Low-Carbon Pathways Overview

Eileen V. Quigley
January 11, 2018

Clean Energy Transition

Agenda

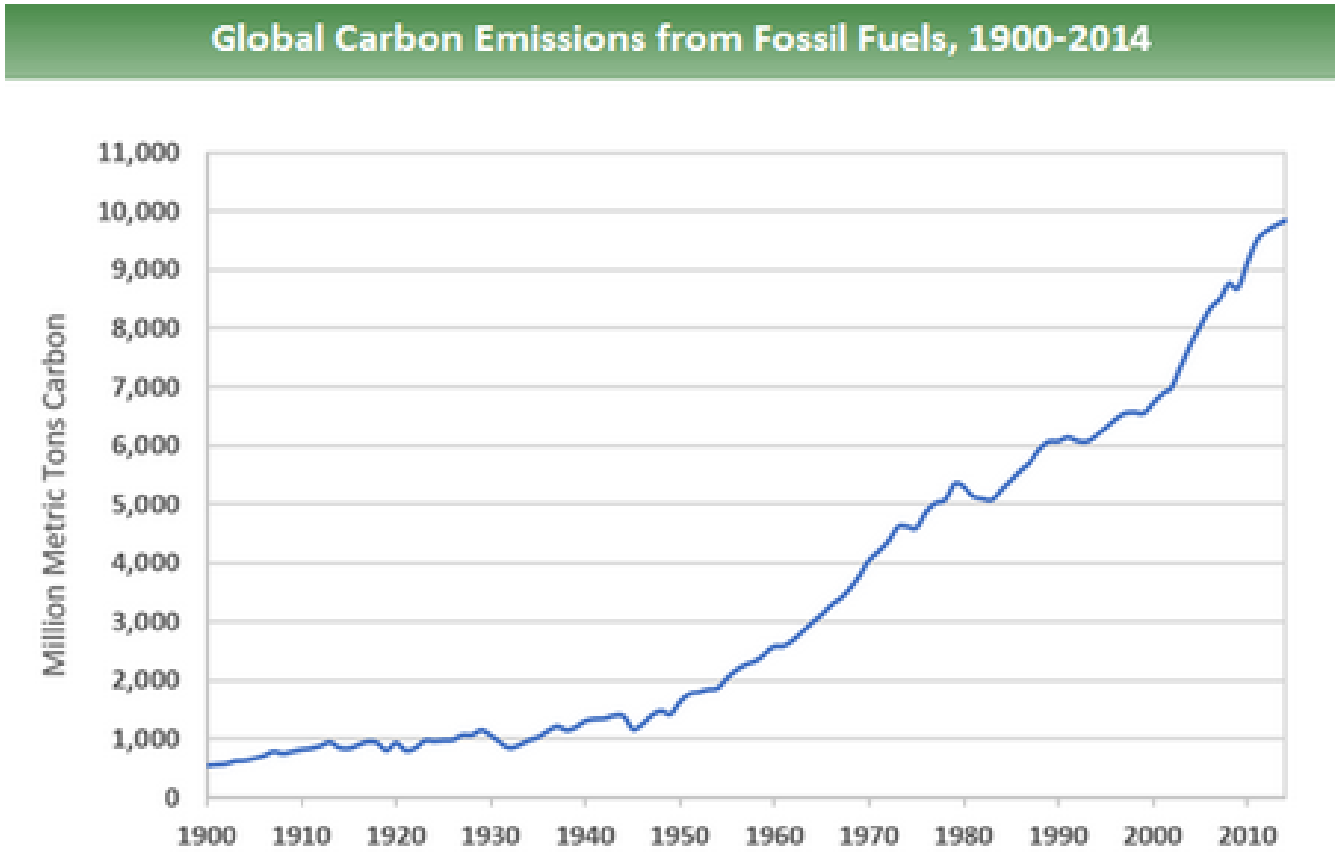
- Overview of Current Energy Systems
- History of Low-Carbon Approaches
- Drawdown Framework
- Overview of Low-Carbon Pathways

