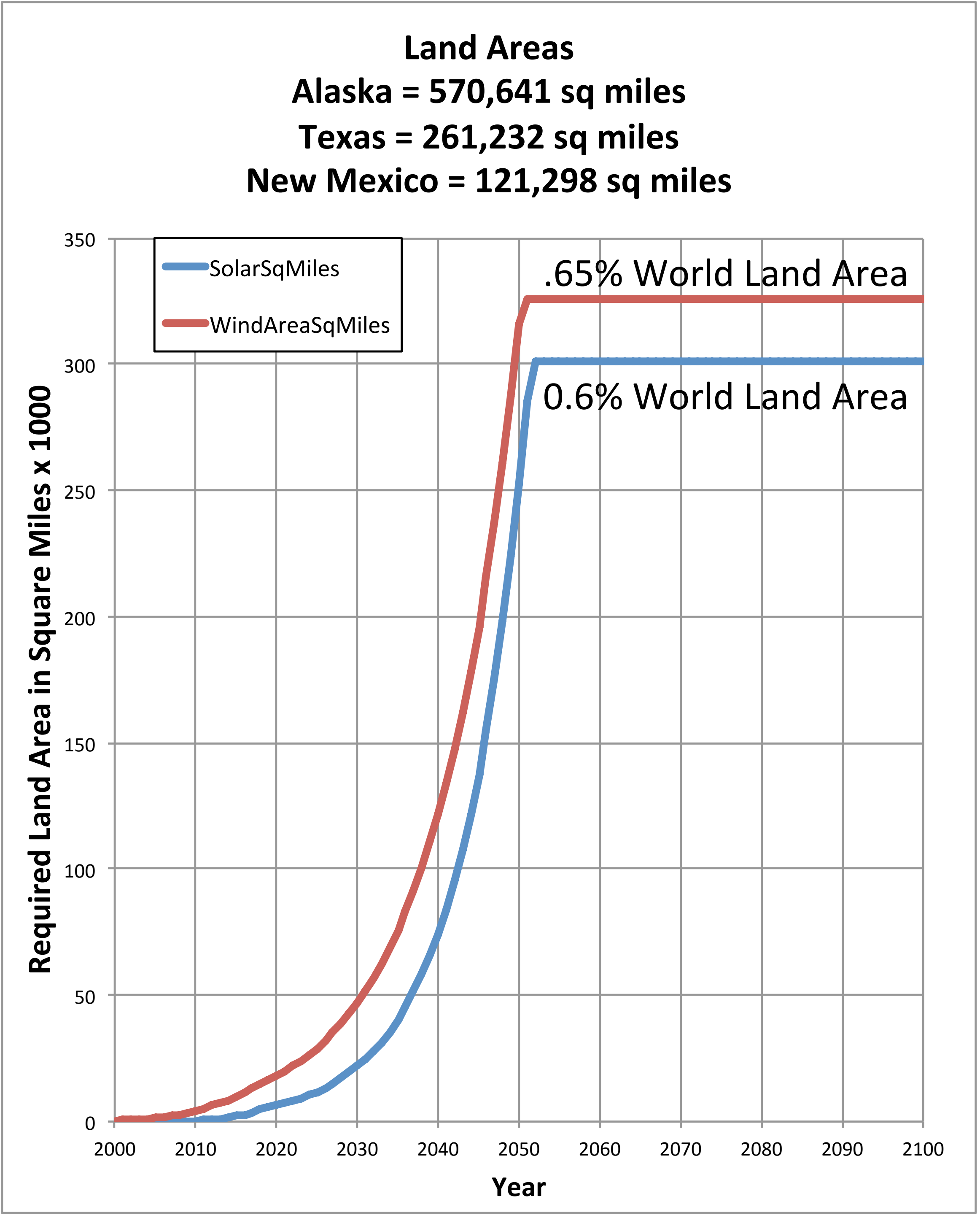


Scenario 1

Nuclear Growth 3.3%
Hydro Growth .5%
Solar Growth 13%
Wind Growth 12%
Wind 38.3 kW/Ac, 30 Ac/Windmill,
WindCapFac 23% GE 5MW/turbine
Solar 55.9 kW/Ac

Plausible to Eliminate Fossil Fuels by 2050:





