


# Impacts of Green New Deal Plans on Cost, Jobs, Health, and Climate in the United States and 143 Countries

An aerial photograph of a wind farm situated in a lush green valley. Several white wind turbines are visible, with one prominently in the foreground. The landscape features rolling green hills, a winding dirt road, and distant mountain ranges under a blue sky with scattered clouds.

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# Wind, Water, Solar (WWS) Solution

**Electrify or Provide Direct Heat For All Sectors and Provide the Electricity and Heat with 100% WWS**

## ELECTRICITY

Wind  
Solar PV/CSP  
Geothermal  
Hydro  
Tidal/Wave

## TRANSPORTATION

Battery-electric  
H<sub>2</sub> fuel cell

## HEATING/COOLING

Electric heat pumps  
Solar heat  
Geothermal heat  
District heat/cold

## INDUSTRY

Electric arc furnaces  
Induction furnaces  
Resistance heaters  
Dielectric heaters  
Electron beam heaters

# Onshore and Floating Offshore Wind





# Solar Photovoltaics (PV)





# Electric & Hydrogen Fuel Cell Transportation



Tesla Semi-electric (850km)



Nikola Tre Semi-hydrogen fuel cell (1250 km)



Fjellstrand electric ferry



Protera electric bus

# Planes: Replace Jet Fuel With Batteries & Hydrogen Fuel Cells



Battery electric aircraft-Ampaire



Cryogenic hydrogen aircraft



Hydrogen fuel cell aircraft



# Electric Appliances



Electric lift



Electric lawn mower



Electric leaf blower

# Types of Storage for a 100% WWS System

## ELECTRICITY

CSP with storage  
Pumped hydro storage  
Existing hydroelectric  
Batteries  
Flywheels  
Compressed air  
Gravitational Storage

## HEATING/COOLING

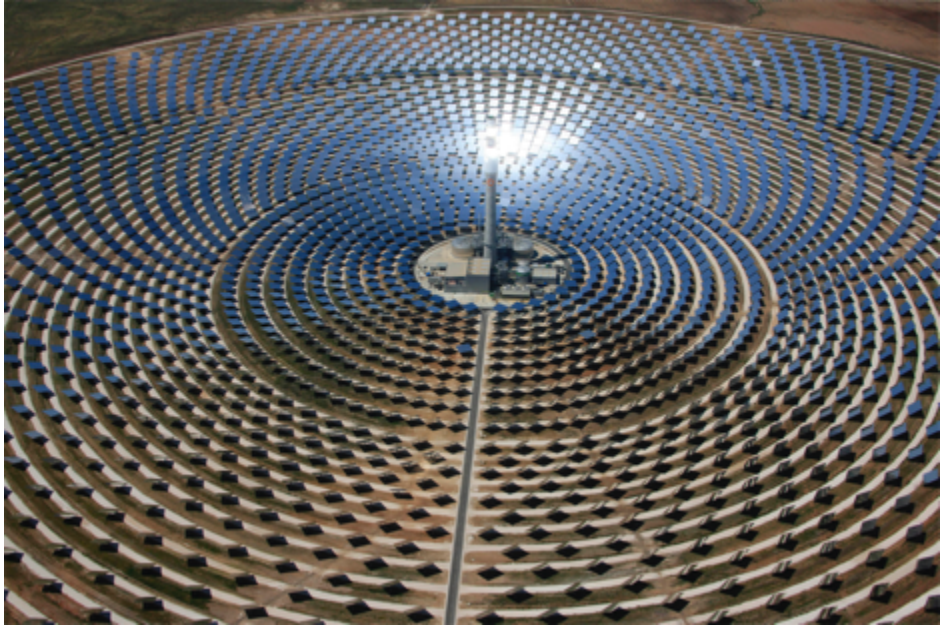
Water tank  
Ice  
Underground  
Borehole  
Water Pit  
Aquifer  
Building materials

## OTHER

Hydrogen



# Concentrating Solar Power



Top: Gemasolar CSP plant. 19.9 MW with 15 hours of storage.