Agenda

Overview of Current Energy Systems

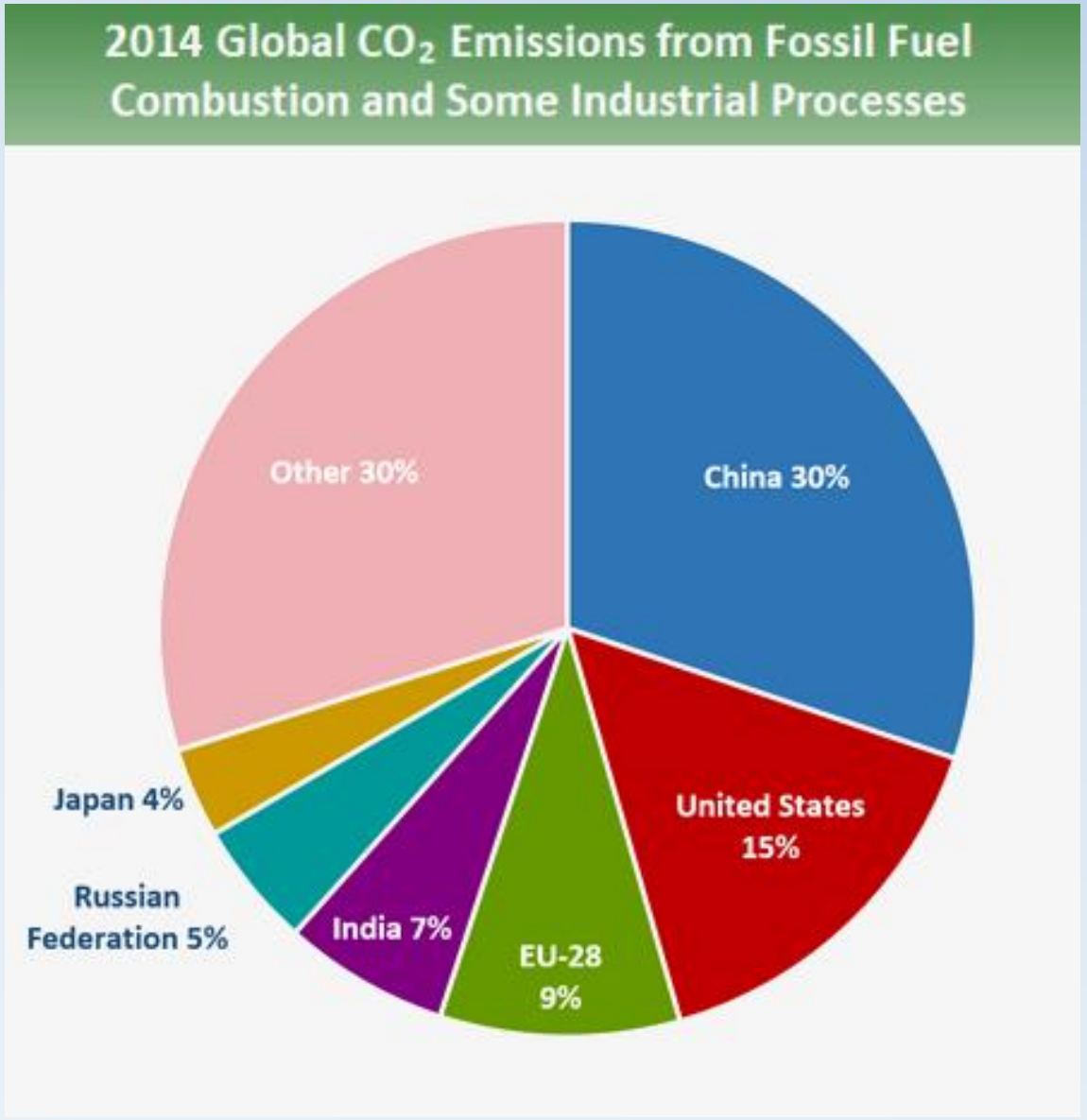
Global GHG Emissions Trends 1900-2010

Trends in Global Emissions

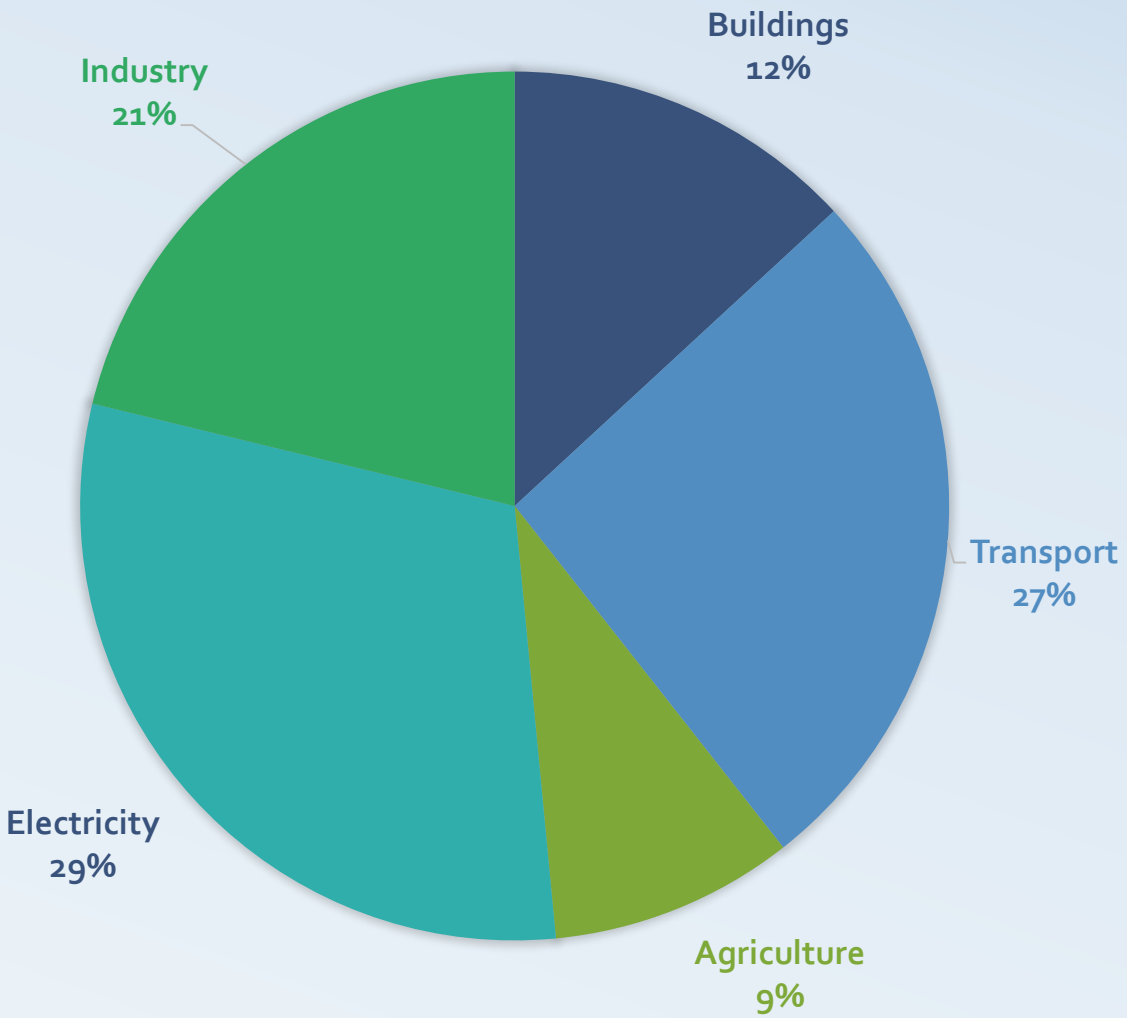


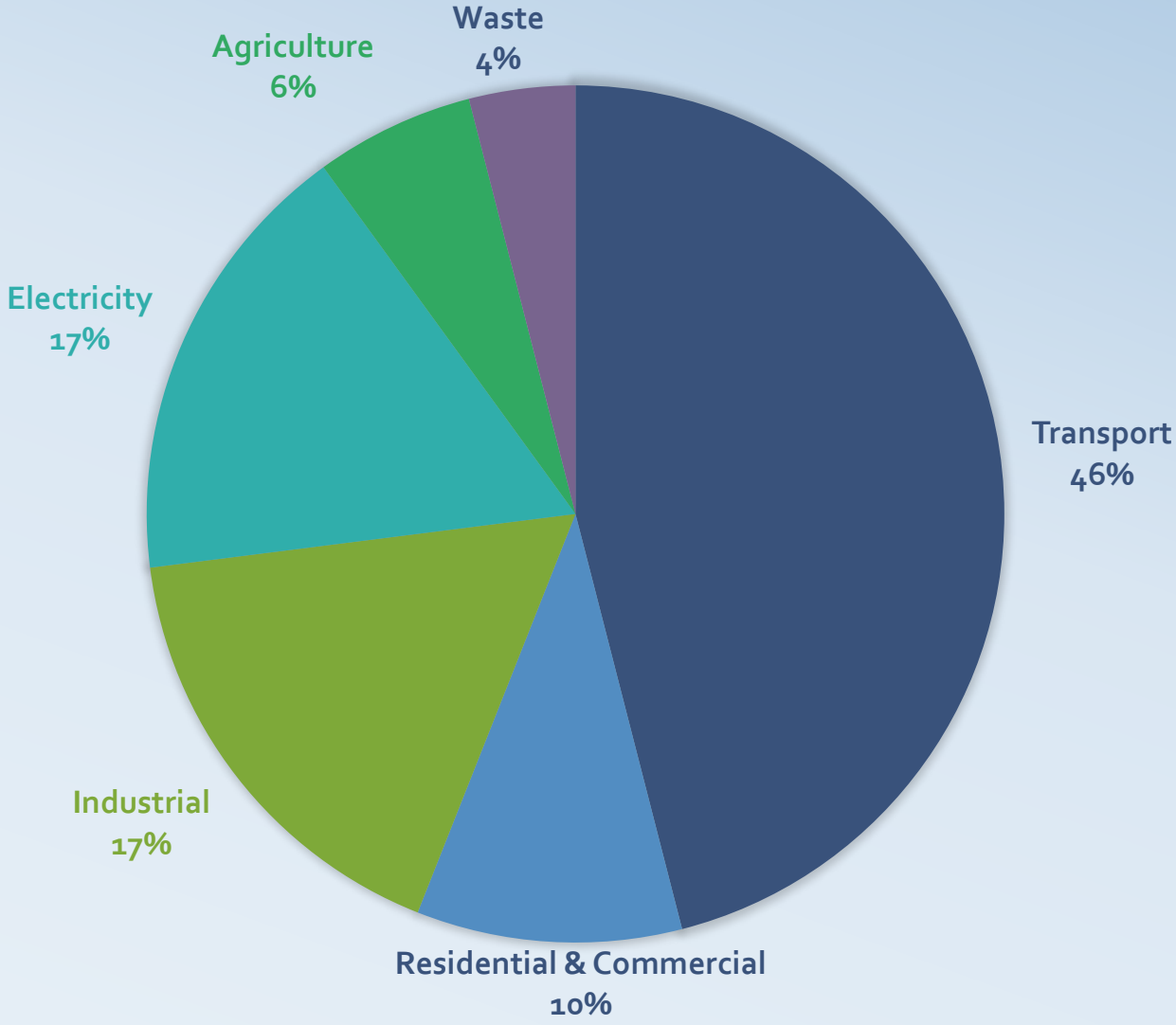
Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO2Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2017.

