International Institute for Applied Systems Analysis
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"Carbon Law" and Sustainable Development Goals

Nebojsa Nakicenovic

Deputy Director General

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Professor Emeritus of Energy Economics

Vienna University of Technology

ALPS International Symposium, Tokyo – 9 February 2018

science for global insight

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TWI2050
The World in 2050
www.twi2050.org

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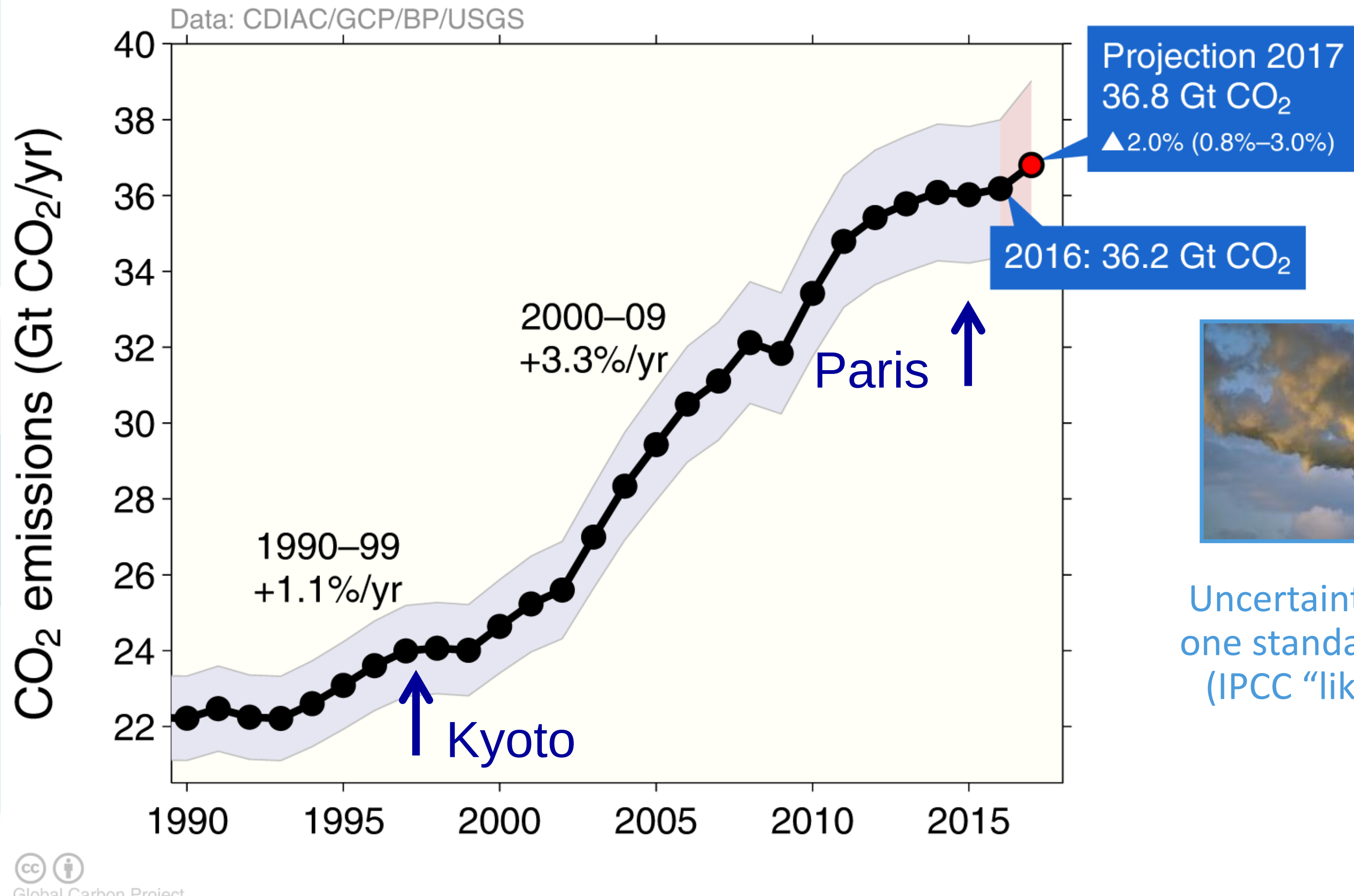
Emissions from fossil fuel use and industry

Global emissions from fossil fuel and industry: 36.2 ± 2 $GtCO_2$ in 2016, 62% over 1990

● Projection for 2017: 36.8 ± 2 $GtCO_2$, 2.0% higher than 2016



Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

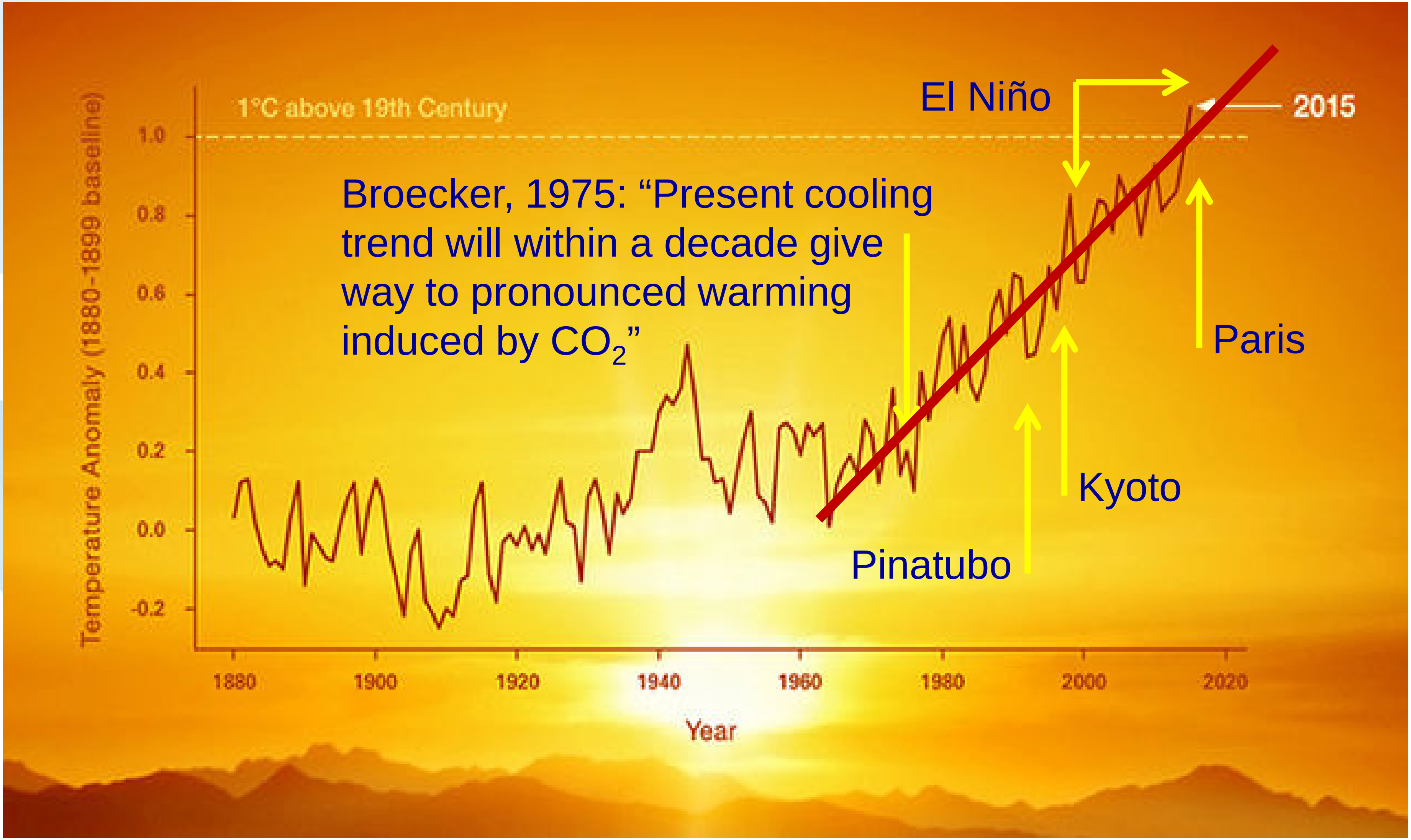
Estimates for 2015 and 2016 are preliminary. Growth rate is adjusted for the leap year in 2016.