Bottom: 392 MW Ivanpah CSP

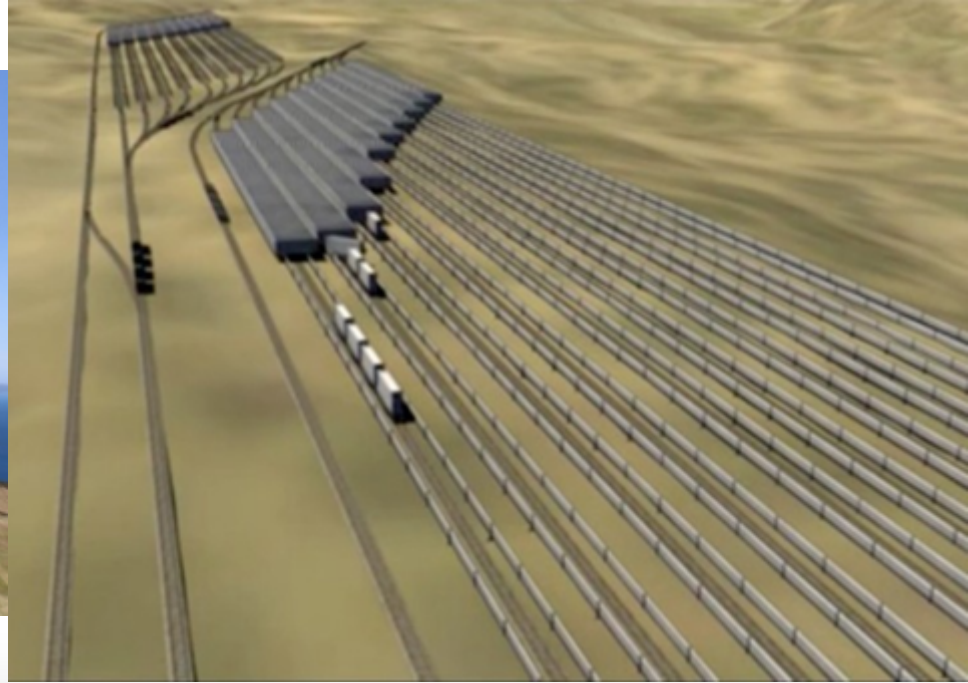


# Stationary Battery Storage





# Gravitational Storage With Solid Masses



# Stanford University 4<sup>th</sup> Generation District Heating System





# Seasonal Heat Storage in Underground Boreholes Okotoks, Canada



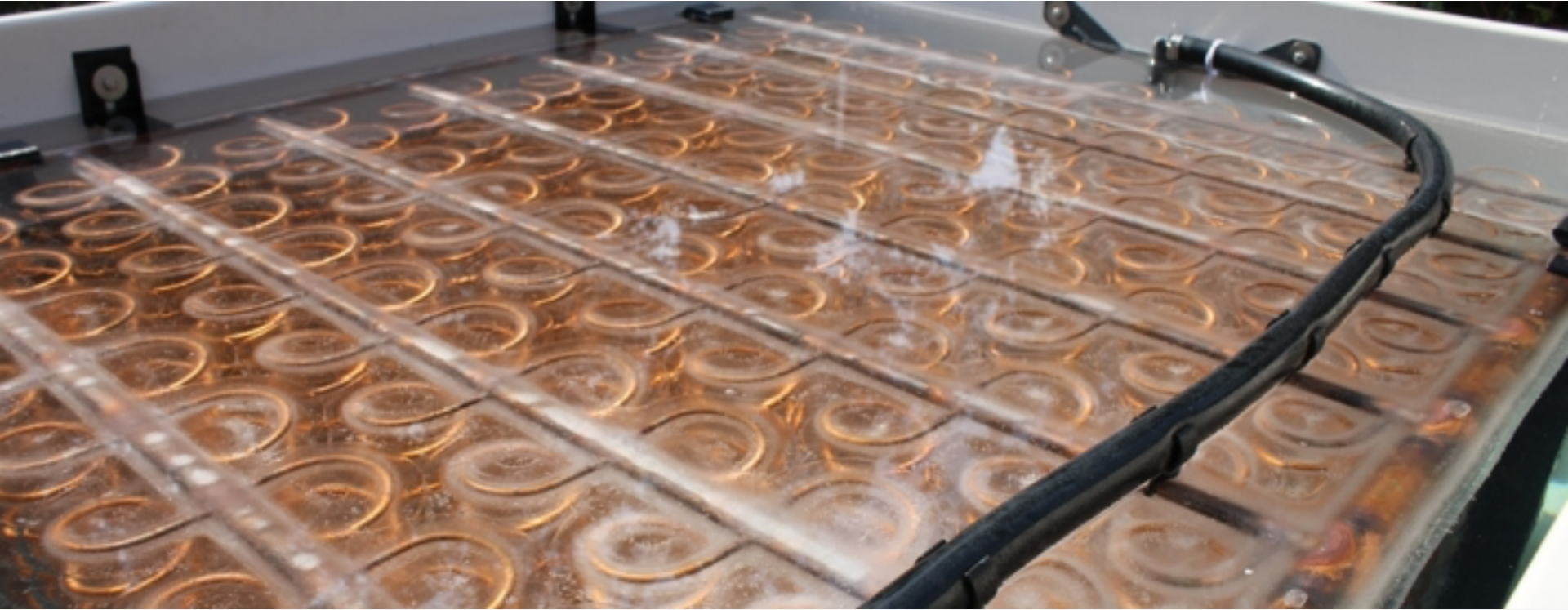


# Seasonal District Heat Storage in Covered Water Pit Vojens, Denmark





# Nighttime Storage in Ice for Daytime Air Cooling



# **Transitioning an Individual Home to Run on WWS Electricity/Storage and No Gas**



# Rooftop