Global GHG Emissions by Country 2014

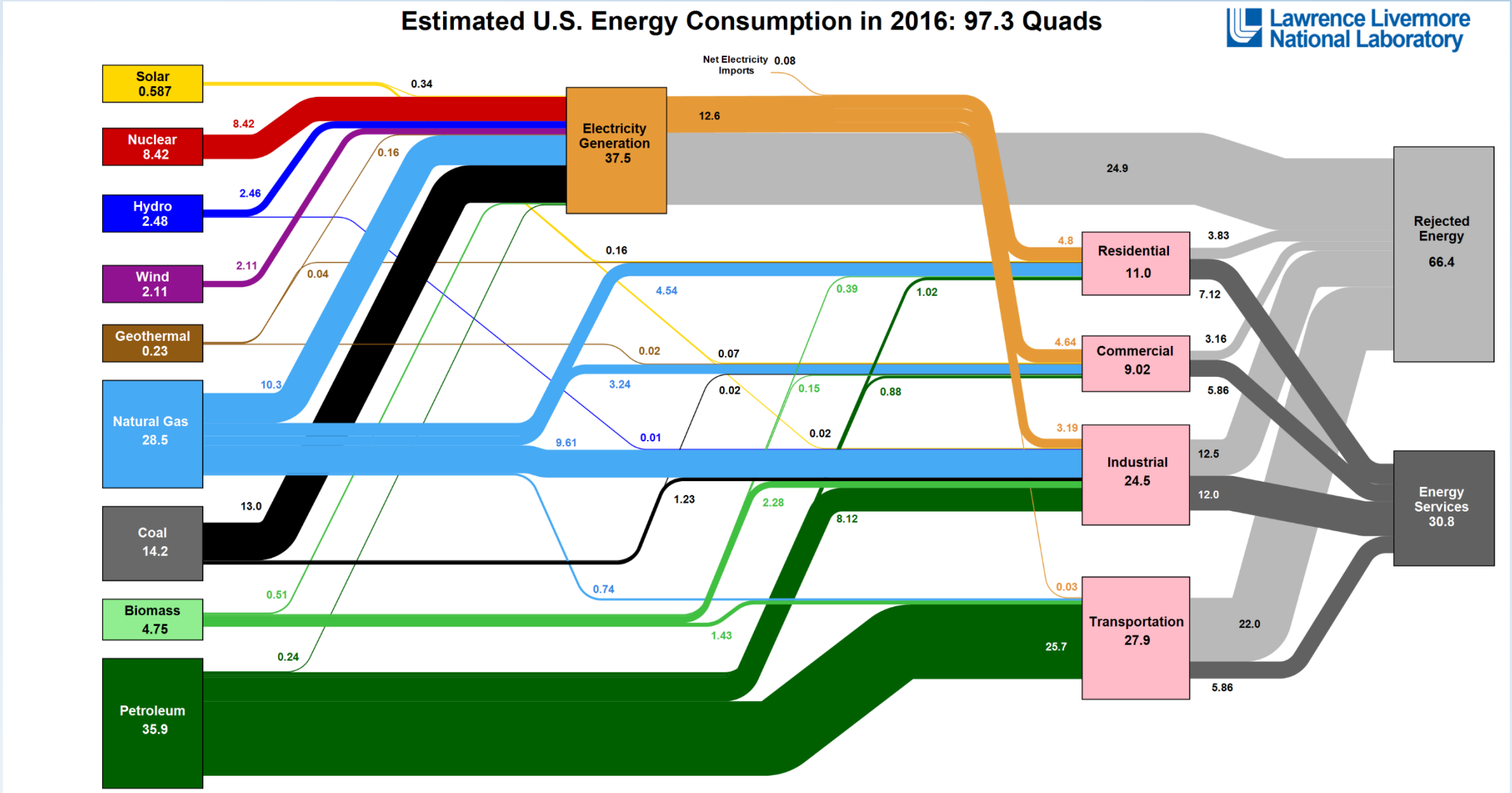


U.S. (2014) & Washington (2011)

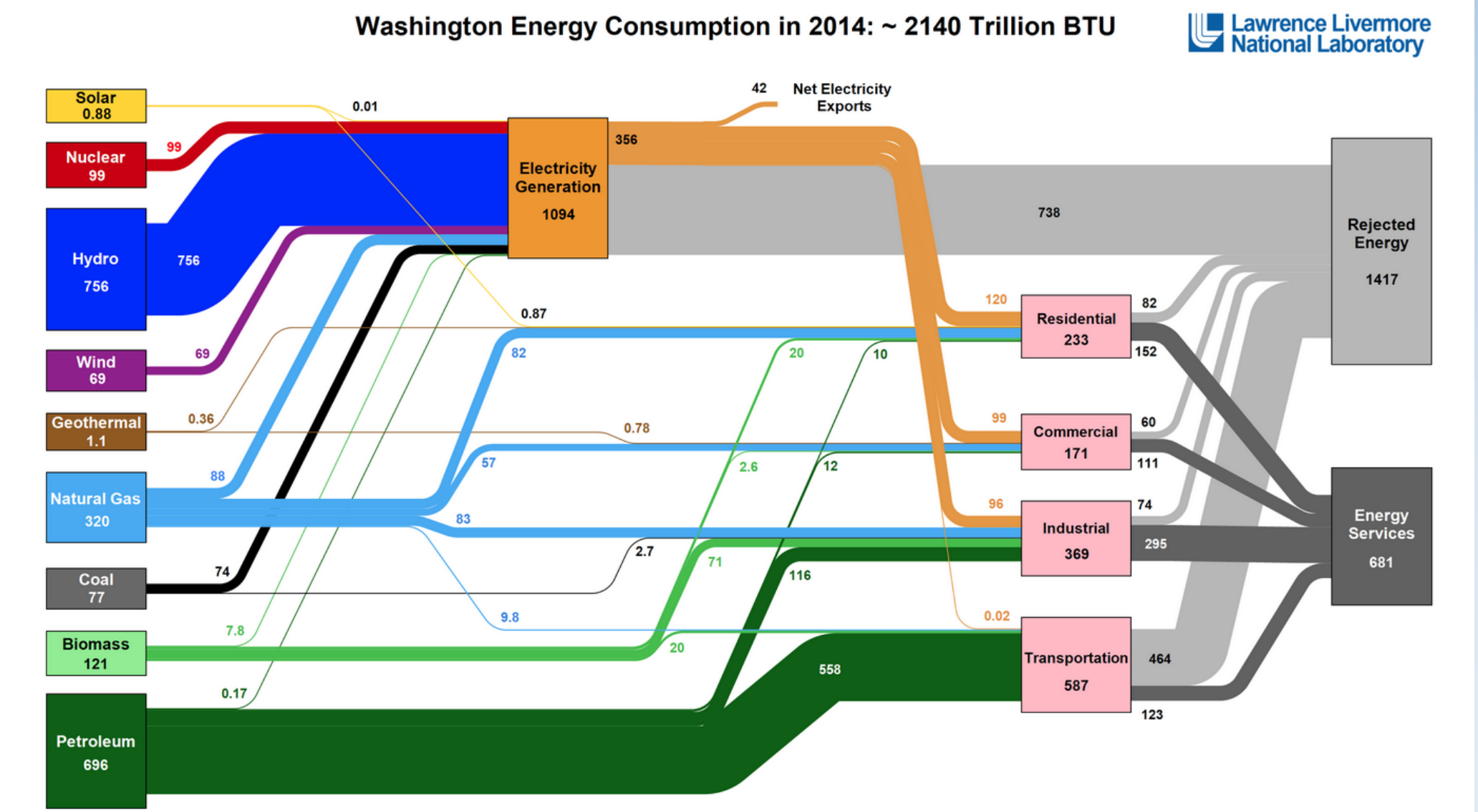




U.S. Energy Flow Map



Washington State Energy Flow Map



Source: LLNL August, 2016. Data is based on DOE/EIA SEDS (2014). 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. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) 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 as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527

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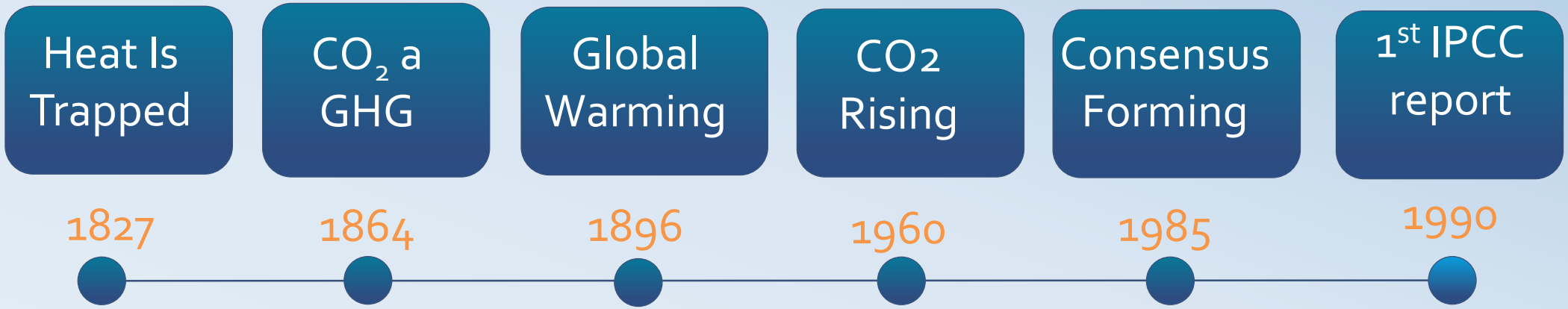
History of Low-Carbon Approaches

Early Recognition of Global Warming



Joseph Fourier observes the trapping of heat by the atmosphere

John Tyndall observes that carbon dioxide and water vapor are greenhouse gases. CO_2 in atmosphere =290 ppm; 1st industrial revolution

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

Charles David Keeling shows that the level of carbon dioxide in the atmosphere is in fact rising. CO_2= 315 ppm

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

1st Intergovernmental Panel on Climate Change PCC report world is warming; future warming likely.