Source: CDIAC; Le Quéré et al 2017; Global Carbon Budget 2017

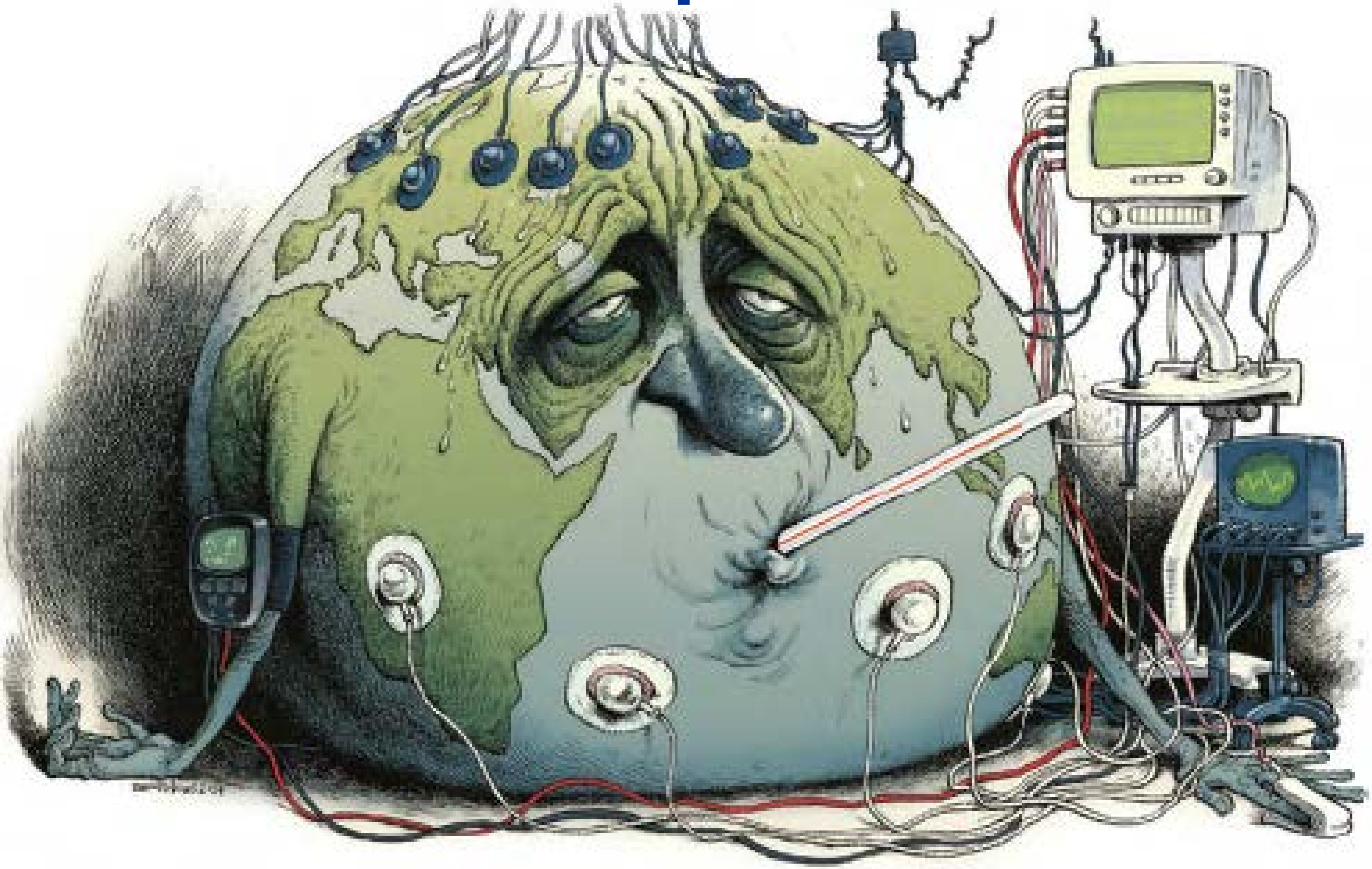

Take action for our future
– reduce your CO_2-emissions
This is the size of
ONE TONNE CO_2
Take up the challenge
– reduce every way YOU can.
Now!

Global Temperature Anomaly

1880 to 2015



Collective Responsibility in the Anthropocene



The Paris Agreement

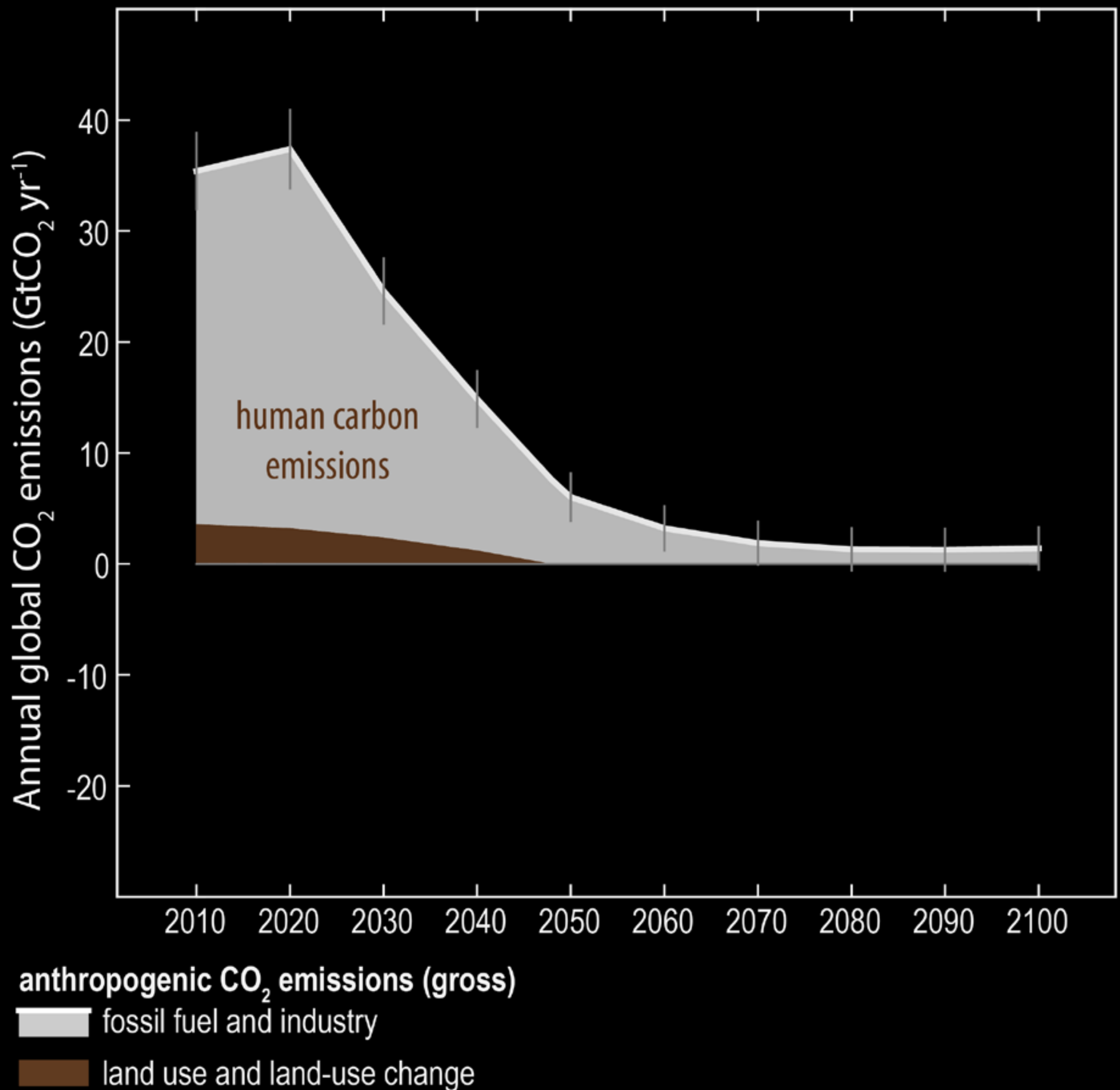
COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

Bildquelle: https://v

Limiting global warming to "well below" 2 degrees celsius	Achieving net-zero GHG emissions by mid of the 21st century	Regular review and improvement of nationally determined contributions	Mobilizing $100 billion a year in support by 2020 through 2025