Solar Plus Battery Storage



# Ductless Mini-Split Electric Heat Pump Air Heater / Air Conditioner



# Electric Heat Pump Water Heater





# Electric Induction Cooktop



# One Year of Energy Use

## Generated 120% of all home and vehicle energy

→ No electric bill, natural gas bill, or gasoline bill

**Received \$530 from CCA for excess electricity to grid**

## Avoided costs of all-electric home

**Gas hookup fee: 3-8 K**

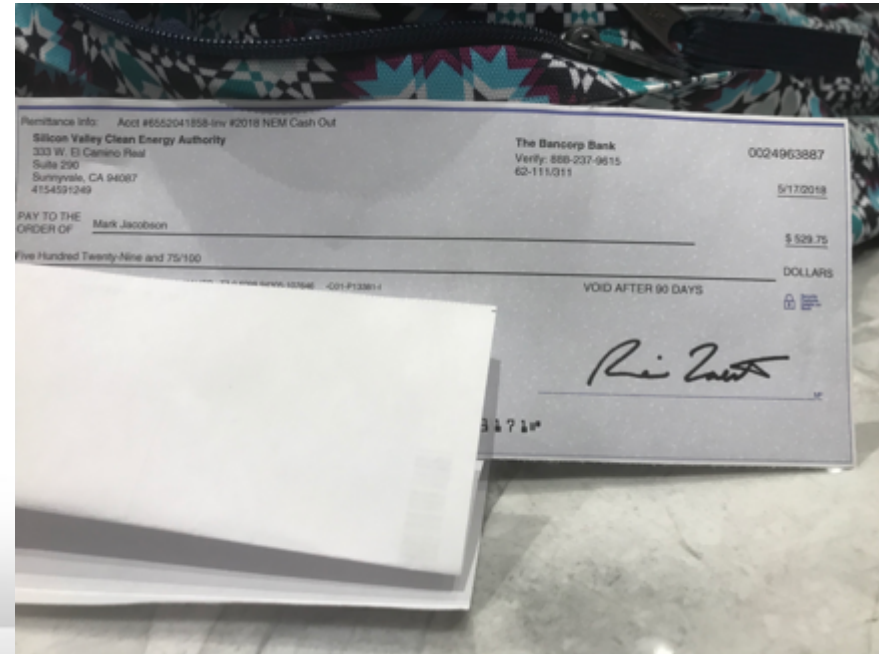
## Gas pipes: 1-7 K

**Electric bill 1-3 K per year**

## Natural gas bill 1-3 K per