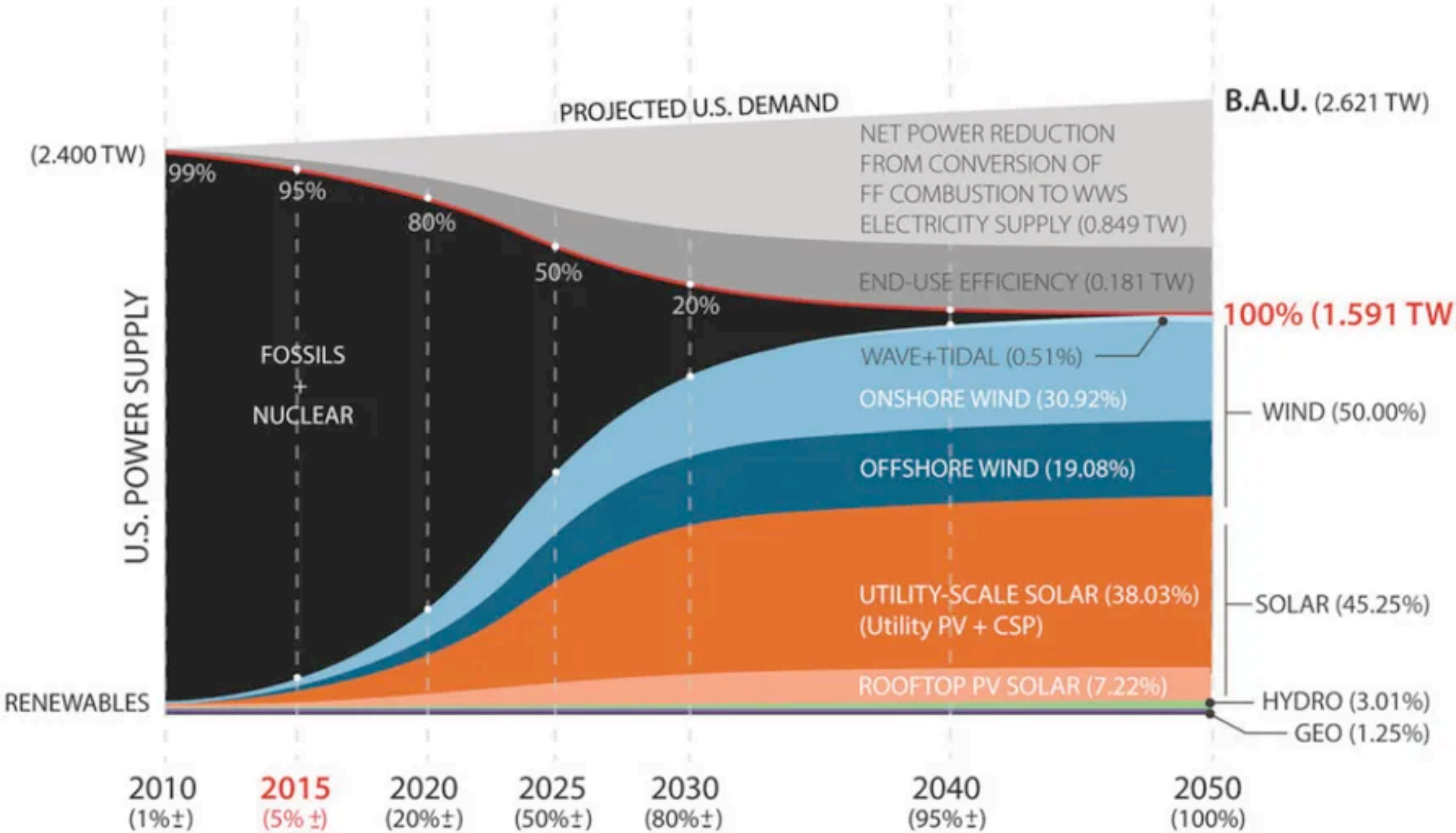
Scenario 2

Nuclear Growth 8%
Hydro Growth .5%
Solar Growth 13%
Wind Growth 10%
Wind 38.3 kW/Ac, 30 Ac/Windmill,
WindCapFac 23% GE 5MW/turbine
Solar 55.9 kW/Ac

What's Wrong With This Picture?

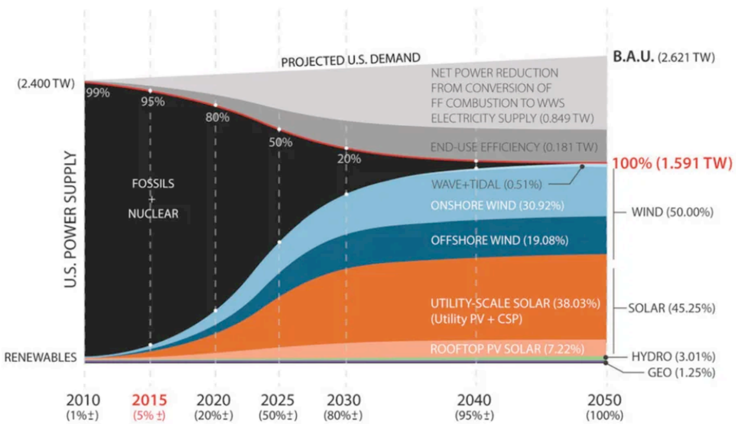
- Numbers are annualized averages
  - On yearly average, Chicago is a moderate climate
- 100% Renewables Assumptions
  - Wind, Solar, Storage (WSS) can do the job
  - Add Demand Response
    - Smart Grid and lots of customer buy-in
  - Add Energy Efficiency
  - **Intermittent energy can be compensated by imported intermittent energy**
    - Assumes large "aggregation areas" and extensive new transmission lines
    - Assumes statistics will always insure Supply ≥ Demand
      - Blackouts and Brownouts are guaranteed
- Does not include all economic sectors