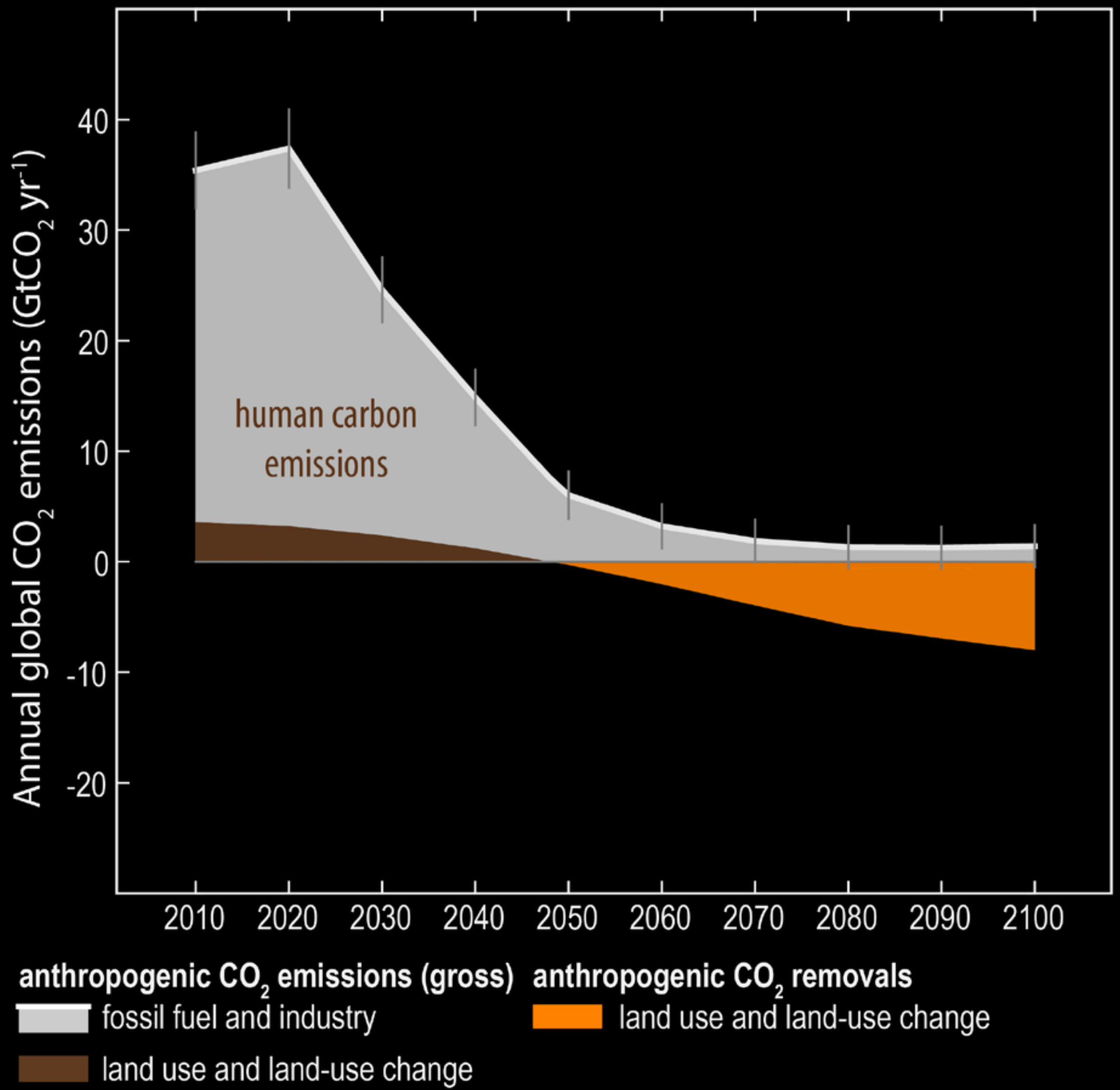
Source: Schellnhuber, 2016

"Carbon Law"



Rockström, Gaffney, Rogelj, Meinshausen, Nakicenovic, Schellnhuber. *Science* 24 March 2017

"Carbon Law"



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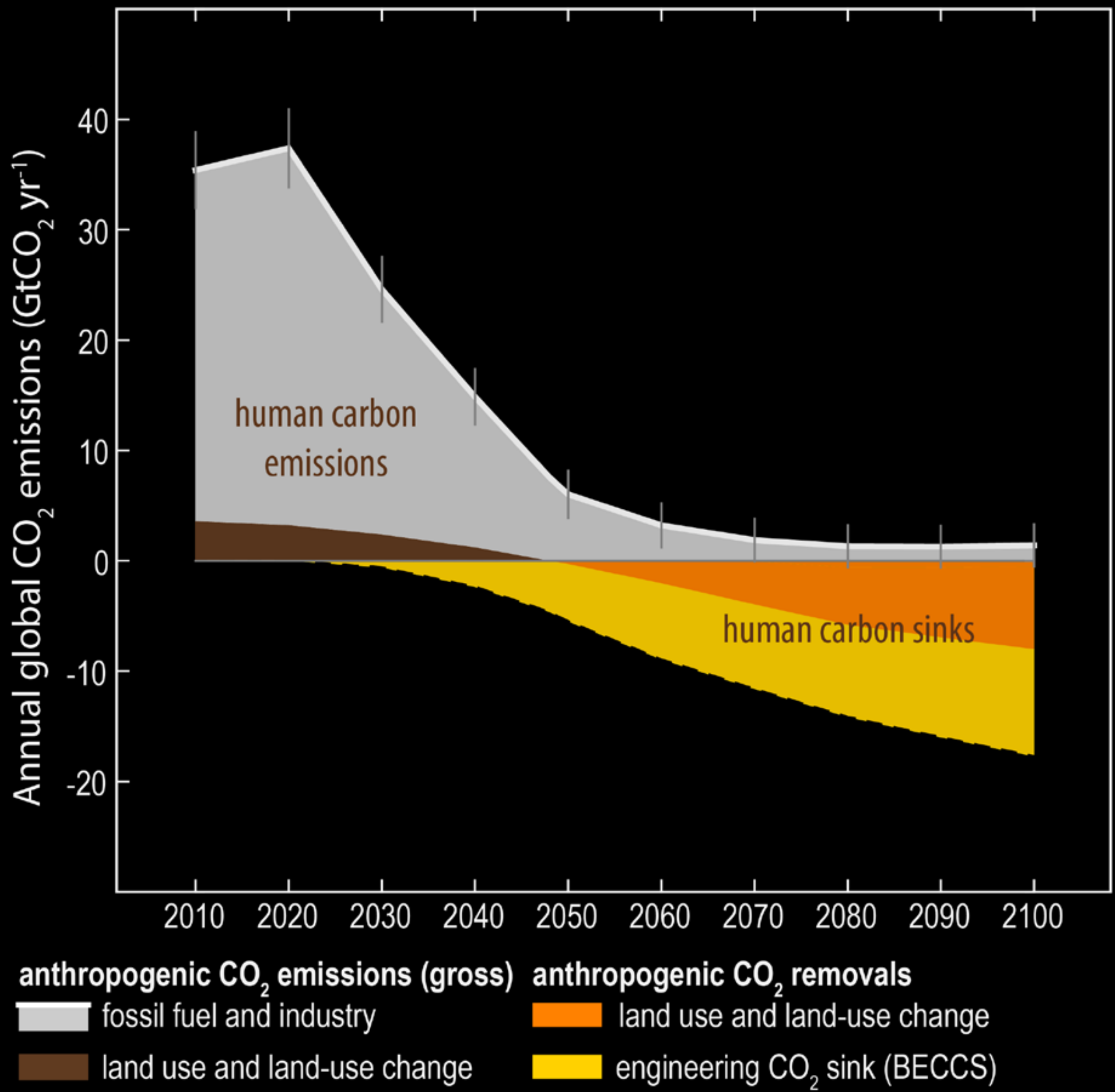

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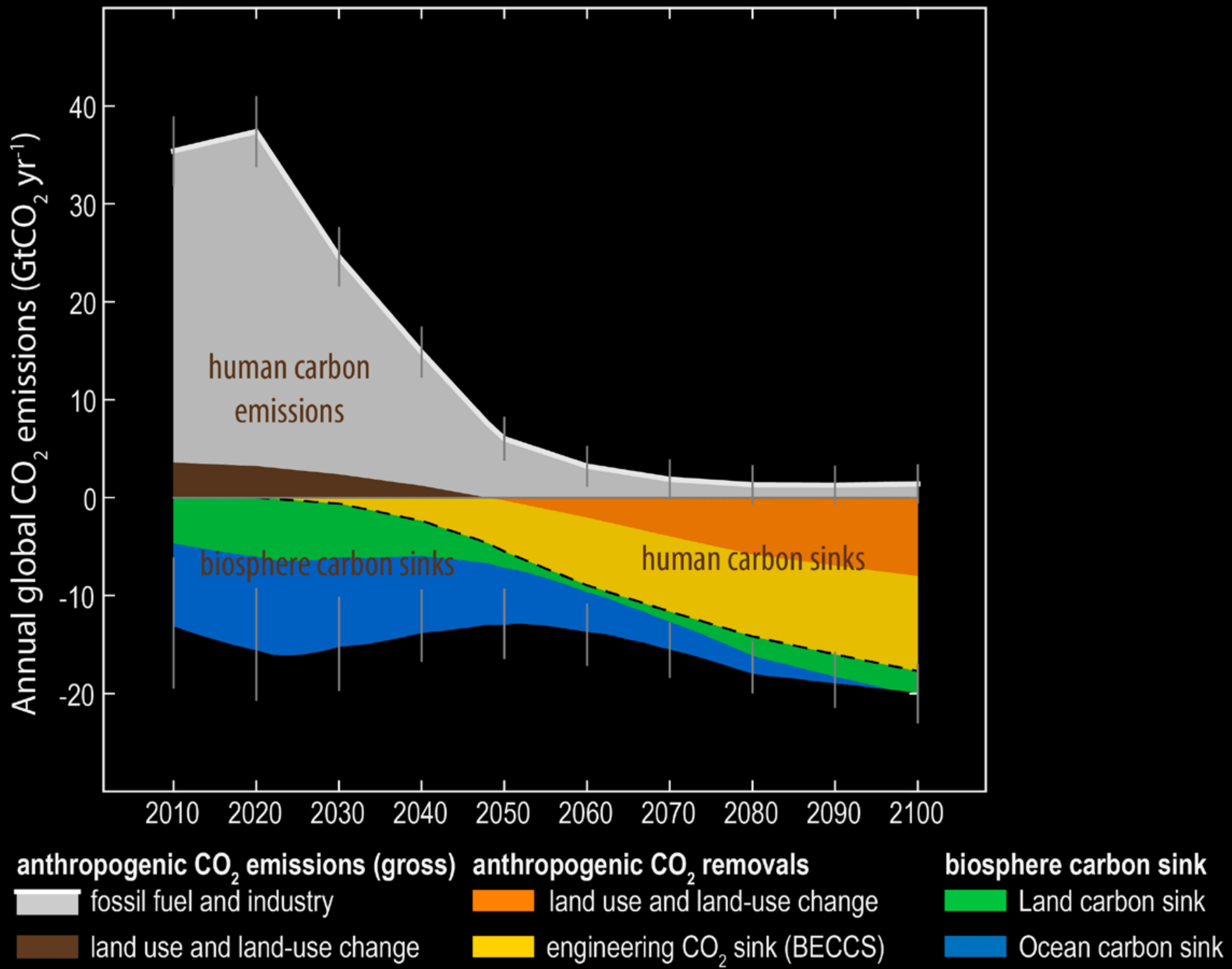

