List of Electric Technologies / Efficiency Measures to Replace 100% of Fossil Fuels Used for Energy Worldwide and Timelines for their Implementation

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Below is a list of efficiency measures, electric appliances, transportation options, and wind-water-solar (WWS) power generators, almost all of which are available today, and the rest of which (e.g., for aircraft and ships in particular) are being designed, to transform the energy infrastructures of cities, counties, states, countries, and the world. The list is not a complete list.

Followed by this list is a timeline to transition the world to these technologies.

1. List of Measures and Technologies

A. Energy Efficiency Measures / Energy Demand Reduction

i. Increase Efficiency in Buildings Through:

Lighting:

LED lighting
Advanced lighting controls

Appliances:

High efficiency industrial pumps and motors
High efficiency commercial appliances (refrigerators, washers, dryers)
Energy efficient residential appliances (refrigerators, vacuum cleaners, etc.)
Variable refrigerant flow

Heating and cooling efficiency in buildings through:

Programmable thermostats
Improved wall, floor, ceiling, and pipe insulation
High-efficiency double and triple-pane windows
Energy efficient framing practices
Passive solar design
Sealing doors, windows, walls, outlets, and fireplaces to reduce heat / cold loss
Evaporative cooling systems
Ductless heat pumps for heating and air conditioning
Water-cooled heat exchanging
Night ventilation cooling

Passive ventilation design
Combined space and water heating
air flow management
Heat recovery ventilation systems
Building energy monitors to identify opportunities to reduce wasted energy

Water efficiency:

High efficiency residential and commercial water fixtures
High efficiency irrigation systems
Greywater re-use systems

ii. Reduced transportation demand through:

Telecommuting rather than commute by car
Improved biking infrastructure
Improved pedestrian infrastructure
Improved public transportation
Transportation Demand Management programs that support adoption of low-carbon transportation practices
Improved carpooling and ride-sharing programs and technologies
Urban land use practices to reduce transportation demand (i.e. mixed use development, increased residential densities)

iii. Improved vehicle efficiency through:

Low rolling resistance tires
Lightweight materials (i.e. carbon fiber, aluminum, fiberglass)
Regenerative braking systems
High efficiency settings or dashboard fuel efficiency displays

B. **WWS Electric Power Generators**

Onshore/offshore wind turbines
Solar photovoltaics (PV) for rooftops and power plants
Concentrated Solar Power (CSP) plants
Geothermal power plants for electricity
Tidal turbines
Wave devices
Existing large hydroelectric reservoirs used more efficiently
Small hydroelectric reservoirs
In-stream hydroelectric turbines

C. Low-Temperature Heat Generators

Geothermal heat pumps
Natural geothermal heating
Solar thermal collection devices for heat

D. Electricity Storage

Geothermal

CSP with storage (either molten salt or phase-change material)
Pumped hydroelectric storage
Hydroelectric power plant reservoirs
Batteries

E. Heat Storage Devices
Hot water tanks
Rocks stored underground
Thermal walls

F. Cold Storage Devices
Chilled water tanks
Ice storage

G. Hydrogen Storage Devices
Electrolyzers to produce hydrogen from electricity
Electric compressors to compress hydrogen
Tanks to store hydrogen for transportation primarily

H. Demand Response
Technology to enable remote start up and shut down of appliances and equipment that have flexible demand (i.e. water heaters, HVAC equipment, electric vehicles)
Utilities provide incentives for industry, companies, and individuals to shift their electricity use for certain uses and processes to non-peak times of day or night

I. Electric Vehicles
Light-, medium-, and heavy-duty on-road automobiles
Short-distance trucks, buses trains, ships, aircraft
Motorcycles
Non-road vehicles
Construction equipment
Agricultural equipment
Forklifts

J. Hydrogen Fuel Cell/Electric Hybrid Vehicles
Long-distance trucks
Buses
Trains
Ships
Aircraft
Construction equipment
Agricultural equipment

K. Electric Car Charging Infrastructure

Home car chargers
Chargers installed in parking garages and on streets

L. High-Temperature Industrial Equipment
Electric arc furnaces
Dielectric heaters
Electric induction furnaces

M. Electric Appliances to Replace Gas or Gasoline
Heat pump air and water heaters
Electric induction cooktop stoves
Electric dryers
Electric leaf blowers
Electric lawnmowers
Electric water sprayers
Electric fans

N. Long-Distance Transmission
High-voltage direct-current (HVDC) lines

2. Timelines for Transitioning Individual Sectors

The overall timeline proposed for transitioning to 100% WWS is 80% by 2030 and 100% by 2050. To meet this timeline, rapid transitions are needed in each technology sector. Below is a list of proposed transformation timelines for individual sectors.

Development of super grids and smart grids: As soon as possible, develop long-term power, transmission, and distribution systems to provide "smart" management of energy demand.

Power plants**:** by 2020, no more construction of new coal, nuclear, natural gas, or biomass fired power plants; all new power plants built should be WWS.

Heating, drying, and cooking in the residential and commercial sectors**:** by 2020, all new devices, appliances, and machines should be electric.

Industrial heat**:** by 2023, all new high-temperature heating equipment for industrial applications should be electric.

Large-scale waterborne freight transport**:** by 2020-2025, all new ships should be electrified and/or use electrolytic hydrogen, all new port operations should be electrified, and port retro-electrification should be well underway.

Rail and bus transport**:** by 2025, all new trains and buses should be electrified. This requires changing the supporting energy-delivery infrastructure and the manufacture method of transportation equipment.

***Off-road transport, small-scale marine*:** by 2025 to 2030, all new production should be electrified.

***Long-distance Heavy-duty truck transport*:** by 2025 to 2030, all new heavy-duty trucks and buses should be electric or hydrogen fuel cell-electric hybrids.

Light-duty on-road transport: by 2025-2030, all new light-duty onroad vehicles should be electric.

***Short-haul aircraft*:** by 2035, all new small, short-range aircraft should be electric.

***Long-haul aircraft*:** by 2040, all remaining new aircraft should be hydrogen fuel cell-electric hybrids.

During the transition, conventional fuels and existing WWS technologies are needed to produce the remaining WWS infrastructure. However, much of the conventional energy would be used in any case to produce conventional power plants and automobiles if the plans proposed here were not implemented. Further, as the fraction of WWS energy increases, conventional energy generation will decrease, ultimately to zero, at which point all new WWS devices will be produced with existing WWS. In sum, the creation of WWS infrastructure may result in a temporary increase in emissions before they are ultimately reduced to zero.

References

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