Popular US 100% Renewable Perspective



(Jacobson et al., Energy & Environmental Science, 2015)

Popular US 100% Renewable Perspective—Issues



- Getting to ZERO by 2050 does not stop climate warming
  - About 1 Trillion Tons CO_2 need to be removed to get back to 350 ppm
  - Will need abundant clean electricity
  - This in not controversial
  - Not a scheme to keep burning fossil fuels
- SDG 7 is a global goal
  - Abundant, Clean, Affordable energy for all
  - Growth in energy production required
- US does not control the rest of the world
- Our position is nuclear is clean energy
  - Part of the solution
  - Area required will become important

(Jacobson et al., Energy & Environmental Science, 2015)

Energy Density

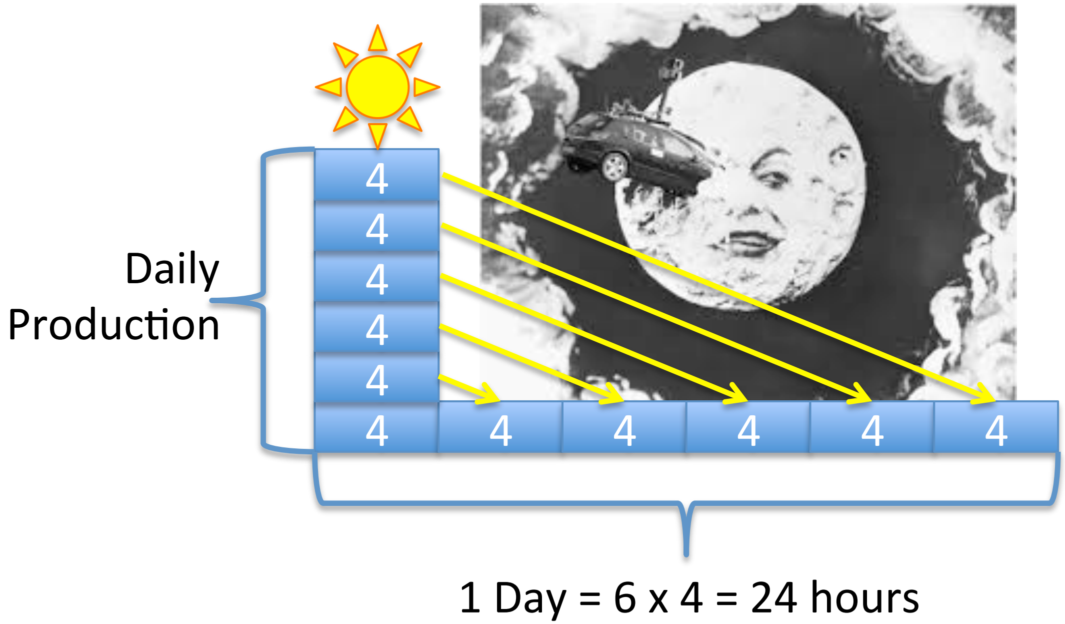
Fuel Type	Reaction Type	Energy Density (MJ/kg)	Typical uses
Wood	Chemical	16	Space heating, Cooking
Coal	Chemical	24	Power plants, Electricity generation
Ethanol	Chemical	26.8	Gasoline mixture, Alcohol, Chemical products
Biodiesel	Chemical	38 [8]	automotive engine
Crude oil	Chemical	44	Refinery, Petroleum products
Diesel	Chemical	45	Diesel engines
Gasoline	Chemical	46	Gasoline engines
Natural gas	Chemical	55	Household heating, Electricity generation
Uranium-235	Nuclear	3 900 000	Nuclear reactor electricity generation

Storage

- Batteries—suitable for a few hours
  - Lithium Ion—e.g., Tesla PowerWall
    - Warranty: in 10 years, capacity ≥ 70%
      - Loses 3.5% of capacity per year (exponential decline)
      - Capacity in 20 years ≈ 49%
  - Promising new technologies, e.g., Lithium Iron
- Molten Salt--hours
- Pumped Hydro—hours to a few days
- Gravity—no time limits
- Hydrogen Conversion—could be seasonal