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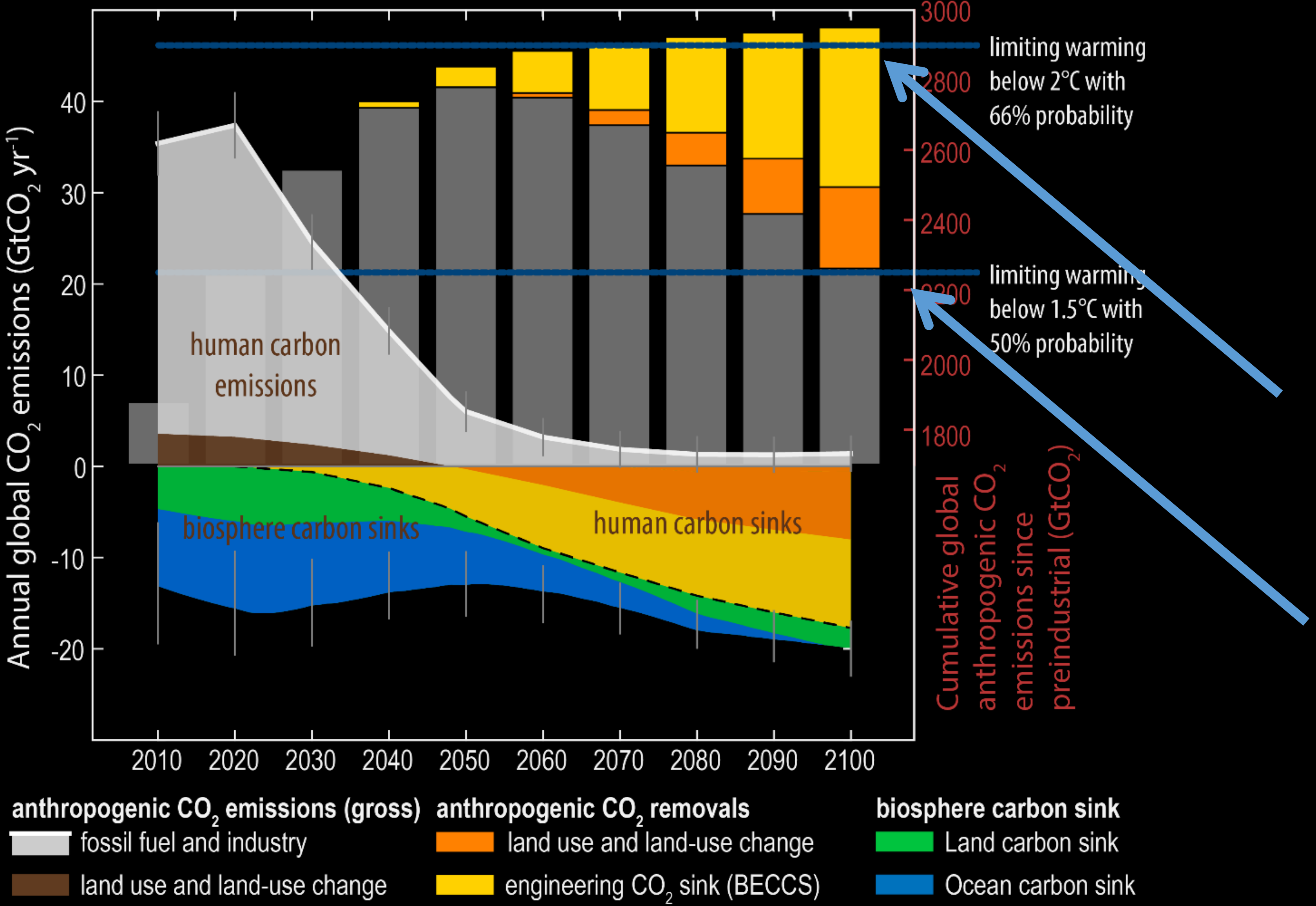
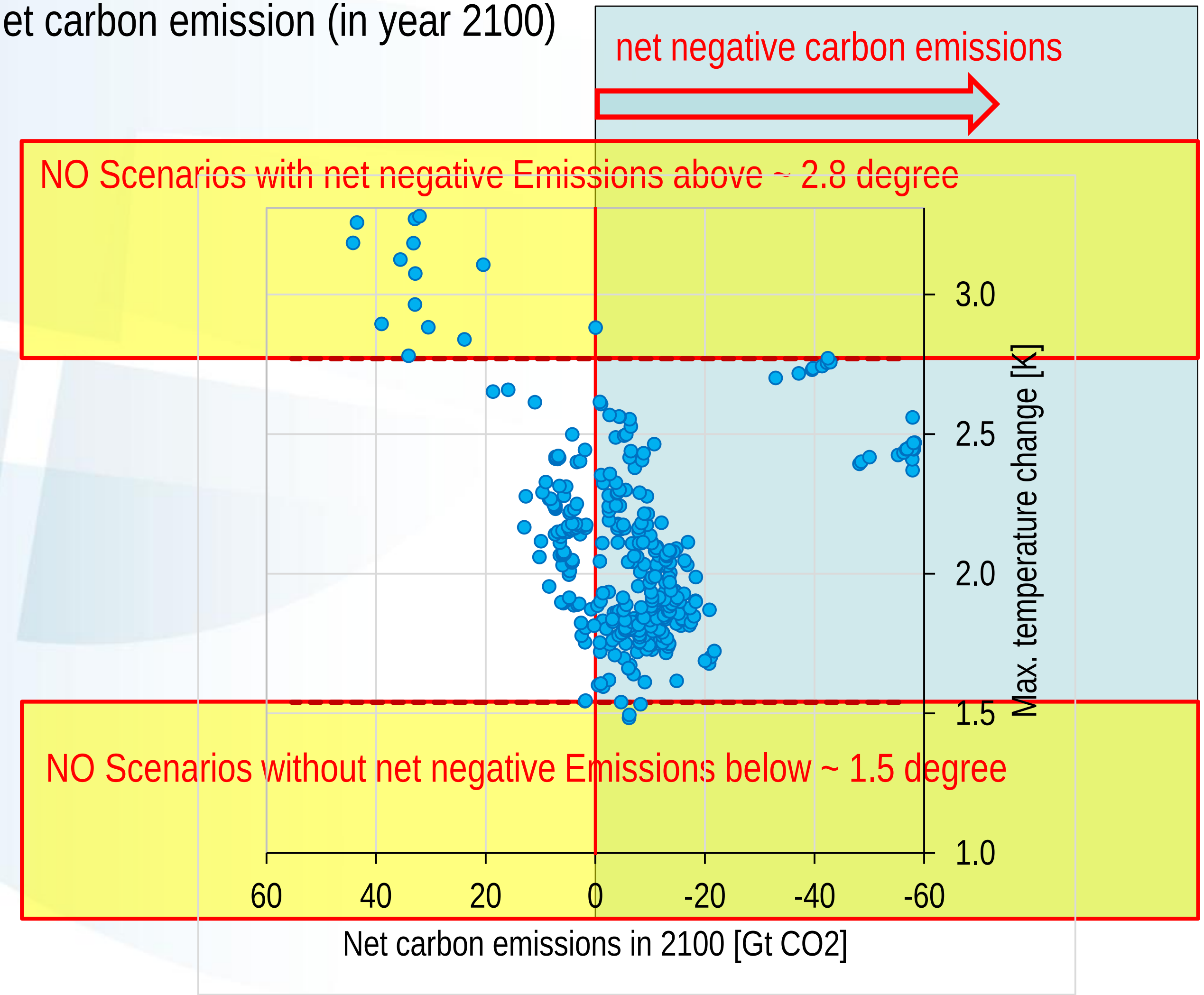