Carbon Emissions Mitigation Efforts

U.N. Earth Summit Rio Romm/Lovins
1992

First international effort create a treaty to stabilize GHG

Amory Lovins and Joe Romm article in *Foreign Policy*, "Fueling a Competitive Economy"

Kyoto Protocol 80% of 1990 levels by 2050
1997

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

Stabilization Wedges
2004

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

RGGI & California AB 32 passed
2005-06

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.

McKinsey Abatement Curve
2007

McKinsey & Co. release first GHG marginal abatement curve in February 2007 ; updated in 2009, 2010

CA & US Low-Carbon/ DDP models
2014-15

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

U.N. COP 21 Paris/ U.S. Mid-Century Strategy
2015-16

Paris Accord Commitment to hold to2° C; aspiration to hold to 1.5° C.

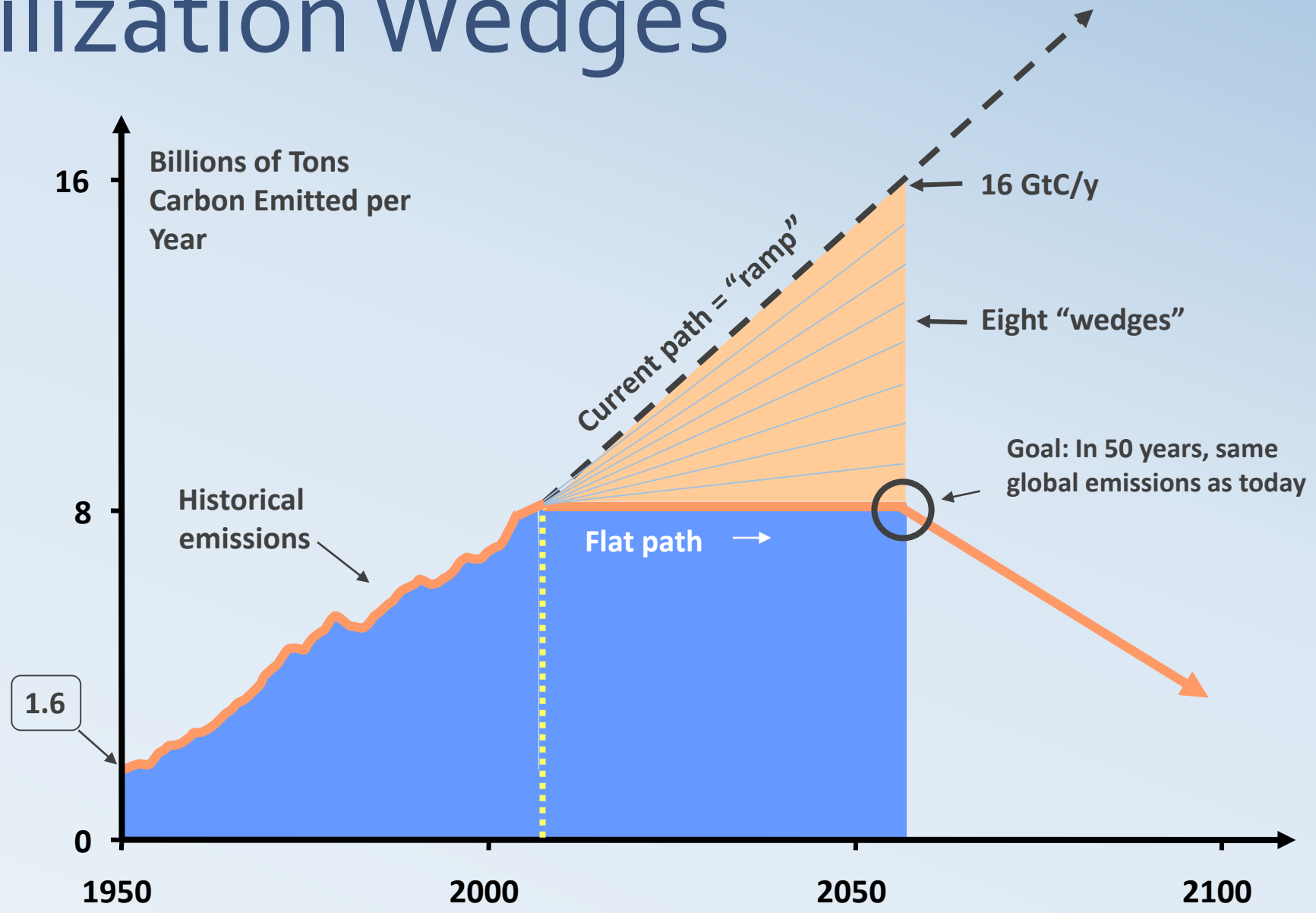
Obama Administration releases Mid-Century Strategy for Deep Decarbonization November 2016

Election of Donald Trump Drawdown Framework
2016-17

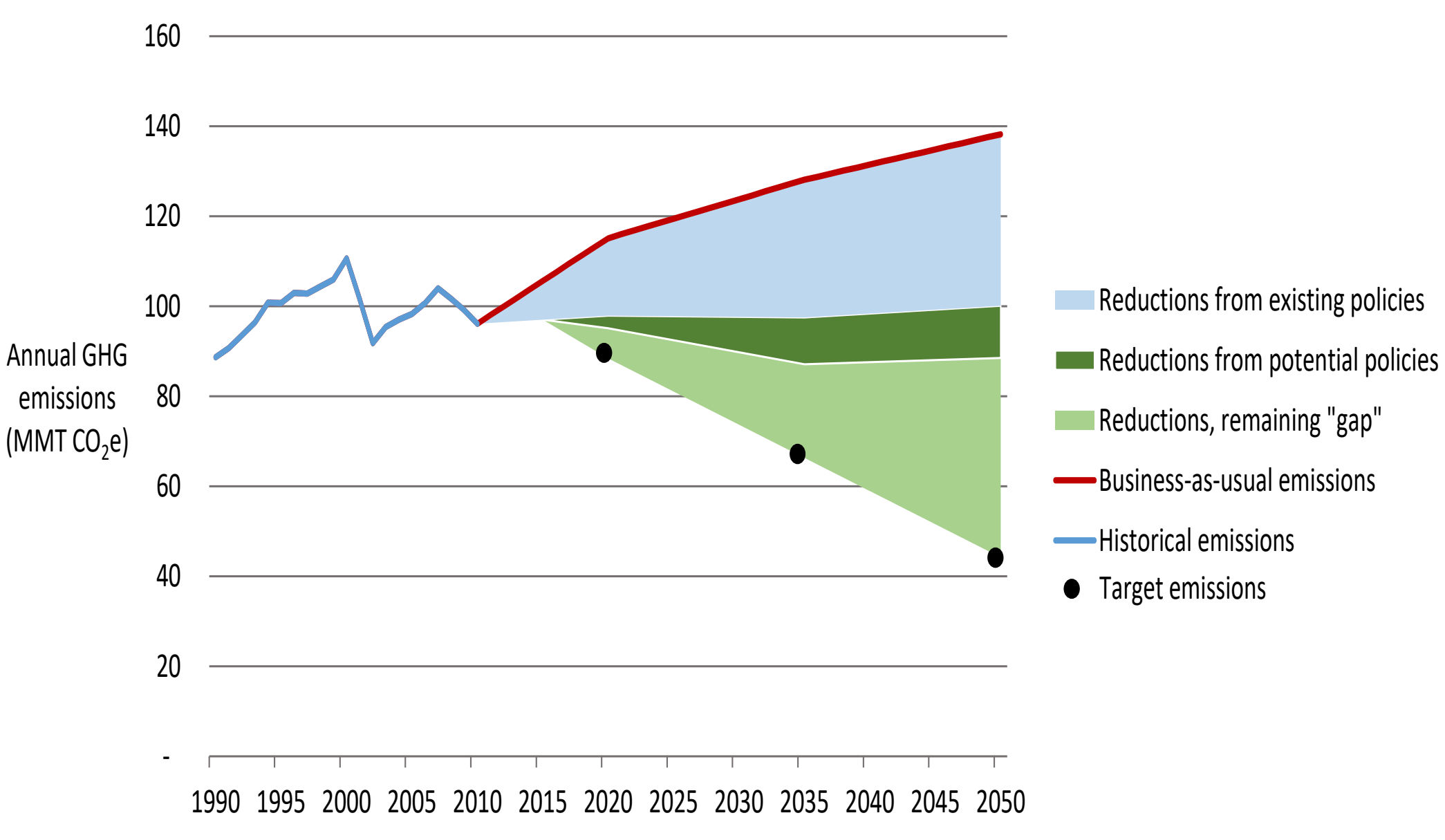
Trump Administration Radical about-face with appointments of pro-fossil fuel administrators Perry (DOE); Pruitt (EPA); and Zinke (Interior)