year

## Vehicle fuel bill 1-4 K per year

**Total: 4-15 K plus 3-10 K per year**



# **Can the World Transition to 100%, Clean, Renewable Energy for all Purposes?**

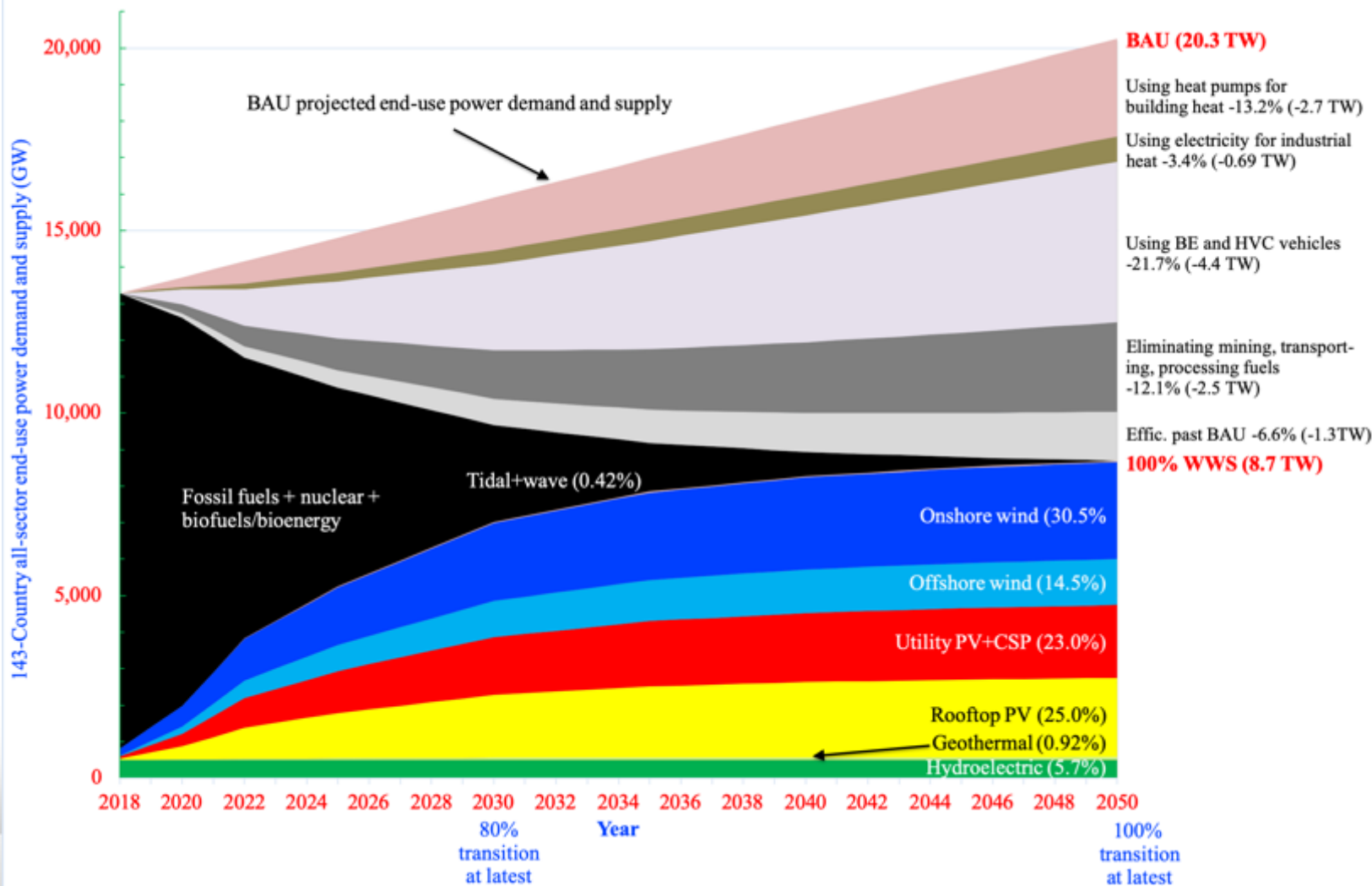
## **Roadmaps for 143 Countries**



# All-Purpose End-Use Power Demand

Year and Fuel Type	143-Countries
2016 End-use demand	12.6 TW
2050 Demand with current fuels (BAU)	20.3 TW
2050 Demand with WWS	8.7 TW
2050 Demand reduction w/ WWS 21.7% efficiency of BE, HFC v. ICE 3.4% efficiency of electric industry 13.2% efficiency of heat pumps 12.1% eliminating fuel mining 6.6% efficiency beyond BAU	57.1%