Rockström, Gaffney, Rogelj, Meinshausen, Nakicenovic, Schellnhuber. *Science* 24 March 2017

Net-negative CO_2 Emissions

Max. temperature change in 21th century
Net carbon emission (in year 2100)



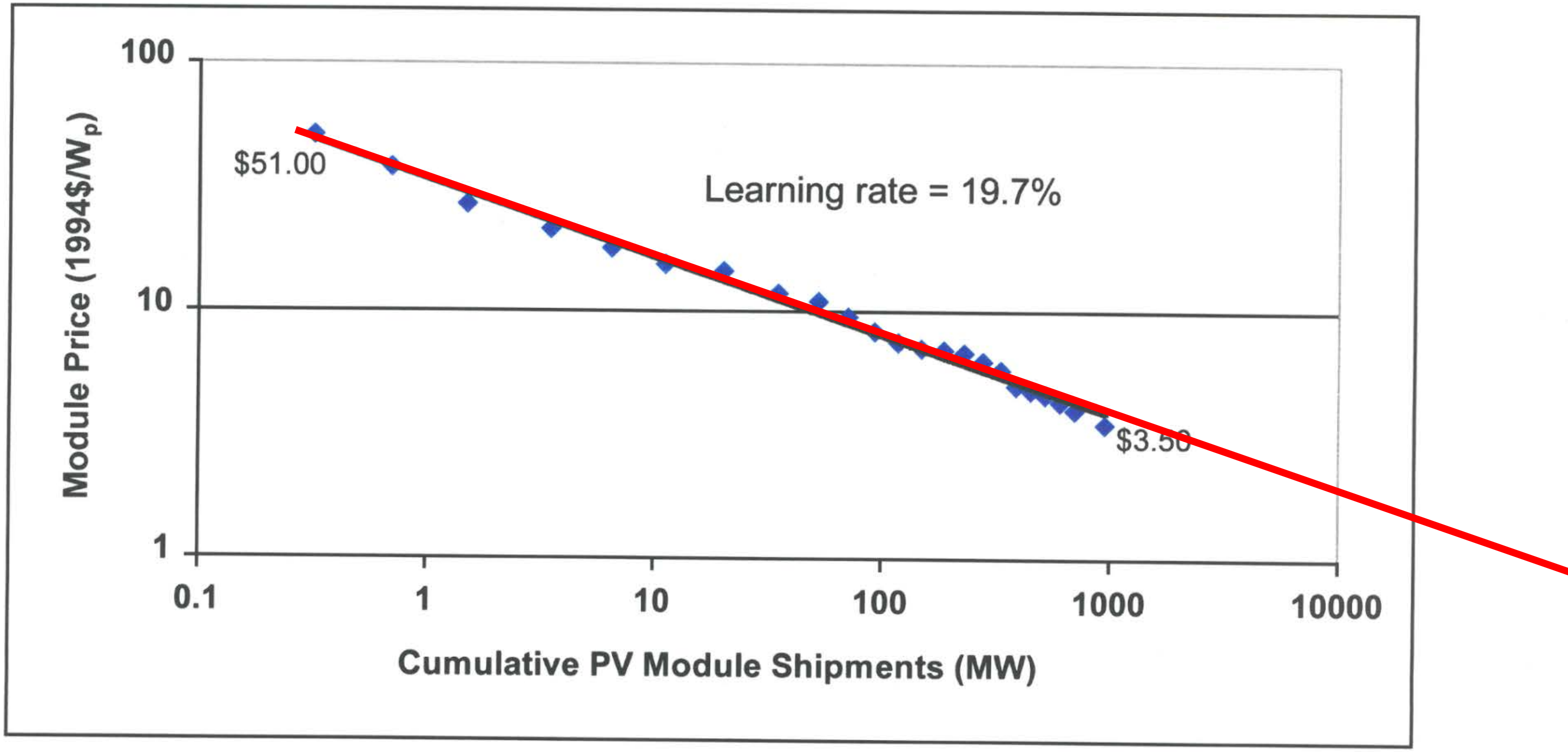
STI Transformational Change

Dynamic, Cumulative, Systemic and Uncertain

- Incremental – gradual (continuous) and cumulative improvements
- Abrupt – radical, discontinuous and disruptive as "gales of creative destruction"
- Add as many mail-coaches as you please, you will never get a railroad by so doing. [Schumpeter, 1935/1951, 136]

Solar PV Modules 1976–1998

(Harmon, 1999)



Data: Ayres (1998), Thomas (1999), Williams and Terzian (1993)

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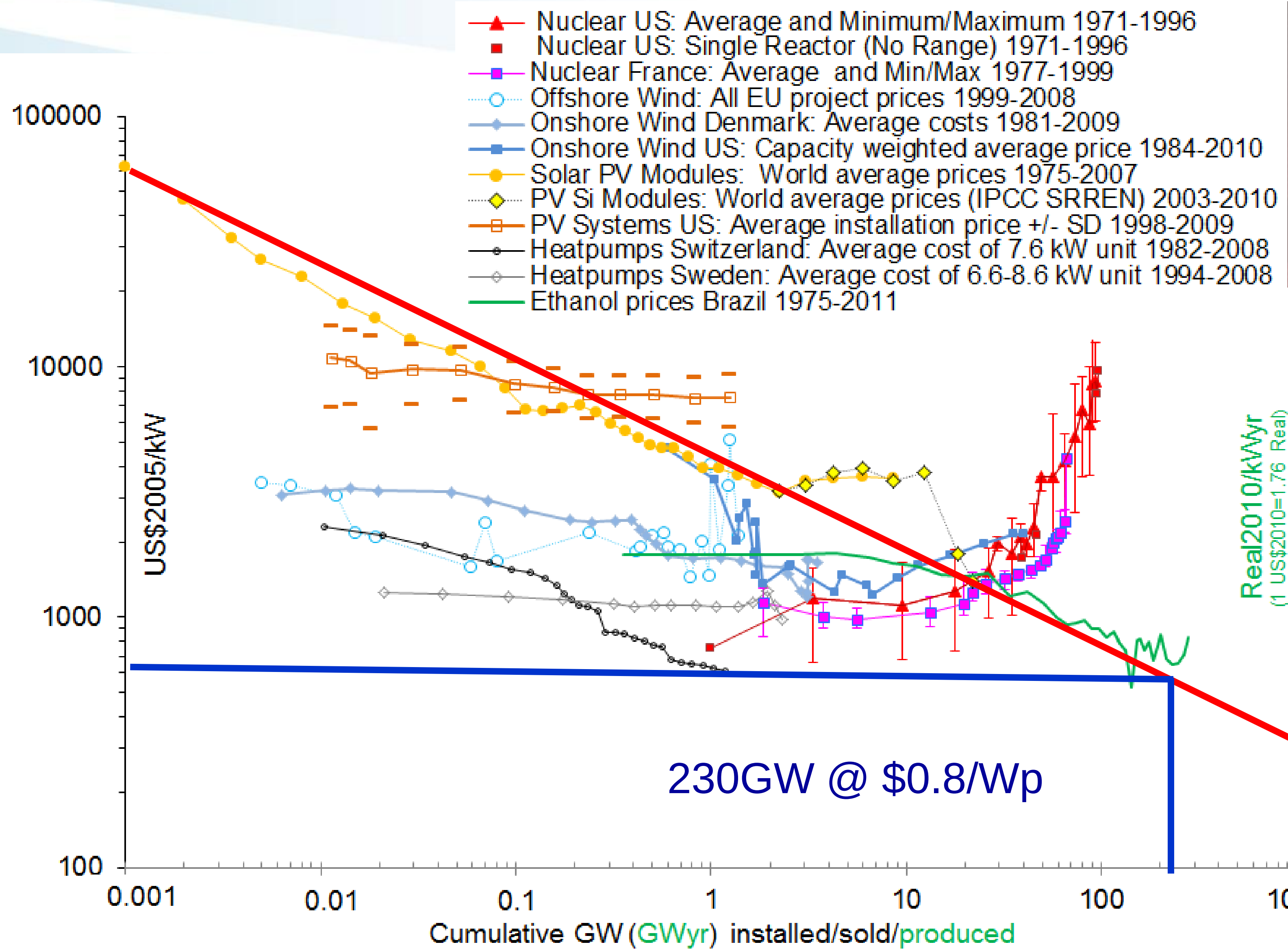
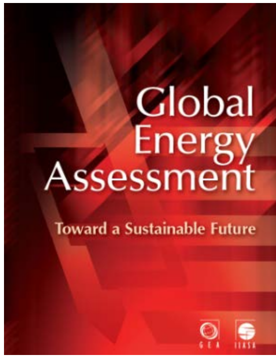
ECS, 1999