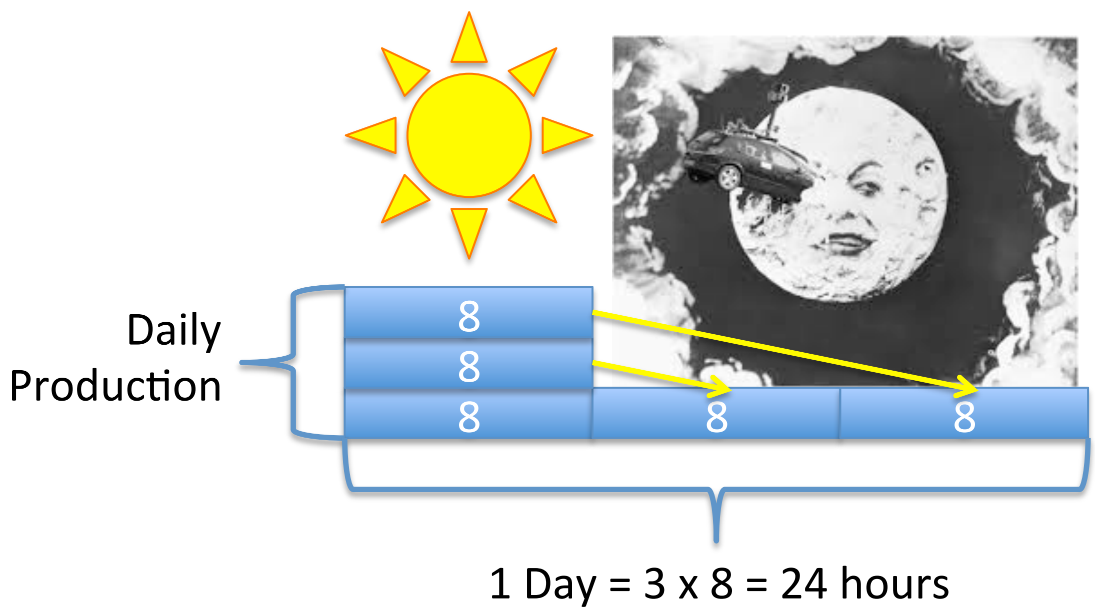
Daily Averages—Solar

- Example 1: Nameplate kW x 4 hours = kWh/day
  - Need 20 hours of storage for rest of the day
  - Suppose home needs 2kW x 24 hr = 48 kWh/day
    - Nameplate = 12kW → 2 kW for usage, 10 kW for storage
    - 10kW x 4hr = 40 kWh battery storage
    - Tesla Power Wall has 13.5 kWh capacity
    - Requires 3 PowerWalls at $10k each → $30k



