Low-Carbon Pathways Overview

Eileen V. Quigley
January 11, 2018
Agenda

- Overview of Current Energy Systems
- History of Low-Carbon Approaches
- Drawdown Framework
- Overview of Low-Carbon Pathways
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Overview of Current Energy Systems
Global GHG Emissions Trends 1900-2010

Trends in Global Emissions

Global Carbon Emissions from Fossil Fuels, 1900-2014

Global GHG Emissions by Country 2014

2014 Global CO₂ Emissions from Fossil Fuel Combustion and Some Industrial Processes

- China: 30%
- United States: 15%
- EU-28: 9%
- India: 7%
- Russian Federation: 5%
- Japan: 4%
- Other 30%
Buildings 12%
Transport 27%
Agriculture 9%
Electricity 29%
Industry 21%

Agriculture 6%
Electricity 17%
Waste 4%
Transport 46%
Residential & Commercial 10%
Industrial 17%

Washington State Energy Flow Map

Washington Energy Consumption in 2014: ~ 2140 Trillion BTU

Source: LBNL Report, 2016. Data is based on DOE/GOES 2015. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributional electricity represents only retail electricity sales and does not include self-generation. EIA imports consumption of renewable resources (i.e., solar, wind, geothermal, and nuclear) for electricity in Btu-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated at 47% for the residential sector, 65% for the commercial sector, 47% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding.
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History of Low-Carbon Approaches
**Early Recognition of Global Warming**

1827

*Heat Is Trapped*

John Tyndall observes that carbon dioxide and water vapor are greenhouse gases. CO$_2$ in atmosphere = 290 ppm; 1st industrial revolution.

1864

*CO$_2$ a GHG*

Svante Arrhenius publishes the first calculations of how much global warming might be caused by burning coal and releasing carbon into the atmosphere.

1896

*Global Warming*

Charles David Keeling shows that the level of carbon dioxide in the atmosphere is in fact rising. CO$_2$ = 315 ppm.

1960

*CO$_2$ Rising*

A Joint UNEP/WMO/ICSU Conference concludes that greenhouse gases “are expected” to cause significant warming in the next century.

1985

*Consensus Forming*

1990

*1st IPCC report*

1st Intergovernmental Panel on Climate Change PCC report: world is warming; future warming likely.
Carbon Emissions Mitigation Efforts

1992
- First international effort create a treaty to stabilize GHG emissions
- U.N. Earth Summit Rio
- Romm/Lovins

1997
- Kyoto Protocol
- 80% of 1990 levels by 2050
- Stabilization Wedges
- 2004

2004
- RGGI & California AB 32 passed

2005-06
- McKinsey Abatement Curve

2007
- CA & US Low-Carbon/ DDP models

2014-15

2015-16
- Models and studies released
- National deep decarbonization studies; low-carbon pathways and low carbon grid studies for California; Jacobsen’s 100% Wind, Water, Sun promise

2016-17
- Paris Accord
- Commitment to hold to 2°C; aspiration to hold to 1.5°C.
- Trump Administration
- Radical about-face with appointments of pro-fossil fuel administrators Perry (DOE); Pruitt (EPA); and Zinke (Interior)

2020
- Drawdown effort
- by Paul Hawken and Amanda Joy Ravenhill, et al., released

First international effort create a treaty to stabilize GHG emissions

Amory Lovins and Joe Romm article in Foreign Policy, “Fueling a Competitive Economy”

Seattle Mayor Greg Nickels launches effort in wake of U.S. failure to adopt Kyoto Protocol cities and states start setting reduction targets

Princeton researcher Stephen Pacala and Robert H. Socolow release first iteration of their climate mitigation wedges

Regional Greenhouse Gas Initiative & AB 32 in California
- 9 states in New England first C & T for power sector;
- CA passes first-in-the-nation, watershed legislation requiring 30% by 2020 GHG reduction.

Drawdown Framework
- 2016-17

RGGI & California AB 32 passed
- 2004
Stabilization Wedges

- **16 GtC/y**
- Eight “wedges”
- Goal: In 50 years, same global emissions as today

Billions of Tons Carbon Emitted per Year

- Historical emissions
- Flat path

Years: 1950, 2000, 2050, 2100

- 16 GtC/y
- Eight “wedges”
- Historical emissions
- Flat path
K4C Achieving 50 X 30 Reductions

Federal Fuel Economy
State RPS
State Energy Code
15% Cleaner Vehicles
20% VMT Reduction
25% Reduction in Building Energy Use
20% Increase in Renewable Electricity, No More Coal, and Limited New Natural Gas for Electricity

50% Carbon Reduction by 2030
Climate Mitigation Cost Abatement Curve

What might it cost?

Global cost curve for greenhouse gas abatement measures beyond “business as usual”; greenhouse gases measured in GtCO₂e.