Supply Technologies Cost Trends





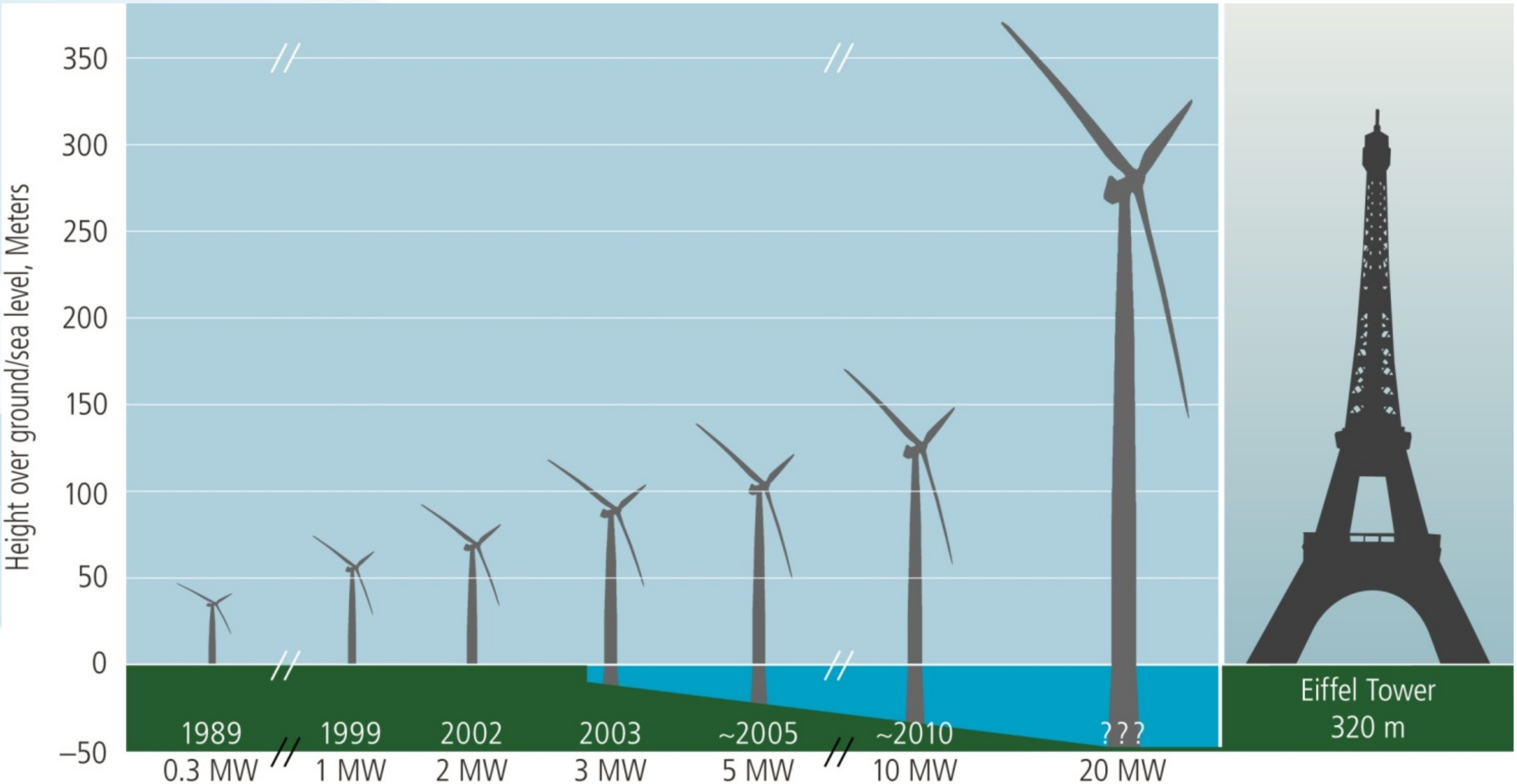
Unsubsidised clean energy world records since April 2016

Solar PV		Onshore wind		Offshore wind	
					
Country:	Mexico	Country:	Morocco	Country:	Germany
Bidder:	FRV	Bidder:	Enel Green Power	Bidder:	DONG/EnBW
Signed:	September 2016	Signed:	January 2016	Signed:	April 2017
Construction:	2019	Construction:	2018	Construction:	2024
Price:	**US$ 2.69 c/kWh**	**Price:**	**US$ 3.0 c/kWh**	**Merchant Price:**	**US$ 4.9 c/kWh**

Note: The offshore wind merchant price is estimated based on project LCOE in real 2016 terms