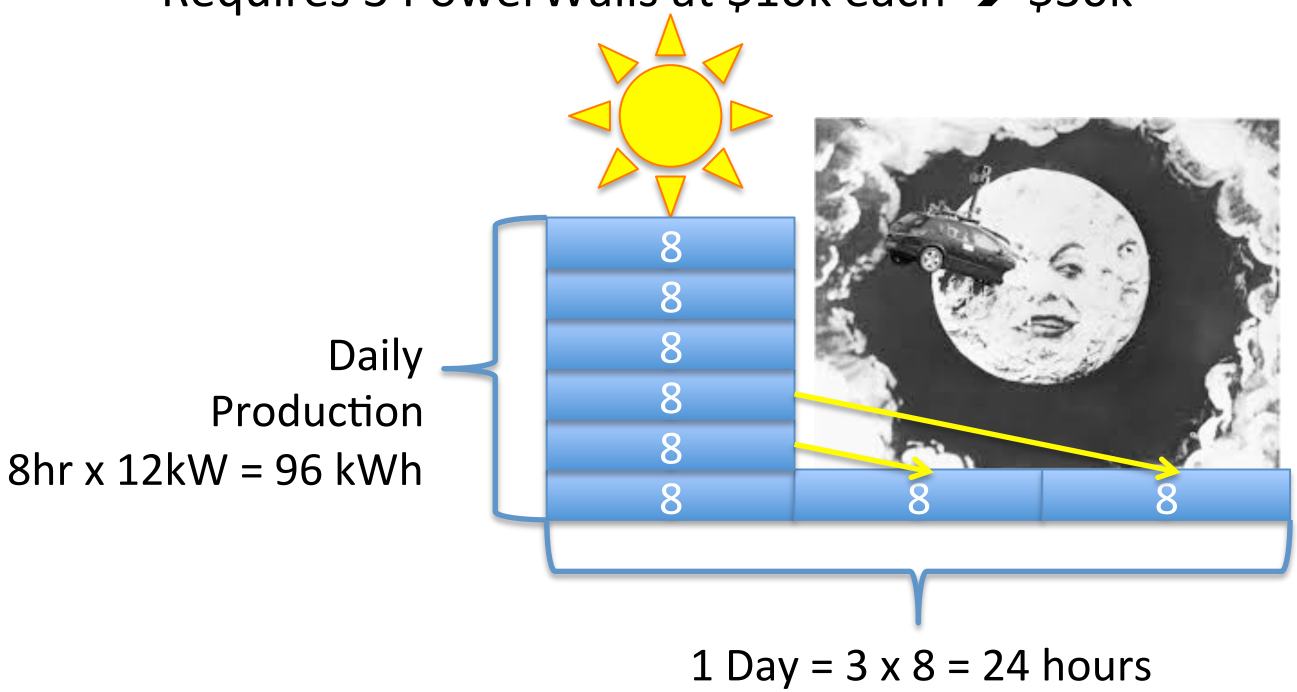
Daily Averages—Solar

- Example 2: Nameplate kW x 8 hours = kWh/day
  - Need 16 hours of storage for rest of the day
  - Suppose home needs 2kW x 24 hr = 48 kWh/day
    - Nameplate = 6kW → 2 kW for usage, 4 kW for storage
    - 4kW x 8hr = 32 kWh battery storage
    - Tesla Power Wall has 13.5 kWh capacity
    - Requires 3 PowerWalls at $10k each → $30k



Daily Averages—Solar

- Example 3: Nameplate kW = 12kW for Winter
  - Suppose home needs 2kW x 24 hr = 48 kWh/day
    - Nameplate = 12kW ➔ 2 kW for usage, 4 kW for winter storage
    - Still need 40 kWh battery storage for winter
    - Daily production 96kW – 40 kWh storage = 56 kWh surplus **every** day
      - Curtail or Sell at Market Value
    - Tesla Power Wall has 13.5 kWh capacity
    - Requires 3 PowerWalls at $10k each ➔ $30k



Annualized Averages—Solar

- Annual Example: My neighbor has
  - 13.5 kW Nameplate capacity rooftop solar panels
  - Summer 7 months NetMetering sends 6400kWh to PUD
  - Winter 5 months draws that down to a few hundred kWh.
  - Equivalent to having around 5400-6400kWh battery storage
    - About 400-474 Tesla PowerWalls ($4,000,000 with cash discount)
    - 84-100 Kia Electric Vehicle batteries

Annualized Averages—Wind

- Wind
  - Can have periods of many hours to days with low to zero output
  - Sources of imported wind energy may also be zero or inadequate
  - It’s a gamble → no way to guarantee that electricity supply will meet demand

Next Week

- What is the electrical grid?
- What is Availability?
- What is Baseload?
  - Is it still important?
- What is Intermittency?
- What is Dispatchable Energy?