# Time-line for a Trans- ition

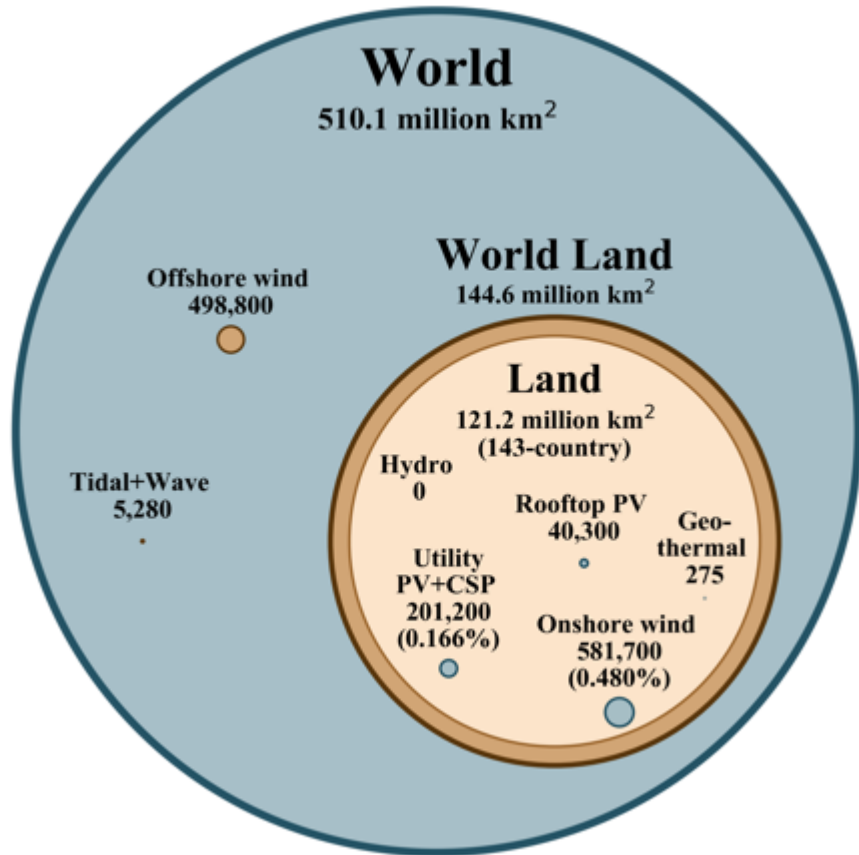


# Percent of 2050 143-Country End-Use Demand Supplied by WWS Devices and Number of New Devices

TECHNOLOGY	PCT SUPPLY 2050 World
5-MW onshore wind turbines	30.5%
5-MW offshore wind turbines	14.5
5-kW Res. roof PV systems	11.1
100-kW com/gov roof PV systems	13.8
50-MW Solar PV plants	19.0
100-MW CSP plants	3.93
100-MW geothermal plants	0.92
1300-MW hydro plants	5.72
1-MW tidal turbines	0.08
0.75-MW wave devices	0.34
	<b>100%</b>