- Carbon capture and storage (CCS); new coal
- Medium-cost forestation
- Co-firing biomass
- Wind; low penetration
- Industrial feedstock substitution
- CCS, enhanced oil recovery, new coal
- Low-cost forestation
- Livestock
- Nuclear
- Industrial non CO₂
- Standby leases
- Sugarcane biofuel
- Fuel efficiency in vehicles
- Water heating, air-conditioning, lighting systems
- Fuel efficiency in commercial vehicles
- Building insulation

Abatement beyond “business as usual,” GtCO₂e per year in 2030

- Approximate abatement required beyond “business as usual,” 2030

- Higher cost abatement

Marginal cost, $/tCO₂e

1 GtCO₂e = gigatons of carbon dioxide equivalent; “business as usual” based on emissions growth driven mainly by increasing demand for energy and transport around the world and by tropical deforestation.

2 CO₂e = ton of carbon dioxide equivalent.

3 Measures costing more than $40 a ton were not the focus of this study.

4 Atmospheric concentration of all greenhouse gases recalculated into CO₂ equivalents; ppm = parts per million.

5 Marginal cost of avoiding emissions of 1 ton of CO₂ equivalent in each abatement demand scenario.
A global carbon law and roadmap to make Paris goals a reality

Decarbonization pathway consistent with the Paris agreement

- Limiting warming below 2°C with 66% probability
- Limiting warming below 1.5°C with 50% probability

Anthropogenic CO₂ emissions (gross)
- Fossil fuel and industry
- Land use and land-use change

Anthropogenic CO₂ removals
- Land use and land-use change
- Engineering CO₂ sink (BECCS)

Biosphere carbon sink
- Land carbon sink
- Ocean carbon sink

Whiskers on total natural sinks: the 90% range of modeled uncertainties.
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Drawdown Framework
What is Drawdown?

- The point in time when the concentration of greenhouse gases in the atmosphere begins to decline on a year-to-year basis
- Meticulous research that maps, measures, models, and describes the most substantive solutions to global warming
- Modeled atmospheric and financial impacts of deploying and scaling existing solutions globally over the next 30 years
Drawdown Framework

- Book released in 2016—most comprehensive plan ever produced to reverse global warming in 30 years
- Inclusive presenting extensive array of impactful measures
- 100 “no regrets” solutions that make sense regardless of climate
- Each modeled to determine carbon impact through 2050, total and net cost to society
## Drawdown Top Ten Solutions

<table>
<thead>
<tr>
<th>Rank</th>
<th>Solution</th>
<th>Sector</th>
<th>Total Atmospheric CO2-EQ Reduction (GT)</th>
<th>Net Cost (Billions US $)</th>
<th>Savings (Billions US $)</th>
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<tr>
<td>1</td>
<td>Refrigerant Management</td>
<td>Materials</td>
<td>89.74</td>
<td>N/A</td>
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<td>2</td>
<td>Wind Turbines (Onshore)</td>
<td>Electricity Generation</td>
<td>84.60</td>
<td>$1,225.37</td>
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<td>3</td>
<td>Reduced Food Waste</td>
<td>Food</td>
<td>70.53</td>
<td>N/A</td>
<td>N/A</td>
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<td>4</td>
<td>Plant-Rich Diet</td>
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<td>66.11</td>
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<td>5</td>
<td>Tropical Forests</td>
<td>Land Use</td>
<td>61.23</td>
<td>N/A</td>
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<td>6</td>
<td>Educating Girls</td>
<td>Women and Girls</td>
<td>59.60</td>
<td>N/A</td>
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<td>7</td>
<td>Family Planning</td>
<td>Women and Girls</td>
<td>59.60</td>
<td>N/A</td>
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<td>8</td>
<td>Solar Farms</td>
<td>Electricity Generation</td>
<td>36.90</td>
<td>$-80.60</td>
<td>5,023.84</td>
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<td>9</td>
<td>Silvopasture</td>
<td>Food</td>
<td>31.19</td>
<td>$41.59</td>
<td>699.37</td>
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<td>Rooftop Solar</td>
<td>Electricity Generation</td>
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<td>$453.14</td>
<td>3,457.63</td>
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# The Periodic Table of Profitable Climate Solutions

* = Ryan Original Films shooting episode featuring profitable climate solution companies. More here 12Climatesolutions.com

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<th>Priority</th>
<th>Symbol</th>
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<td>Ws</td>
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<td>I</td>
<td>Iodine 0.70</td>
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<td>2</td>
<td>Xe</td>
<td>Xenon 0.60</td>
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<tr>
<td>1</td>
<td>He</td>
<td>Helium 0.50</td>
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</tbody>
</table>

## Contacts

**Contact the Author**

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## Uses

- Food
- Transport
- Women & Girls
- Materials
- Land Use
- Buildings & Cities
- Electricity and Generation