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

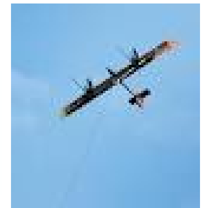
“Learning” Through Scale



Economies of scale, US wind turbines

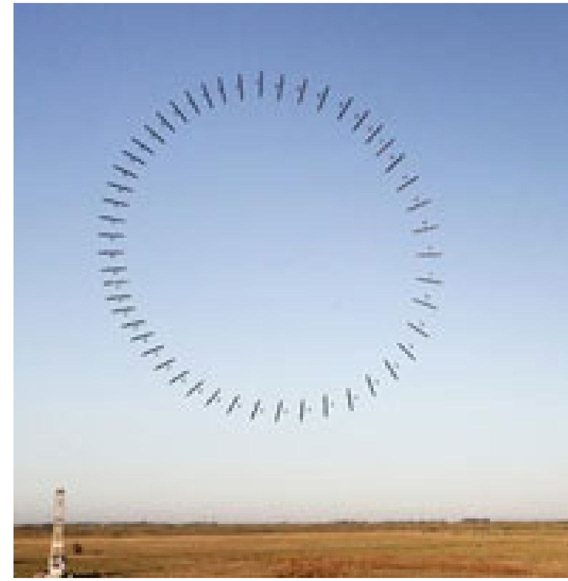
Source: Grubler et al. ALPS-2012

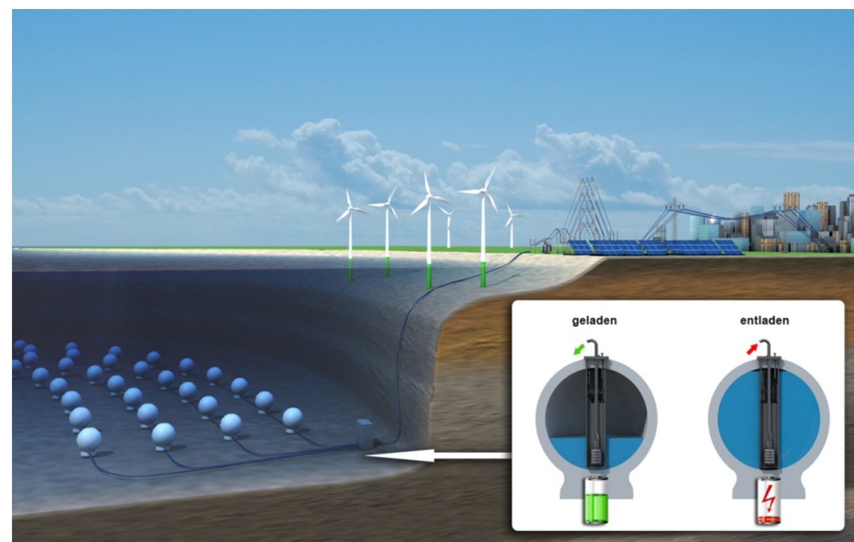
Possible Transformational Technologies



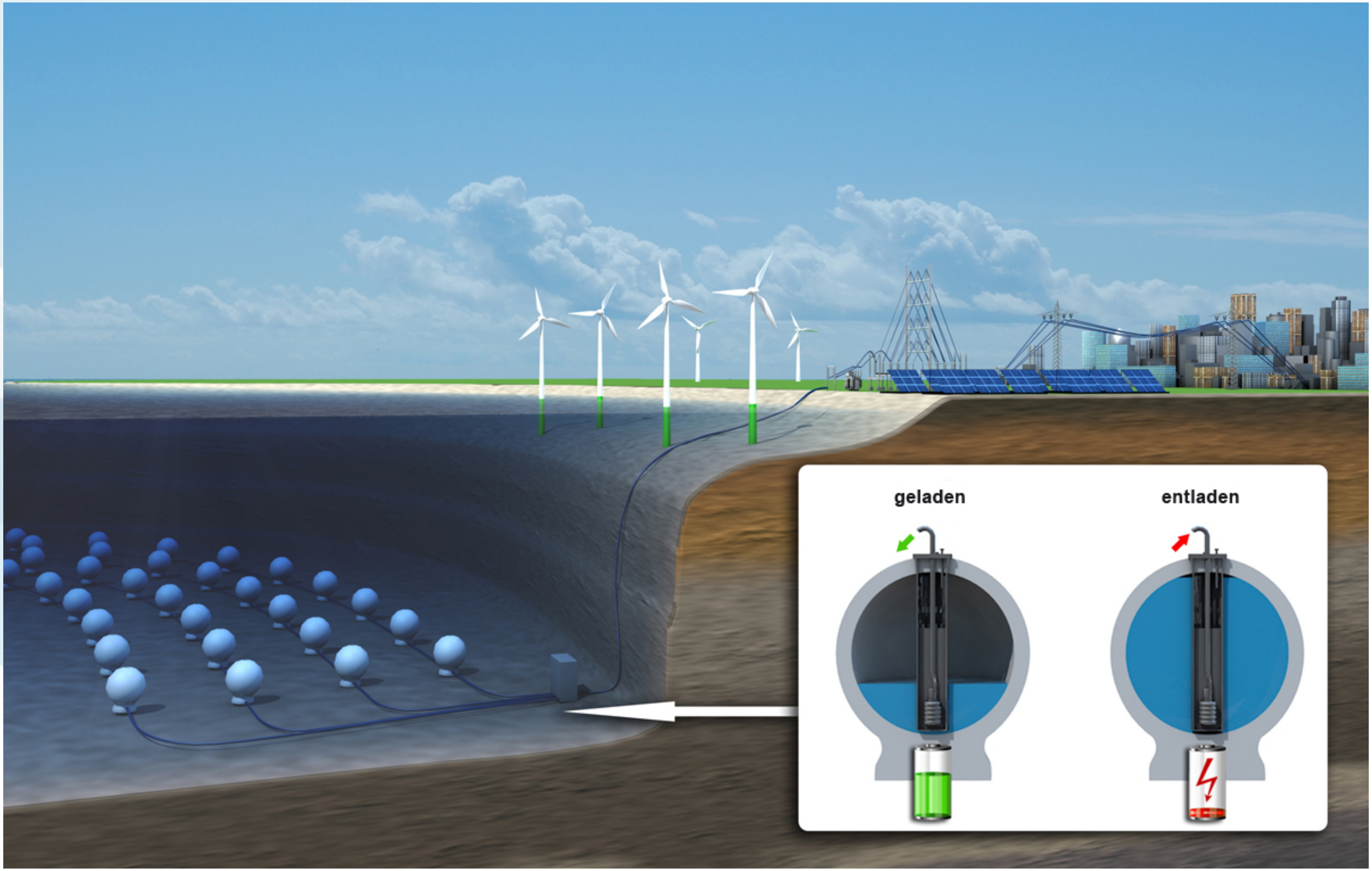
MAKANI POWER

Google X

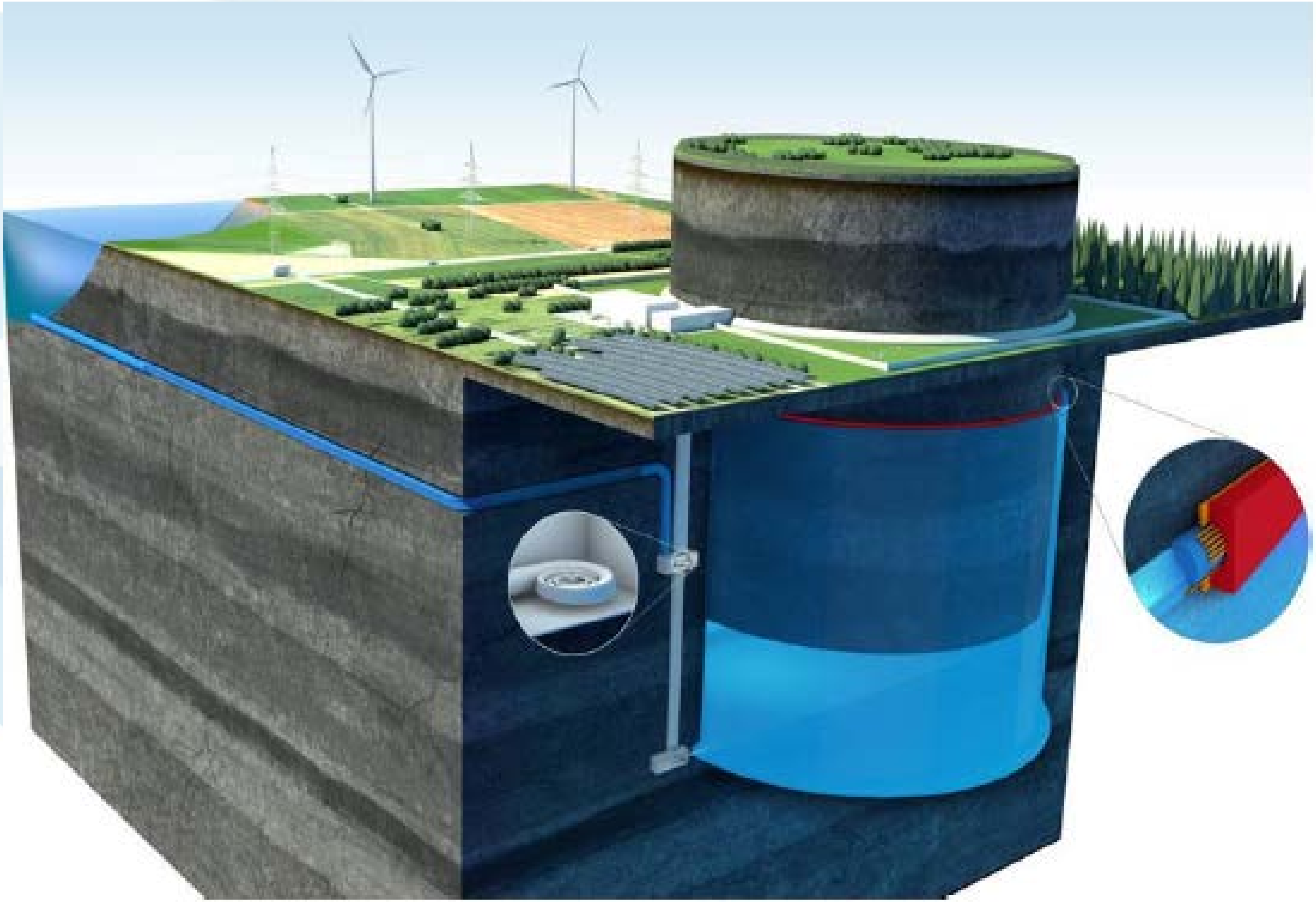




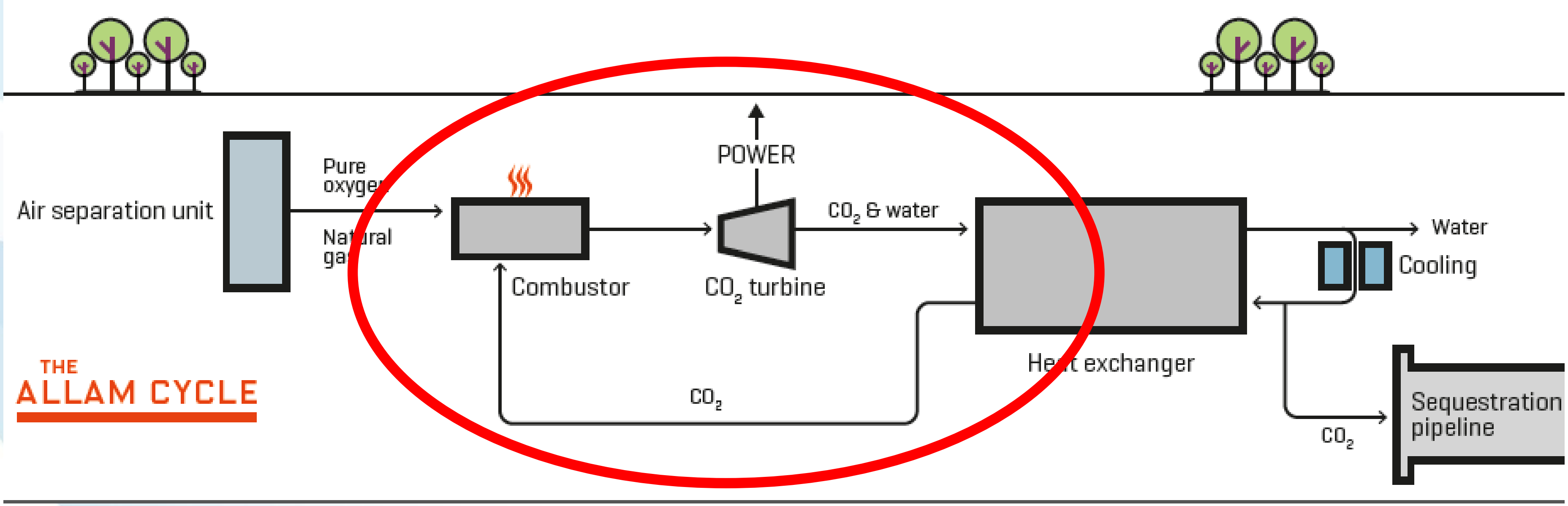
Deep Ocean Storage Sphere
@700m, Ø30m ≈ 20MWh