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

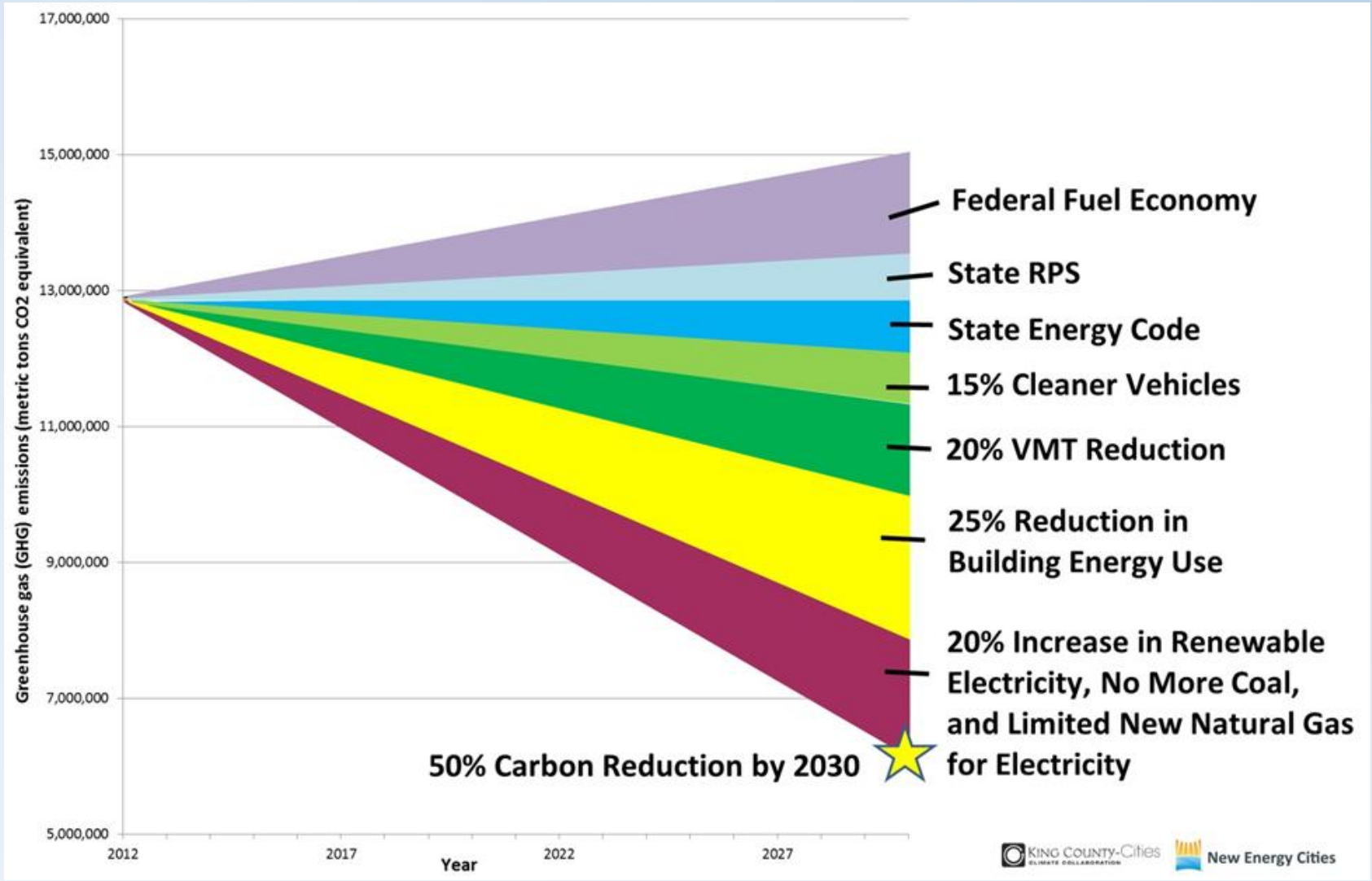
Stabilization Wedges



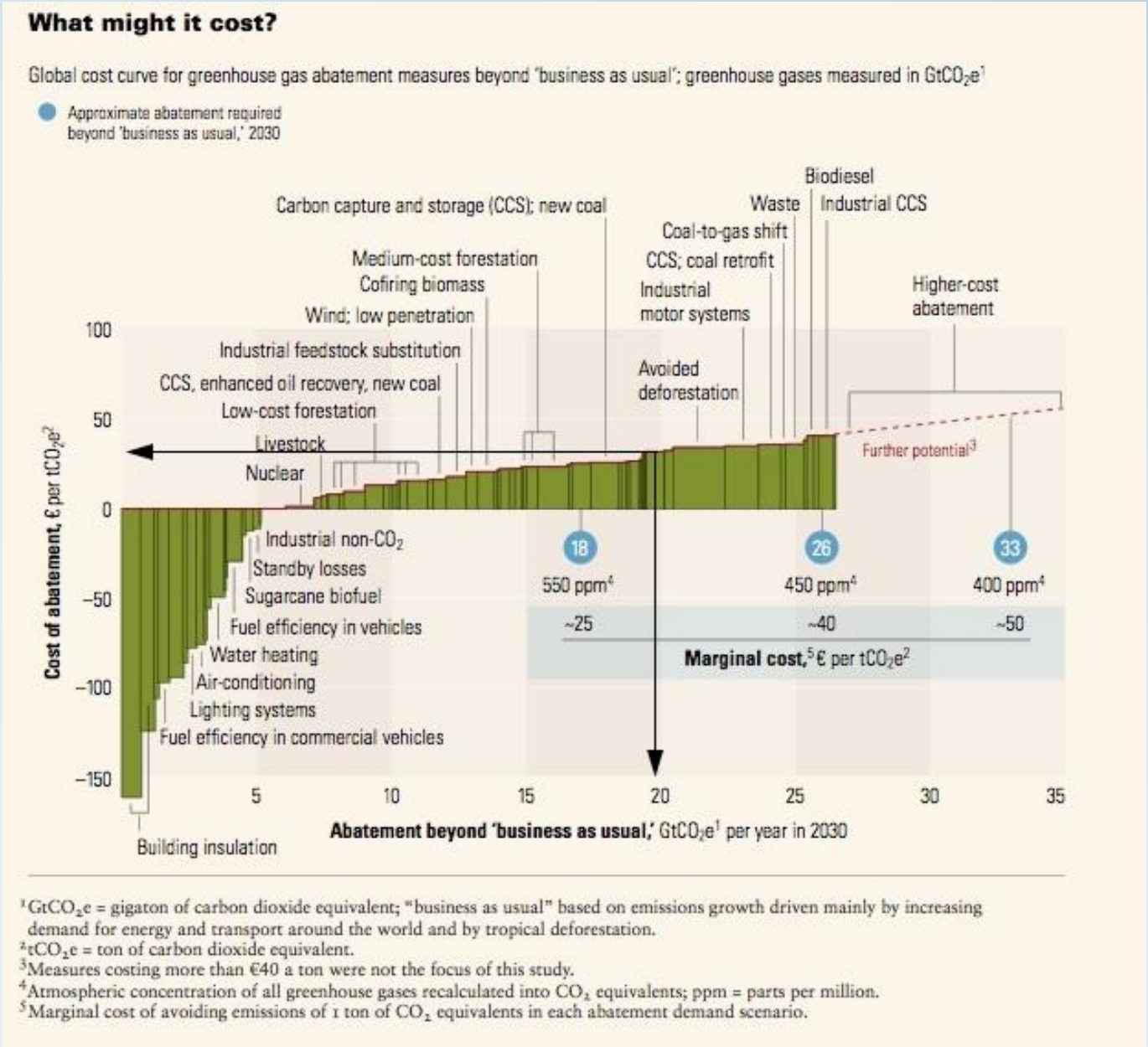
Washington Historical GHG Emissions, BAU Projection, & Emissions Targets