## Credits & Mentions

- PROJECT MANAGEMENT is the source of data for the prioritization of climate initiatives and amount of carbon saved. [http://www.projectmanagement.org](http://www.projectmanagement.org)
- THE GLOBAL CANNON PROJECT is the largest carbon emission reduction program in the world. [http://www.globalcannonproject.org](http://www.globalcannonproject.org)
- FCHI (First Grows on Climate-Related Financial Disclosures) for their work on climate-related financial disclosures across governments, strategies, risk management and metrics & targets to reduce their vulnerability to the transition to a lower carbon economy.
- CANNON TRACKER for their work on alignment of capital market actions with climate reality, including calculation of the total carbon budget for the oil and gas sector. [https://www.carbontracker.org](https://www.carbontracker.org)
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Overview of Low-Carbon Pathways
Decarbonization Guidelines

- Major reduction in greenhouse gas emissions
- Comprehensive changes in energy sourcing
- Rethinking forest and agricultural systems management
- Major focus on how we live and move in urban areas
- Must address consumption and waste
Deep Decarbonization Pathways

- Conservation & Efficiency
- Decarbonization
- Fuel-Shifting
- Waste Reduction
- Emission Sequestration
- Methane Emission Reduction
- Carbon Capture and Sequestration
Six Sectors to Decarbonize

- Energy supply
- Transportation (air, marine, fleet, freight)
- Residential and commercial
- Industrial (manufacturing, construction, agriculture energy transformation, mining)
- Agriculture and waste
- Land use and forestry
Electricity Sector

▪ Ramp up energy efficiency to decrease energy required; stretch existing resources; obviate the need for new fossil fuel supplies

▪ New utility business models to transform utilities and power markets to incentivize decarbonization

▪ Decarbonize the electricity sector; replace coal and natural gas with renewables

▪ Modernize the grid to integrate renewables and storage
Transportation Sector

- Vastly improve fuel and engine efficiencies
- Electrify as many transportation uses as possible with an increasingly clean grid
- Reduce vehicle miles traveled
- Fuel-switch to replace petroleum-based fuels with as many low- or no-carbon alternatives as possible
Residential and Commercial Sectors

- Deep energy efficiency, and energy conservation
- Fuel-switching from oil or natural gas for space and water heating to clean electricity; onsite renewables
- Energy storage in buildings in electric vehicles batteries parked onsite
- Buildings to produce energy
Industrial Sector

- Deep energy efficiency, and energy conservation
- Fuel-switching from oil or natural gas for industrial processes to clean electricity; onsite renewables
- Onsite energy management such as combined heat and power plants to capture and reuse waste heat
Agriculture and Waste Sectors

- Reducing harmful methane emissions from land, agriculture, and animals
- Decreasing nitrogen in fertilizers
- Increasing nutrients in carbon-capturing soil
- Developing processed that convert manure to energy to power farm operations
- Electrifying farm equipment and using onsite renewable energy generation
Land Use and Forestry Sectors

- Maintain/increase forests as critical carbon sinks
- Curtail logging
- End deforestation, esp. for development; reforestation and afforestation essential
- Increase carbon sequestration potential of lands and natural areas in urban areas for carbon-capturing and heat-cooling
Low-Carbon Pathways

- Efficiency & Conservation
- Fuel-Switching
- Decarbonizing Electricity
- Decarbonizing Liquid & Gas Fuels

➢ All applied to all sectors
Four ‘Pillars’ of GHG Mitigation

1. Efficiency and Conservation
   - Energy use per capita (MMBtu/person)

2. Fuel switching
   - Share of electricity & H₂ in total final energy (%)

3. Decarbonize electricity
   - Emissions intensity (tCO₂e/MWh)

4. Decarbonize fuels (liquid & gas)
   - Emissions intensity (tCO₂/EJ)

* Example from California PATHWAYS results
U. S. Mid-Century Strategy

- Paris agreement in December 2015: Parties agree to achieve net-zero global emissions in 2\textsuperscript{nd} half of century
- Countries submit near-term targets called “nationally determined contributions” NDCs
- Develop a “mid-century, long-term low greenhouse gas emission development strategies”
U. S. Mid-Century Strategy

- **Low carbon energy system**: cutting energy waste; decarbonize electricity; deploy clean electricity, and low-carbon fuels in transportation, buildings, and industrial sectors.

- **Sequestering carbon**: forests, soils ("land sinks") + CO₂ removal carbon beneficial bioenergy with carbon capture and storage (BECCS).

- **Reducing non-CO₂ emissions**: methane, nitrous oxide, fluorinated gases.
Summary

- Exceptionally complex and dynamic
- Considerable activity globally, regionally, and locally in the absence of nationally in the U.S.
- We will dig deeply into an economy-wide pathways roadmap approach for the Northwest
Thank you

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Transitioning from Fossil Fuel to Clean Energy

www.cleanenergytransition.net