Wind Turbine Sizes

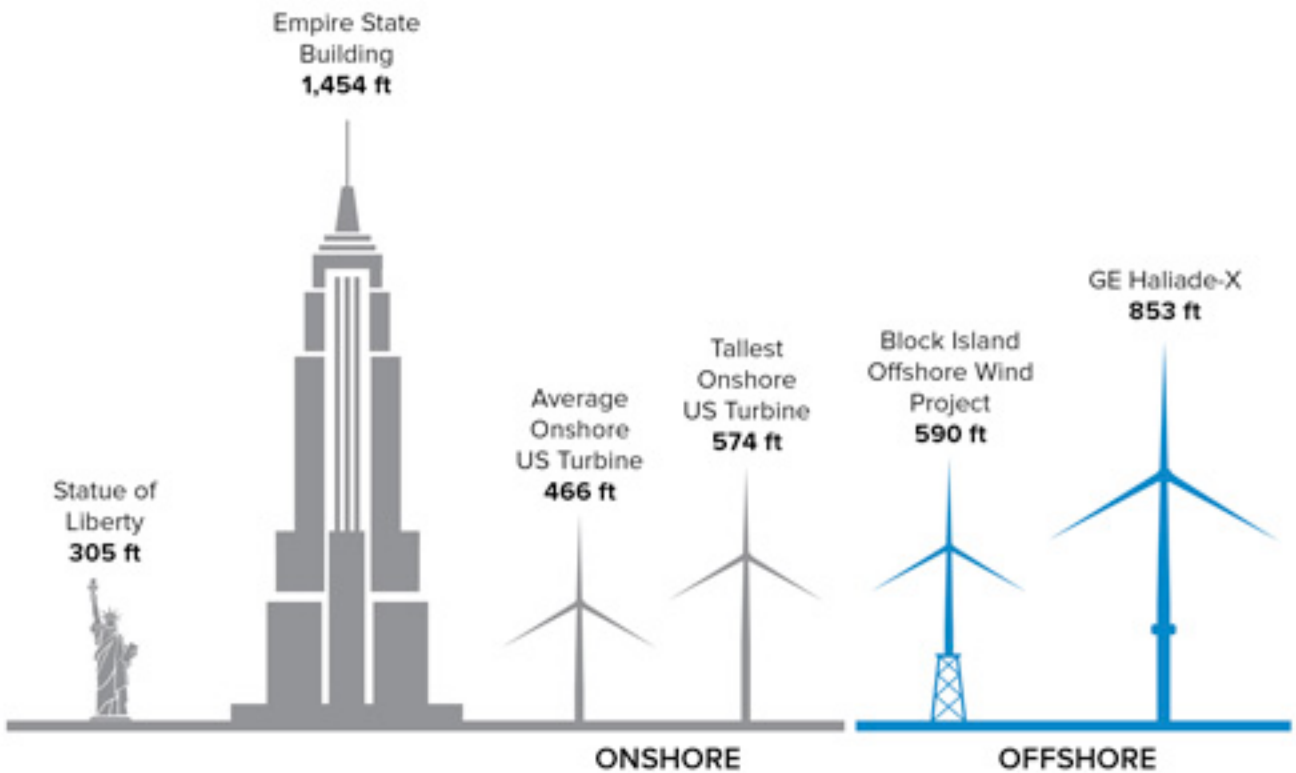
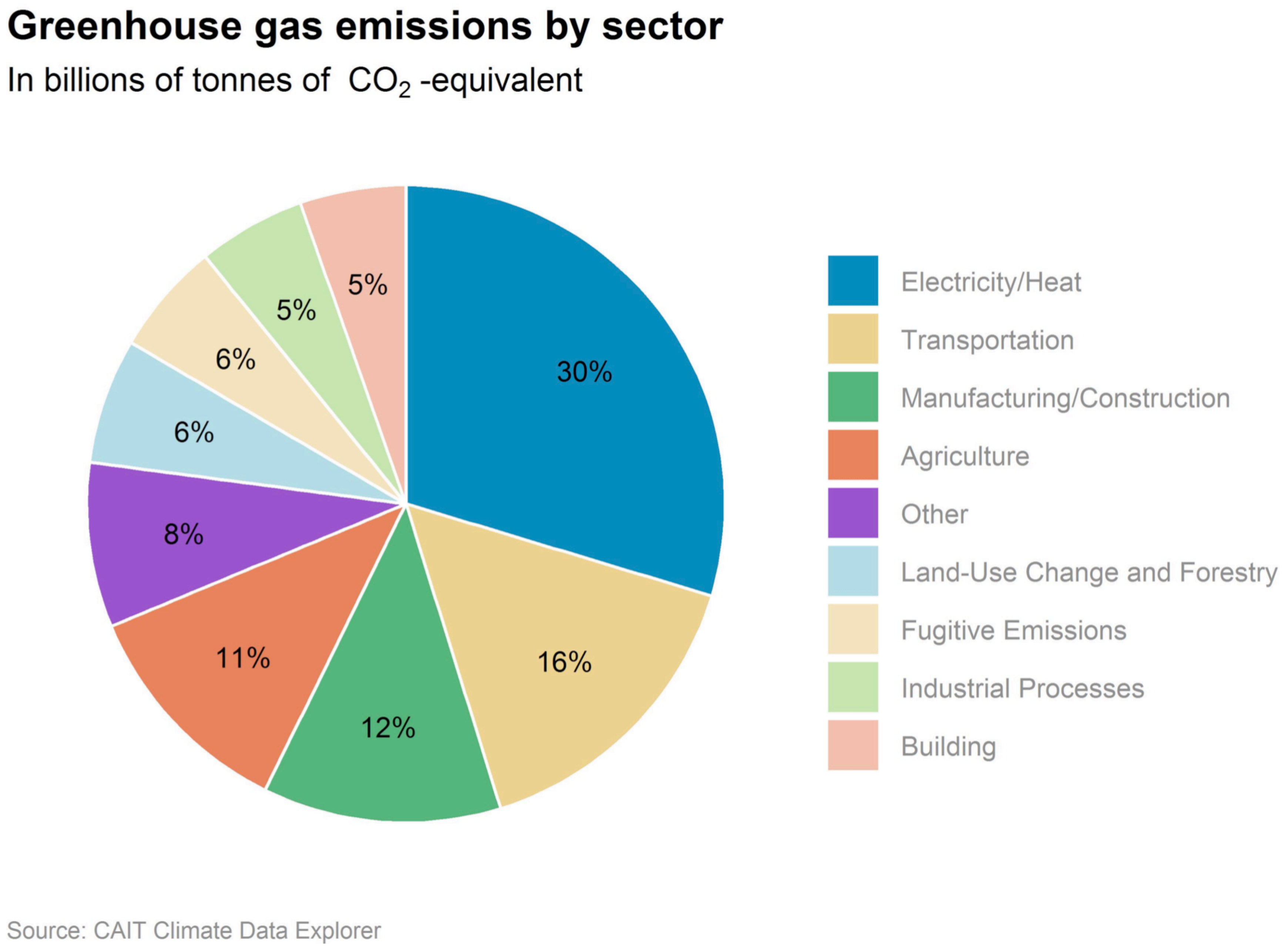


Exhibit 16:



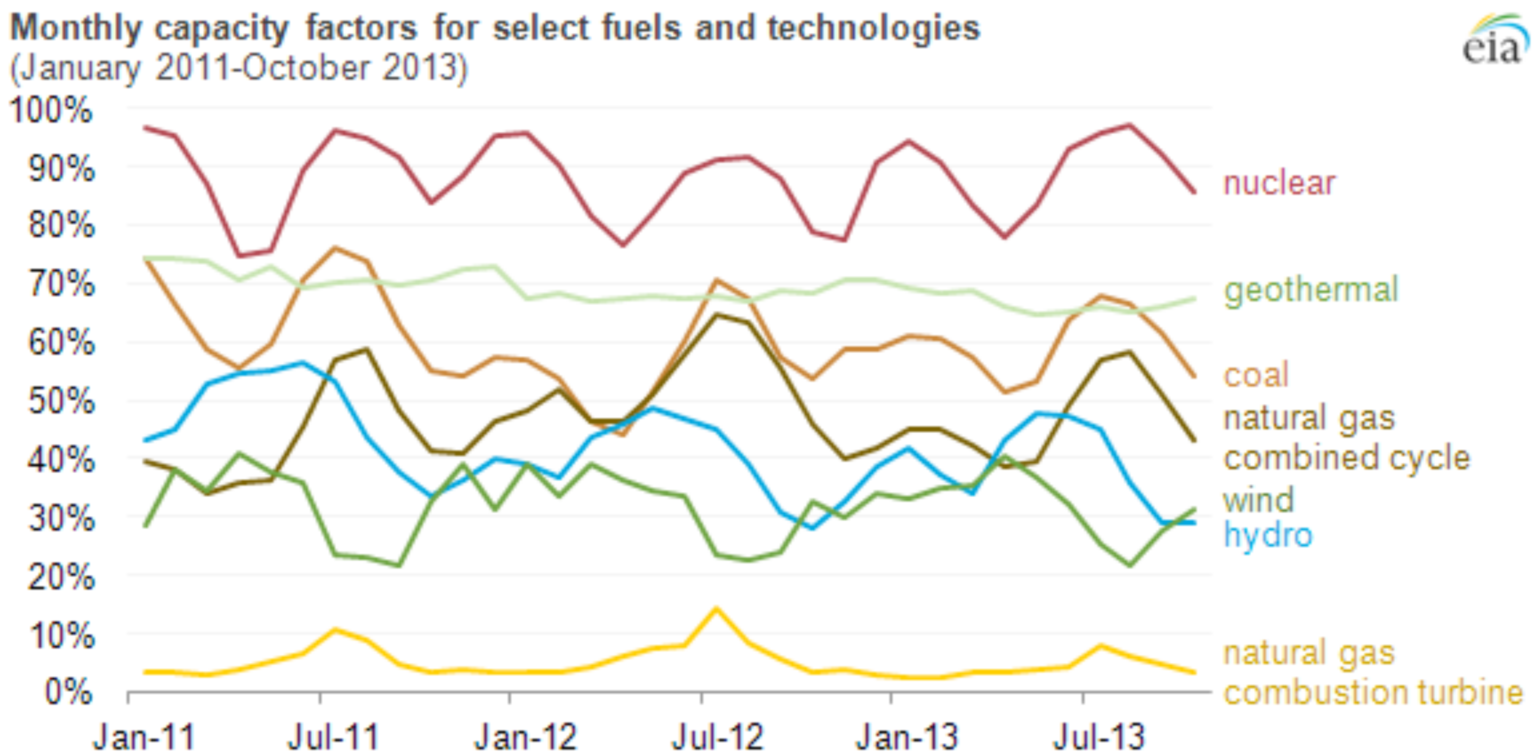
Greenhouse gas emissions by sector
In billions of tonnes of CO_2 -equivalent
30%
16%
12%
11%
8%
6%
6%
5%
5%
Electricity/Heat
Transportation
Manufacturing/Construction
Agriculture
Other
Land-Use Change and Forestry
Fugitive Emissions
Industrial Processes
Building
Source: CAIT Climate Data Explorer