# Area Beyond 2018 Installations to Power 143 Countries for all Purposes With 100% WWS in 2050



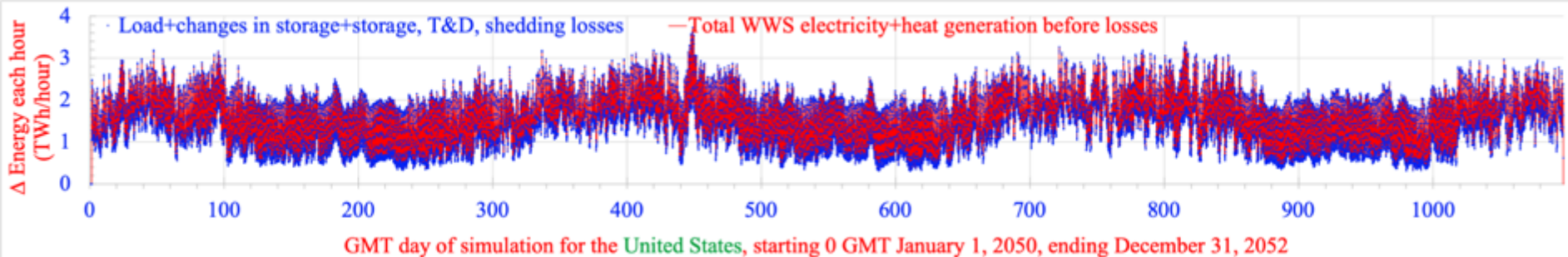
## Percent of 143-Country Land

Onshore wind: 0.48%

Utility PV+CSP: 0.17%

Total 0.65%

# Matching **U.S.** All-Sector Demand Every 30 Sec. With 100% WWS+Storage for 3 Years (2050-2052) and 100 Days



**Red = Energy supply**

**Blue = Energy demand + change in storage + losses + shedding**

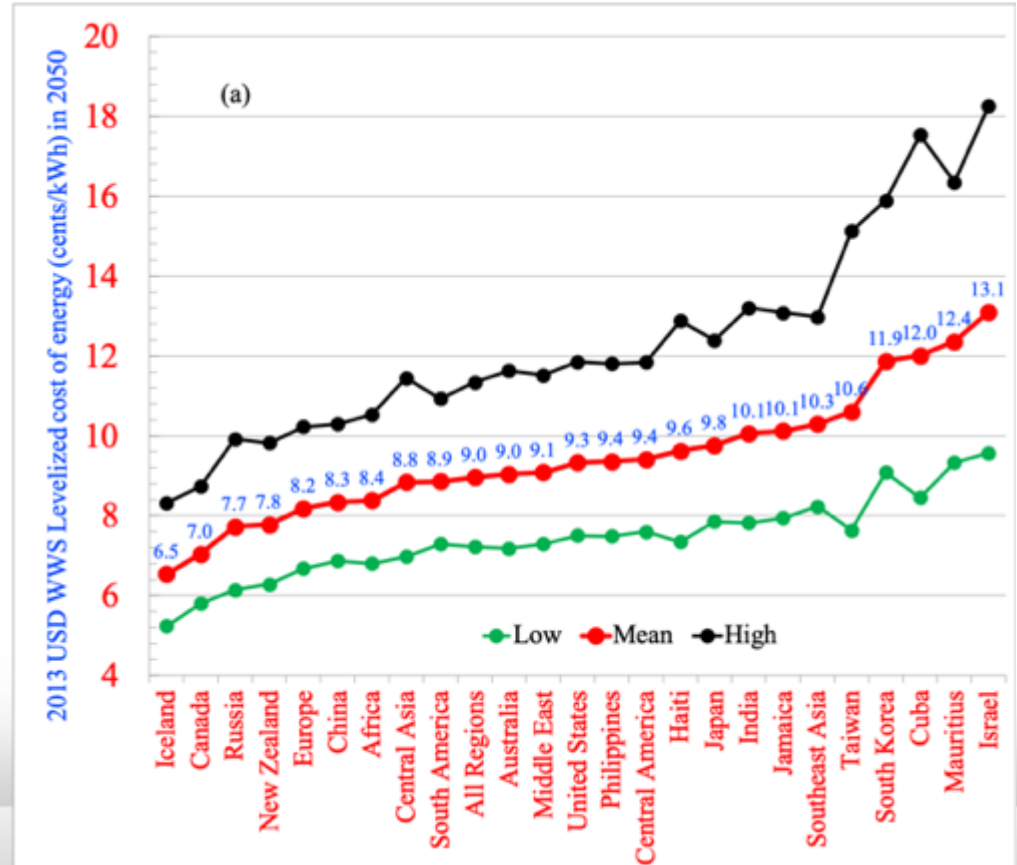
# Energy Cost for 143 Countries in 24 Regions Resulting in a Stable Grid Upon Electrification of all Energy With 100% WWS+Storage