K4C Achieving 50 X 30 Reductions

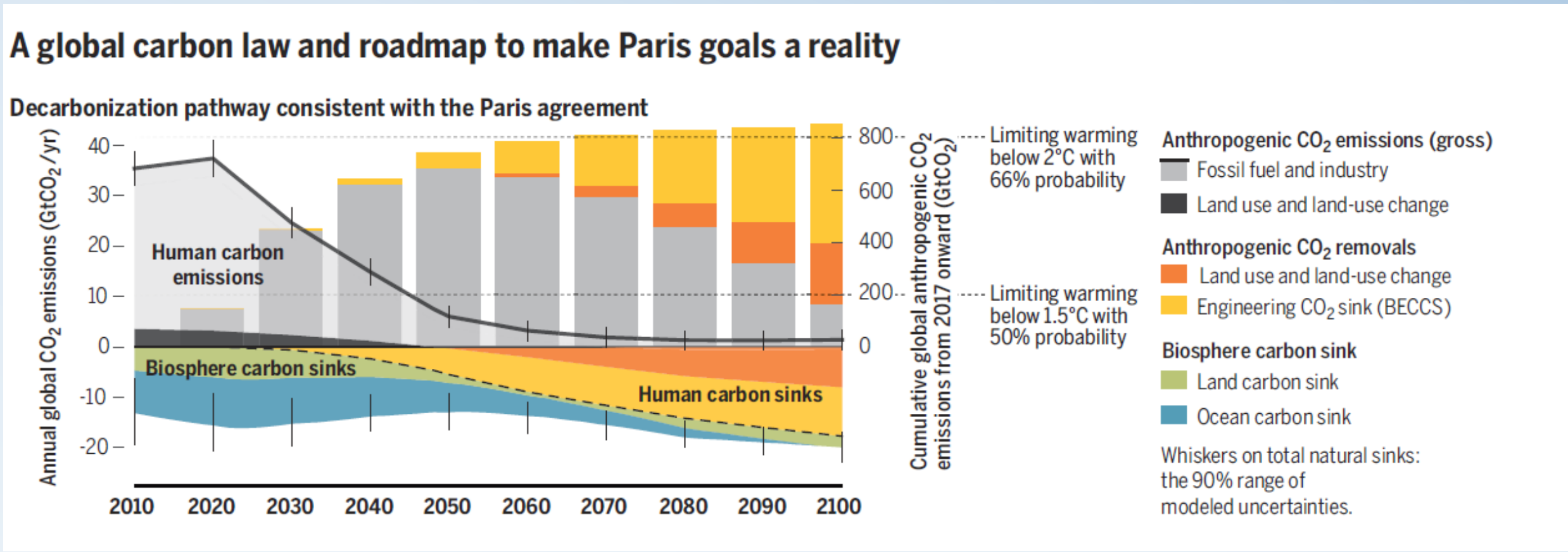


Climate Mitigation Cost Abatement Curve

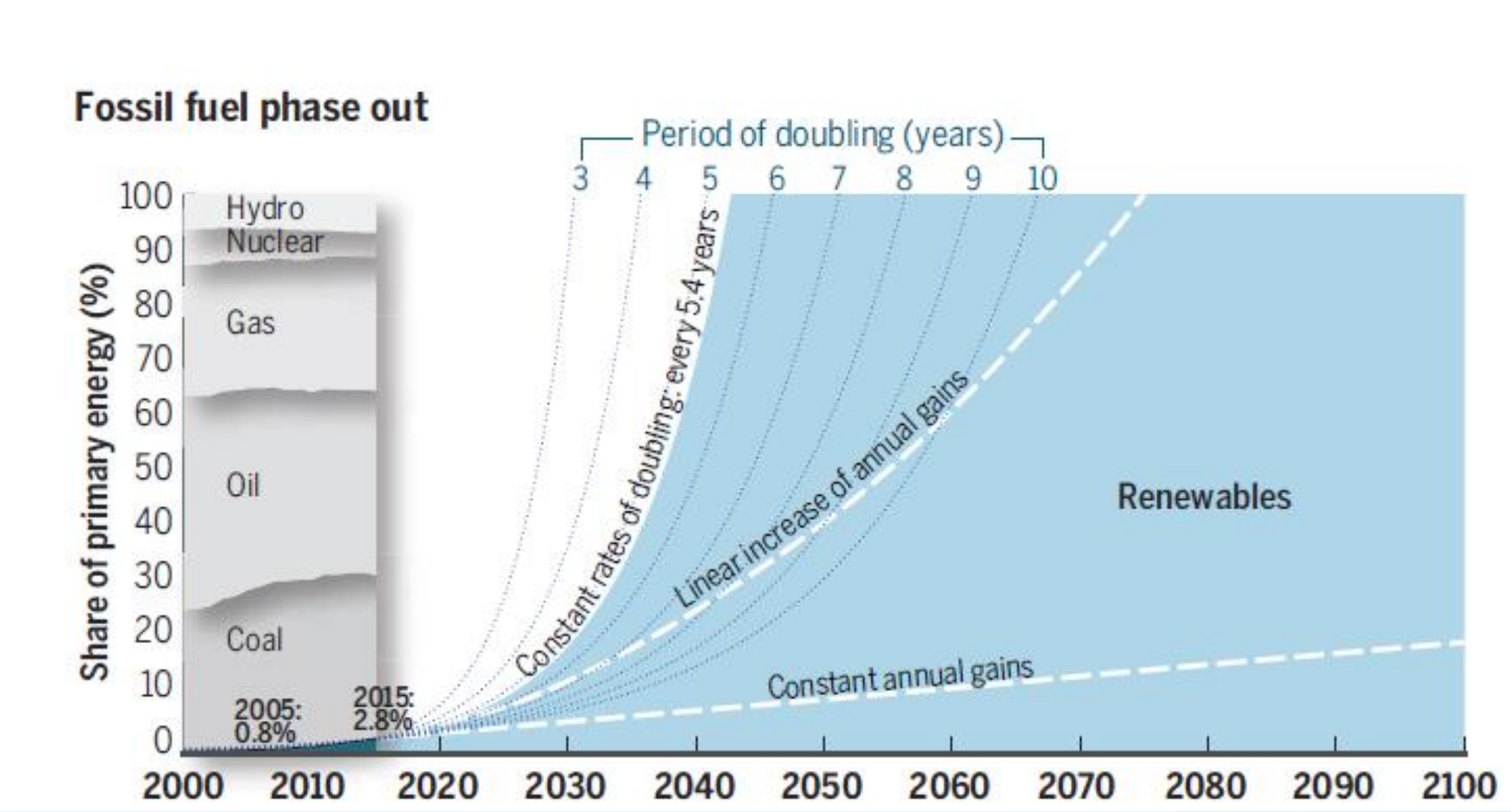


[1] $GtCO_2e$ = gigaton of carbon dioxide equivalent; "business as usual" based on emissions growth driven mainly by increasing demand for energy and transport around the world and by tropical deforestation.
[2] tCO_2e = ton of carbon dioxide equivalent.
[3] Measures costing more than €40 a ton were not the focus of this study.
[4] Atmospheric concentration of all greenhouse gases recalculated into CO_2 equivalents; ppm = parts per million.
[5] Marginal cost of avoiding emissions of 1 ton of CO_2 equivalents in each abatement demand scenario.