Largest Wind Turbine

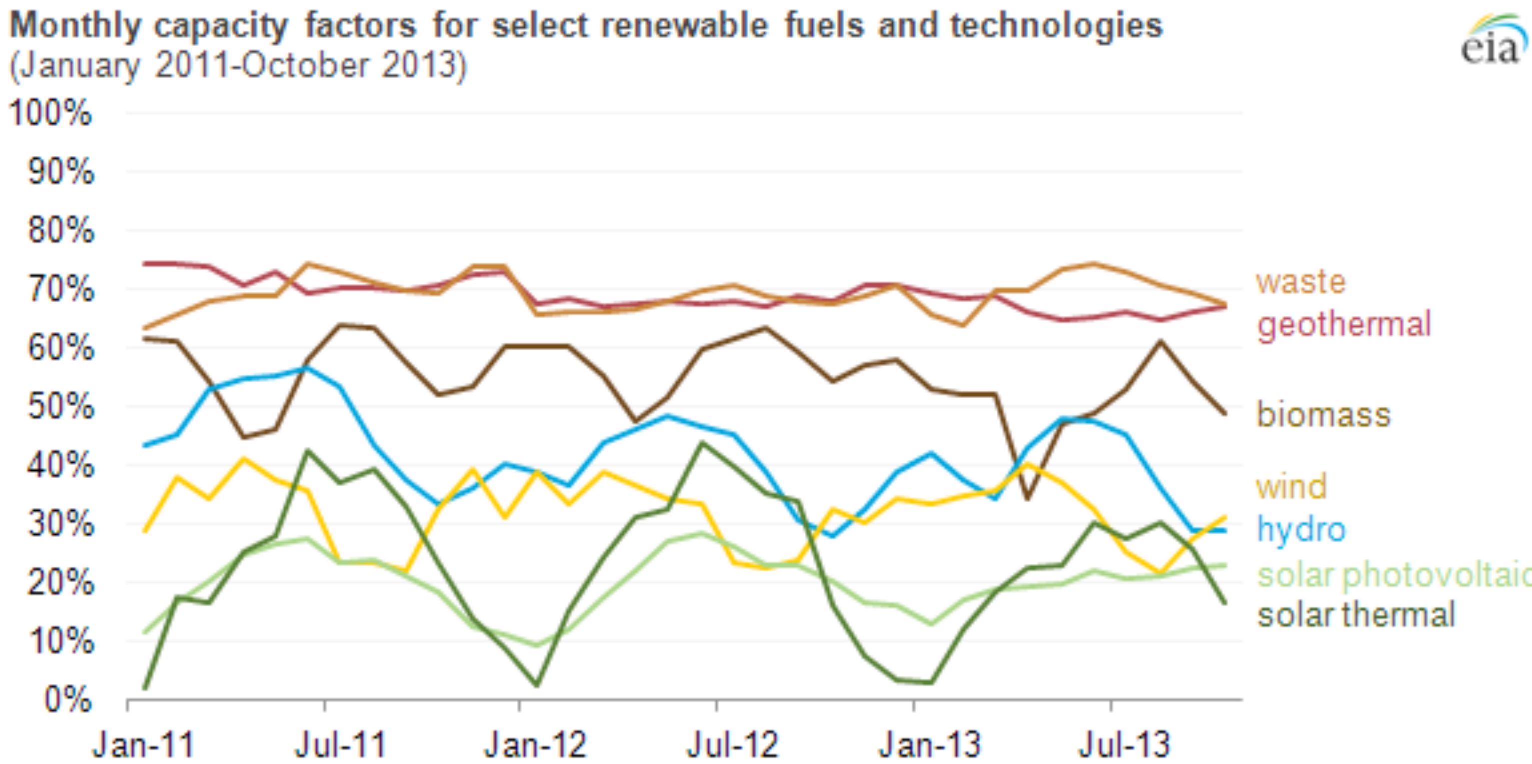
SPECIFICATIONS

Haliade-X wind turbine technical specifications

Haliade-X	12 MW	13 MW	14 MW
Output (MW)	12	13	14
Rotor diameter (m)	220	220	220
Total height (m)	up to 260	up to 260	up to 260
Frequency (Hz)	50 & 60	50 & 60	50 & 60
Gross AEP (GWh)	~68	~71	~74
Capacity Factor (%)	63	60-64%	60-64%
IEC Wind Class	IB	IC	IC



Monthly capacity factors for select fuels and technologies
(January 2011-October 2013)
eia
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
nuclear
geothermal
coal
natural gas
combined cycle
wind
hydro
natural gas
combustion turbine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20%
10%
0%
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
waste
geothermal
biomass
wind
hydro
solar photovoltaic
solar thermal

Presenter Bios

- **Steve Blake** retired in 2011 from power generation utilities in the US and Germany. He was in Germany when the government issued its renewable energy mandates. He understands what happens when undependable power (solar and wind) is fed to the grid.
- **David Blessing** worked at Naval Reactors, the joint DOE/Navy nuclear power program for 32 years and for 9 years at Lockheed Martin on various nuclear design concept developments.
- **Chelcie Liu** is retired from 20+ years of teaching physics at City College of San Francisco. He is interested in global climate change and technologies being developed to reduce CO_2 emissions while supplying the world's ever increasing need for energy.
- **Dave Clive** served in the United States Navy for 23 years as a nuclear power plant operator and trainer. He taught theory and reactor plant technology at the Naval Nuclear Power School.
- **Gary Nelson** is a retired telecommunication engineer with an interest in understanding how smart grid and fiber optic communications technologies will help enable safely producing abundant energy with zero CO_2 emissions.
- **Doug Rodgers** is retired from a 30+ year career with GE nuclear. He worked in various R&D areas including molten metals, high temperature batteries and radioactive materials transport.