**World: 9.0 cents/kWh**  
**Capital Cost: \$73 trillion**

**U.S.: 9.3 cents/kWh**  
**Capital cost: \$7.8 trillion**

**China: 8.3 cents/kWh**  
**Capital cost: \$16.6 trillion**

**Europe: 8.2 cents/kWh**  
**Capital cost: \$6.2 trillion**





# 2050 World BAU vs WWS Cost

BAU fuel energy cost	\$17.7 trillion/yr
BAU fuel health cost	\$30.0 trillion/yr
<u>BAU fuel climate cost</u>	<u>\$28.4 trillion/yr</u>
Total conventional fuel electricity sector cost	\$76.1 trillion/yr

WWS replacing all BAU energy sectors \$6.8 tril/yr

WWS reduces energy cost 61.4% and economic (social) cost 91%

## 61 Countries Committed to 100% Renewable Electricity

<b>Afghanistan</b>	<b>Denmark</b>	<b>Kirbati</b>	<b>Papua N.G.</b>	<b>Tanzania</b>
<b>Aruba</b>	<b>Djibouti</b>	<b>Lebanon</b>	<b>Philippines</b>	<b>Timor-Les</b>
<b>Bangladesh</b>	<b>Dominica</b>	<b>Madagas</b>	<b>Portugal</b>	<b>Tokelau</b>
<b>Barbados</b>	<b>Dom Rep.</b>	<b>Malawi</b>	<b>Rwanda</b>	<b>Tunisia</b>
<b>Bhutan</b>	<b>Ethiopia</b>	<b>Maldives</b>	<b>Samoa</b>	<b>Tuvalu</b>
<b>Burkina Faso</b>	<b>Fiji</b>	<b>Marsh Is.</b>	<b>Senegal</b>	<b>Scotland</b>
<b>Cabo Verde</b>	<b>Gambia</b>	<b>Mongolia</b>	<b>Solom Is.</b>	<b>Vanuatu</b>
<b>Cambodia</b>	<b>Ghana</b>	<b>Morocco</b>	<b>S. Sudan</b>	<b>Vietnam</b>
<b>Colombia</b>	<b>Grenada</b>	<b>Nepal</b>	<b>Spain</b>	<b>Yemen</b>
<b>Comoros</b>	<b>Guatemala</b>	<b>Niger</b>	<b>Sri Lanka</b>	
<b>Congo, DR</b>	<b>Haiti</b>	<b>Niue</b>	<b>St. Lucia</b>	
<b>Cook Islands</b>	<b>Honduras</b>	<b>Palau</b>	<b>Sudan</b>	
<b>Costa Rica</b>	<b>Kenya</b>	<b>Palestine</b>	<b>Sweden</b>	