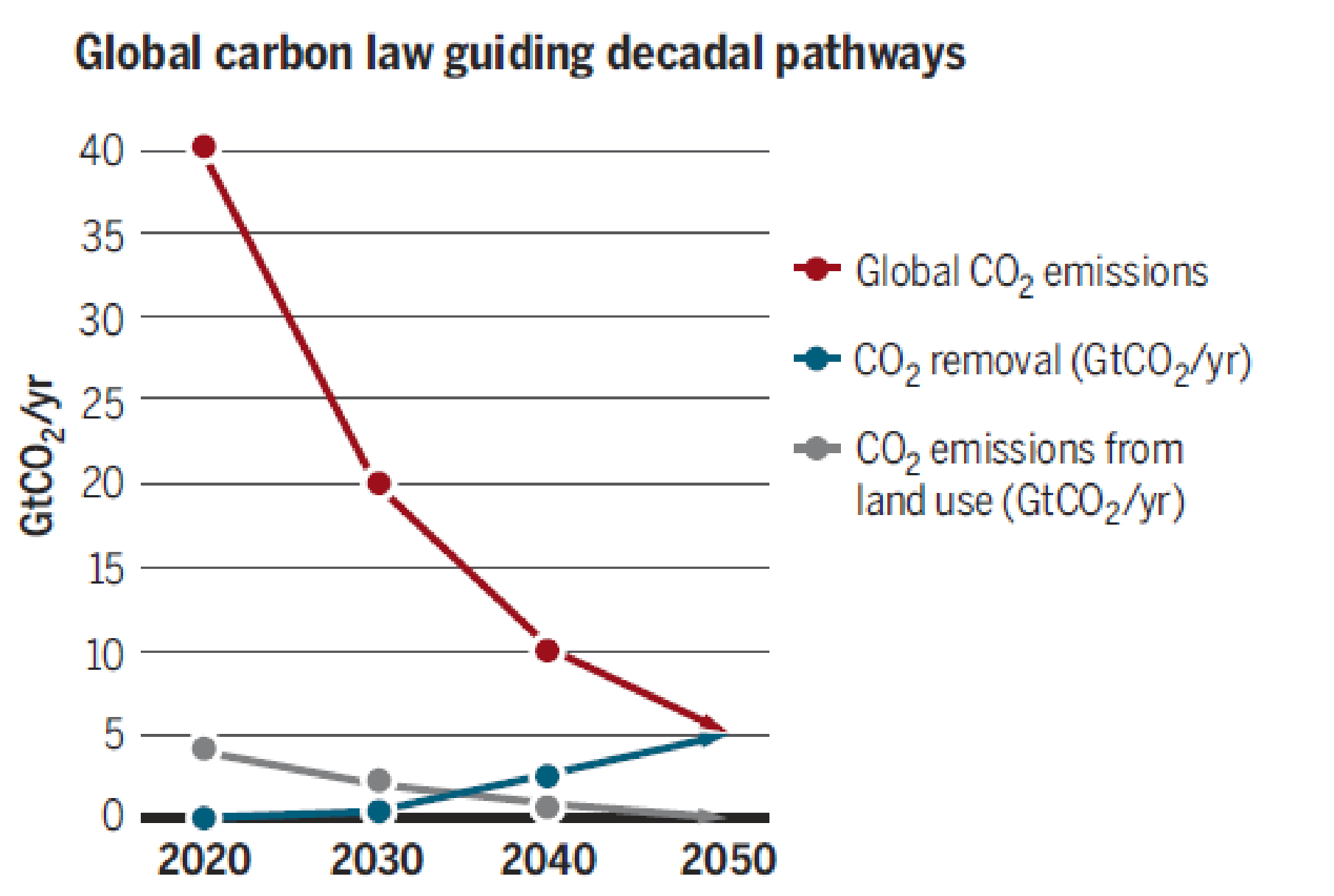
Roadmap to Paris-Global Carbon Law



Fossil Fuel Phase-Out



Global Carbon Law-Decadal Pathways



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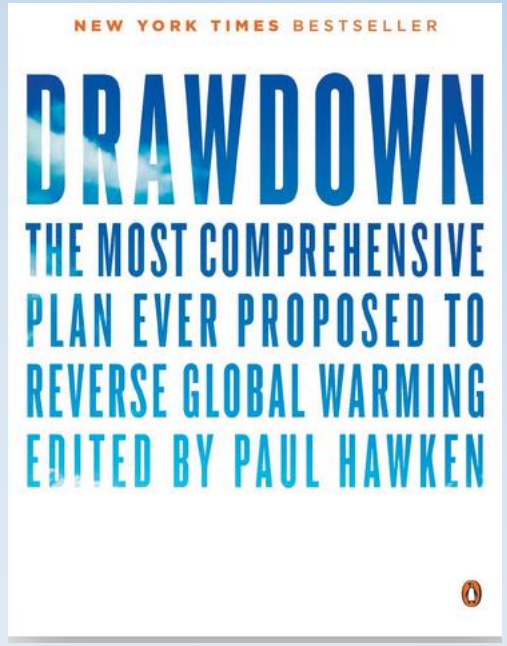
Drawdown Framework

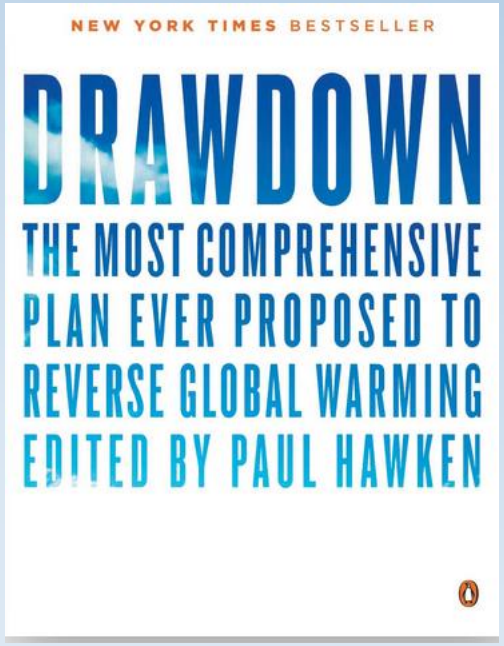
What is Drawdown?

- 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

Rank	Solution	Sector	TOTAL ATMOSPHERIC CO2-EQ REDUCTION (GT)	NET COST (BILLIONS US $)	SAVINGS (BILLIONS US $)
1	**Refrigerant Management**	Materials	89.74	N/A	$-902.77
2	**Wind Turbines (Onshore)**	Electricity Generation	84.60	$1,225.37	$7,425.00
3	**Reduced Food Waste**	Food	70.53	N/A	N/A
4	**Plant-Rich Diet**	Food	66.11	N/A	N/A
5	**Tropical Forests**	Land Use	61.23	N/A	N/A
6	**Educating Girls**	Women and Girls	59.60	N/A	N/A
7	**Family Planning**	Women and Girls	59.60	N/A	N/A
8	**Solar Farms**	Electricity Generation	36.90	$-80.60	$5,023.84
9	**Silvopasture**	Food	31.19	$41.59	$699.37
10	**Rooftop Solar**	Electricity Generation	24.60	$453.14	$3,457.63

The Periodic Table of Profitable Climate Solutions

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

Contact the Author Insta / Fb / Tw @ryan2dotzero ryan@ryanjennings.net

Priority — 43 — Featured (12climatesolutions.com) — * — Symbol — Ap — Name — Airplanes — CO2 Saved (Gigatons) — 5.05

Priority	Symbol	Name	CO2 Saved	Featured
6	E	Educating Girls	59.6	*
7	F	Family Planning	59.6	
62	Ws	Women Smallholders	2.06	
1	Rm	Refrigerant Mgmt	89.4	*
5	T	Tropical Forests	61.23	*
3	R	Reduced Food Waste	70.53	
4	P	Plant Rich Diet	66.11	*
36	Ac	Alternative Cement	6.69	
12	Te	Temperate Forests	22.61	
9	S	Silvopasture	31.19	
11	Ra	Regenerative Agriculture	23.15	*
14	Tt	Tropical Staple Trees	20.19	
46	Ws	Water Saving - Home	4.61	
13	Pl	Peatlands	21.57	
2	W	Wind Turbines Onshore	84.60	*
8	Sf	Solar Farms	36.9	
18	G	Geothermal	16.6	
20	N	Nuclear	16.09	
29	Wa	Wave & Tidal	9.2	
48	H	Hydro	4.0	
50	Co	Cogeneration	3.97	
76	Mw	Micro wind	0.2	
77	Ed	Energy Storage Distributed	N/A	
82	Gf	Grid Flexibility	N/A	
16	Ca	Conservation Agriculture	17.35	
17	Ti	Tree Intercropping	17.20	
53	Ri	System of Rice Intensification	3.13	
47	B	Bioplastic	4.30	
15	A	Afforestation	18.06	*
39	Im	Indigenous People Land Management	6.19	
10	Rs	Rooftop Solar	24.6	*
41	Sw	Solar Water	6.08	
22	Wo	Wind Turbines Offshore	14.10	
30	Md	Methane Digesters	8.4	
34	Bm	Biomass	7.5	
64	Ms	Methane Digesters Small	1.9	*
68	We	Waste to Energy	1.1	
81	Eu	Energy Storage Utilities	N/A	
78	M	Microgrids	N/A	
19	Mg	Managed Grazing	16.34	
21	Cc	Clean Cookstoves	15.81	*
23	Fr	Farmland Restoration	14.08	
55	Hr	Household Recycling	2.77	
35	Bo	Bamboo	7.22	
51	Pb	Perennial Biomass	3.33	
25	Cs	Concentrated Solar	10.9	
27	Dh	District Heating	9.38	
31	In	Insulation	8.27	
33	Lh	LED Lighting Household	7.81	
42	Hp	Heatpumps	5.20	
45	Ba	Building Automation	4.62	
54	W	Walkable Cities	2.92	
57	St	Smart Thermostats	2.62	
58	Lm	Landfill Methane	2.50	
24	Ir	Improved Rice Cultivation	11.34	
28	Ma	Multistrata Agroforestry	9.28	
60	C	Composting	2.28	
56	Ir	Industrial Recycling	2.77	
38	Fp	Forest Protection	6.20	
52	Cw	Coastal Wetlands	3.19	
59	Bi	Bike Infrastructure	2.31	
61	Sg	Smartglass	2.19	
71	Wd	Water Distribution	0.87	
44	Lc	LED Lighting Commercial	5.04	*
73	Gr	Green Roofs	0.77	
79	Nz	Net Zero Buildings	N/A	
80	Re	Retrofitting	N/A	
66	Hs	High Speed Rail	1.52	*
69	Eb	Electric Bikes	0.96	
65	Nm	Nutrient Management	1.91	
67	Fi	Farmland Irrigation	1.33	
72	Bc	Biochar	0.81	
26	Ev	Electric Vehicles	10.80	
32	Sh	Ships	7.87	
37	Mt	Mass Transit	6.57	
40	Tr	Trucks	6.18	
43	Ap	Airplanes	5.05	
49	Cr	Cars	4.00	
63	Tp	Telepresence	1.99	
74	Tr	Trains	0.52	
79	Rs	Ride Sharing	0.32	