**U.S. House H.Res.540 (2015), Senate S.Res.632 (2016)**  
**U.S. transition to “100% clean renewable energy by 2050”**

**U.S. Senate Bill S.987 (2017) and House Bill H.R. 3314 (2017)**  
**“100% clean and renewable energy by 2050”**

**U.S. House Bills H.R. 3671 (2017), H.R. 330 (2019)**  
**“100% clean, renewable energy by 2035”**  
**“100% renewable electricity by 2035”**

**U.S. Green New Deal (H.Res. 109; S.Res. 59)**  
**100% Renewable Energy for the U.S. by 2030**



# 100% Renewable Electricity State Laws Resulting From WWS Roadmaps

**100% by 2030**

**Rhode Island**

**By 2032**

**Washington D.C.**

**By 2040**

**Connecticut**

**By 2045**

**Hawaii, California, New Mexico, Washington State, New York**

**By 2050**

**Puerto Rico, Nevada, Maine, Wisconsin, Virginia, New Jersey**

## Some of 140 Cities/Counties Committed to 100% Renewables

Atlanta (GA)

Chicago (IL)

Cincinnati (OH)

Cleveland (OH)

Denver (CO)

Kansas City (MO)

Los Angeles (CA)

Madison (WI)

Minneapolis (MN)

Orlando (FL)

Philadelphia (PA)

Portland (OR)

Salt Lake City (UT)

San Diego (CA)

San Francisco (CA)

San Jose (CA)

Spokane (WA)

St. Louis (MO)

St. Paul (MN)

St. Petersburg (FL)

Tallahassee (FL)

Abita Springs (LA)

Sarasota (FL)

Hanover (NH)

Sylva (NC)

Moab (UT)

Boulder (CO)

Burlington (VT)

Rochester (MN)

Fayetteville (AR)

Palo Alto (CA)

Middleton (WI)

Missoula (MT)

Questa (NM)

Fayetteville (AR)

Clarkston (GA)

# Some of the 221 Companies Committed to 100% Renewables

IKEA	Adobe	JPMor/Chas	Coca Cola
Google	H&M	HP	Goldman-Sachs
Microsoft	Nestle	Nike	Johnson & Johnson
Apple	S&P	Starbucks	Walmart
Workday	T-Mobile	AB InBev	Bank of America
Bloomberg	BMW Group	Burberry	Citi
P&G	Ebay	Facebook	Estee Lauder
GM	Goldman-Sachs	HSBC	Infosys
Kellogg's	Lego	Mars	Morgan Stanley
Salesforce	Organic Valley	Amazon	Wells Fargo



# Some of the 100+ NGOs Committed to 100%

The Solutions Project

100.Org

Sierra Club

350.Org

Greenpeace

theRE100.org

go100percent.org

renewables100.org

Climate Reality

iclei.org

The Center for Working Families

Miami Climate Alliance

Environment America

Toxics Action Center

Renewable Cities

National People's Action

Institute for Self-Reliance

Hip Hop Caucus

Environmental Action

Renewable Energy Long Island

Emerald Cities Collaborative

Community Power

Center for Community Change

Asian Pacific Environmental Network

# Summary – Transitioning to 100% WWS

**Creates 28 million more jobs than are lost worldwide**

**Requires only 0.17% of land for footprint; 0.48% for spacing**

**Avoids ~7 mil. air pollution deaths per year**

**Slows then reverses global warming**

**Grids can stay stable throughout the world with 100%**

**WWS absolute energy costs are 60% less than of fossils**

**WWS absolute energy+health+climate costs 90% less than of fossils**

## Online Course on 100% WWS

<http://stanford.io/windwatersolar>

## Roadmaps

[web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html](http://web.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html)

## Infographic maps

[www.thesolutionsproject.org](http://www.thesolutionsproject.org)

## Textbook on 100% WWS

<https://web.stanford.edu/group/efmh/jacobson/WWSBook/WWSBook.html>

Twitter: @mzjacobson