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

The Periodic Table of Profitable Climate Solutions categorises 80 innovative ways of reducing the impact of climate change through carbon reduction initiatives.

Companies engaged in delivering climate solutions can therefore be grouped by industry and by initiative.

This is important because climate related innovation is a leading indicator of financial performance and company success.

CREDITS & MENTIONS

PROJECT DRAWDOWN is the source of data for the prioritisation of climate initiatives and amount of carbon saved. http://www.drawdown.org/solutions-summary-by-rank

THE GLOBAL CARBON PROJECT for providing the planets overall burnable carbon budget of 2,800 Gigatons CO2. http://www.globalcarbonproject.org/carbonbudget/16/files/GCP_CarbonBudget_2016.pdf

TCFD (Task Force on Climate-Related Financial Disclosures) for their work on climate-related financial disclosures across governance, strategy, risk management and metrics & targets to reduce risks during the transition to a lower carbon economy.

CARBON 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/wp-content/uploads/2017/10/2degrees-separation-infographic-V.4NE-01.png

Agenda

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

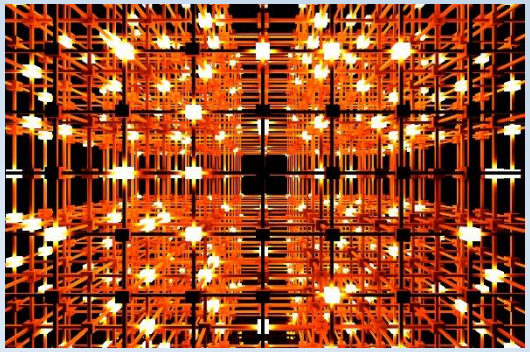
- Conservation & Efficiency
- Decarbonization
- Fuel-Shifting
- Waste Reduction
- Emission Sequestration
- Methane Emission Reduction
- Carbon Capture and Sequestration

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

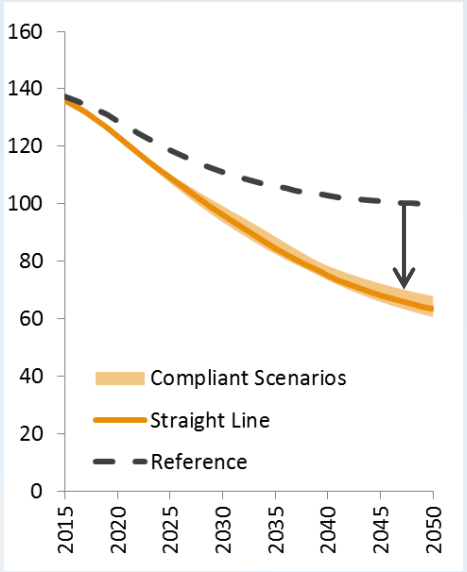
- Efficiency & Conservation
- Fuel-Switching

- Decarbonizing Electricity
- Decarbonizing Liquid & Gas Fuels
  - All applied to all sectors

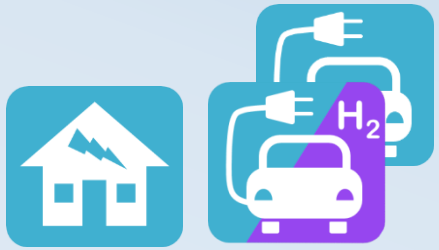
Four 'Pillars' of GHG Mitigation

1. Efficiency and Conservation

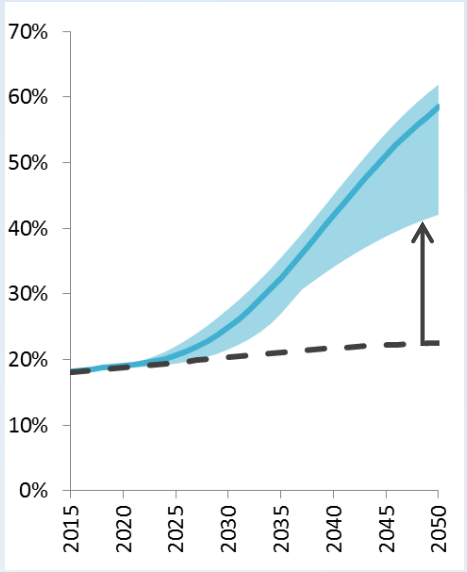
Energy use per capita (MMBtu/person)



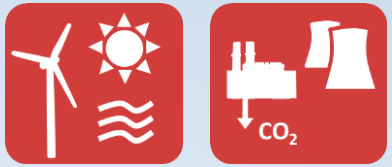
2. Fuel switching



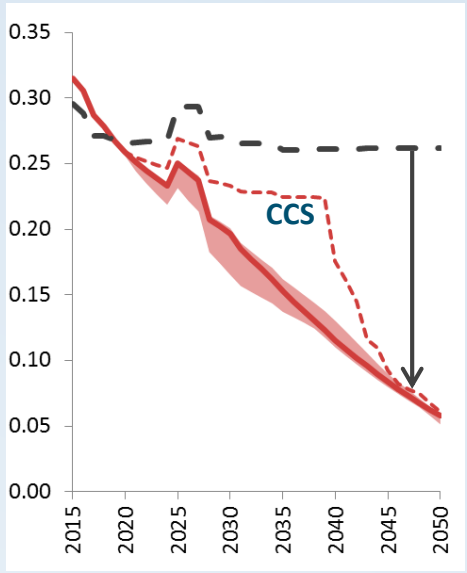
Share of electricity & H_2 in total final energy (%)



3. Decarbonize electricity

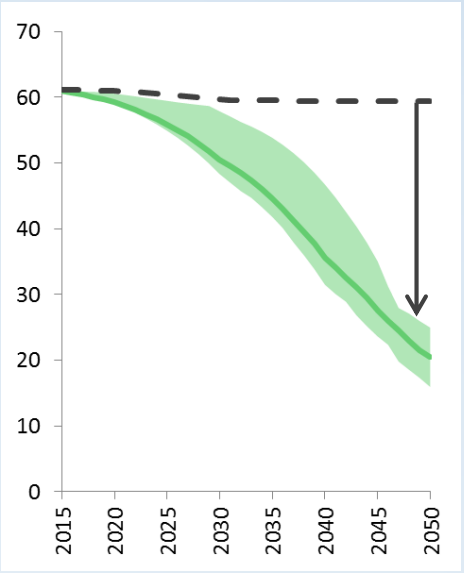


Emissions intensity (tCO2e/MWh)



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 2nd 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") + CO_2 removal carbon beneficial bioenergy with carbon capture and storage (BECCS)
- Reducing non-CO_2 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

Eileen V. Quigley, Director

eileen@cleanenergytransition.net

Clean Energy Transition

Transitioning from Fossil Fuel to Clean Energy

www.cleanenergytransition.net