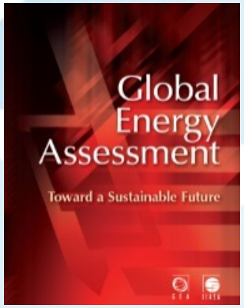
Hydraulic Electricity Storage

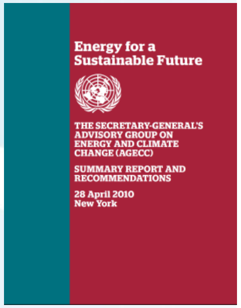


NET POWER Breaks Ground on Demonstration Plant for Oxyfuel, Nantural Gas ZEP, La Porte, Texas



Carbon Dioxide Storage
Sleipner since 1996





SUSTAINABLE ENERGY FOR ALL

7 AFFORDABLE AND CLEAN ENERGY

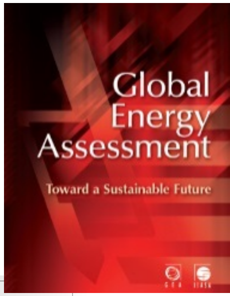
2030 GEA Goals and Targets

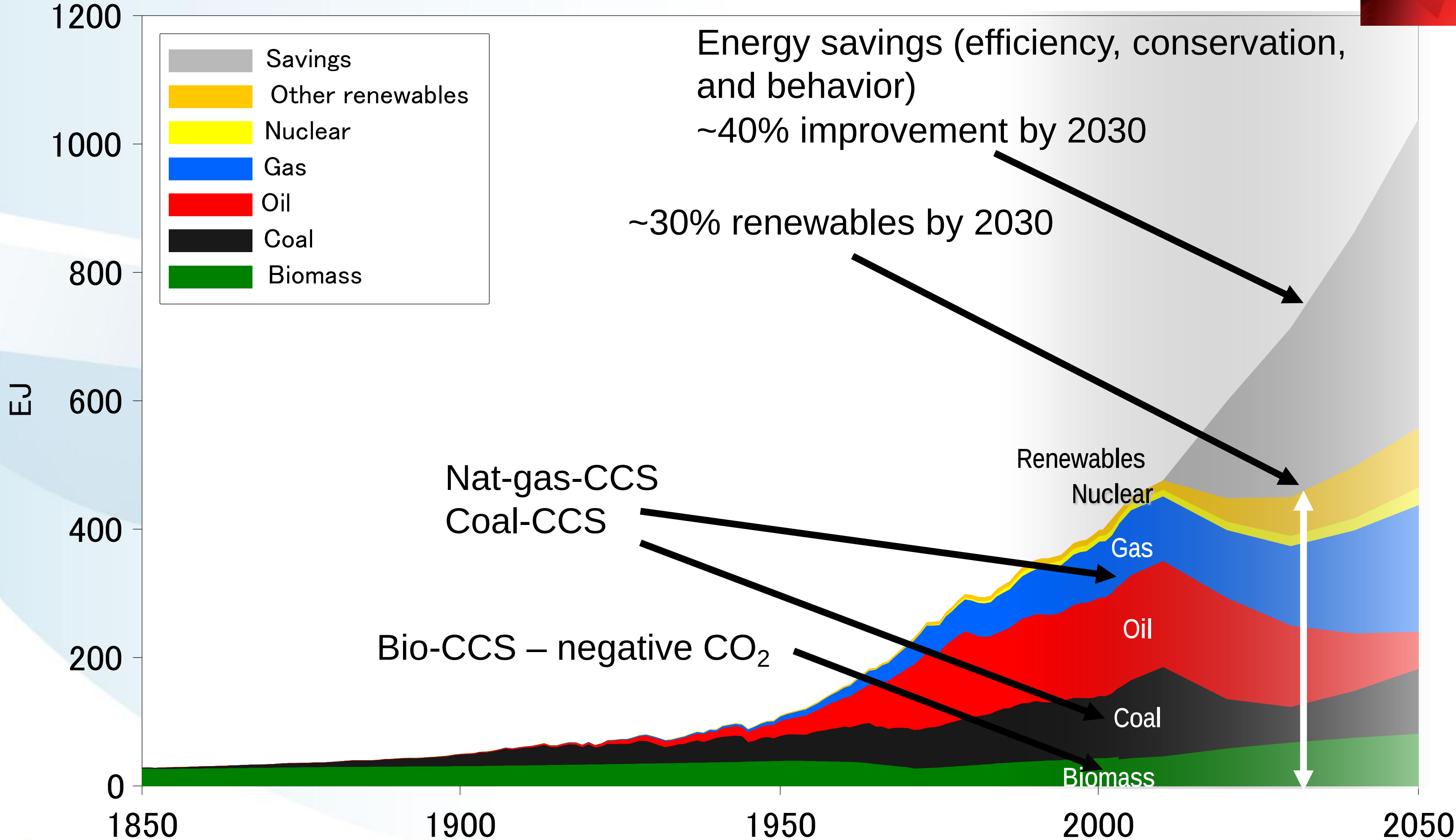
- Universal Access to Modern Energy
- Double Energy Efficiency Improvement
- Double Renewable Share in Final Energy

Aspirational & Ambitious but Achievable

Global Primary Energy

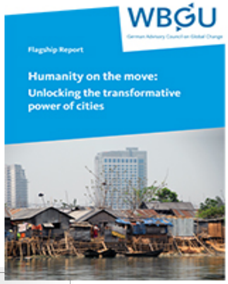
A Transformational Pathway

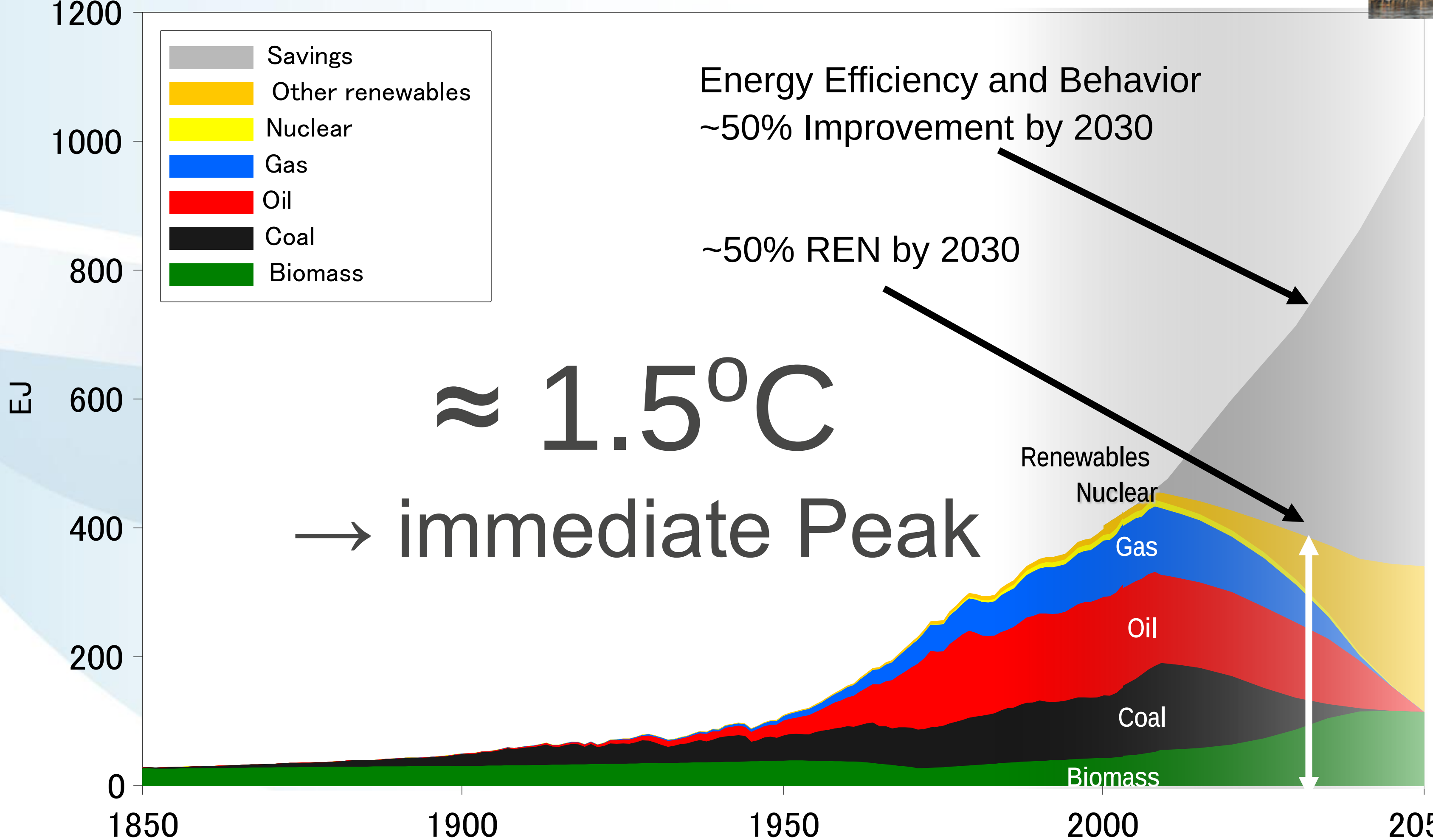




Global Primary Energy

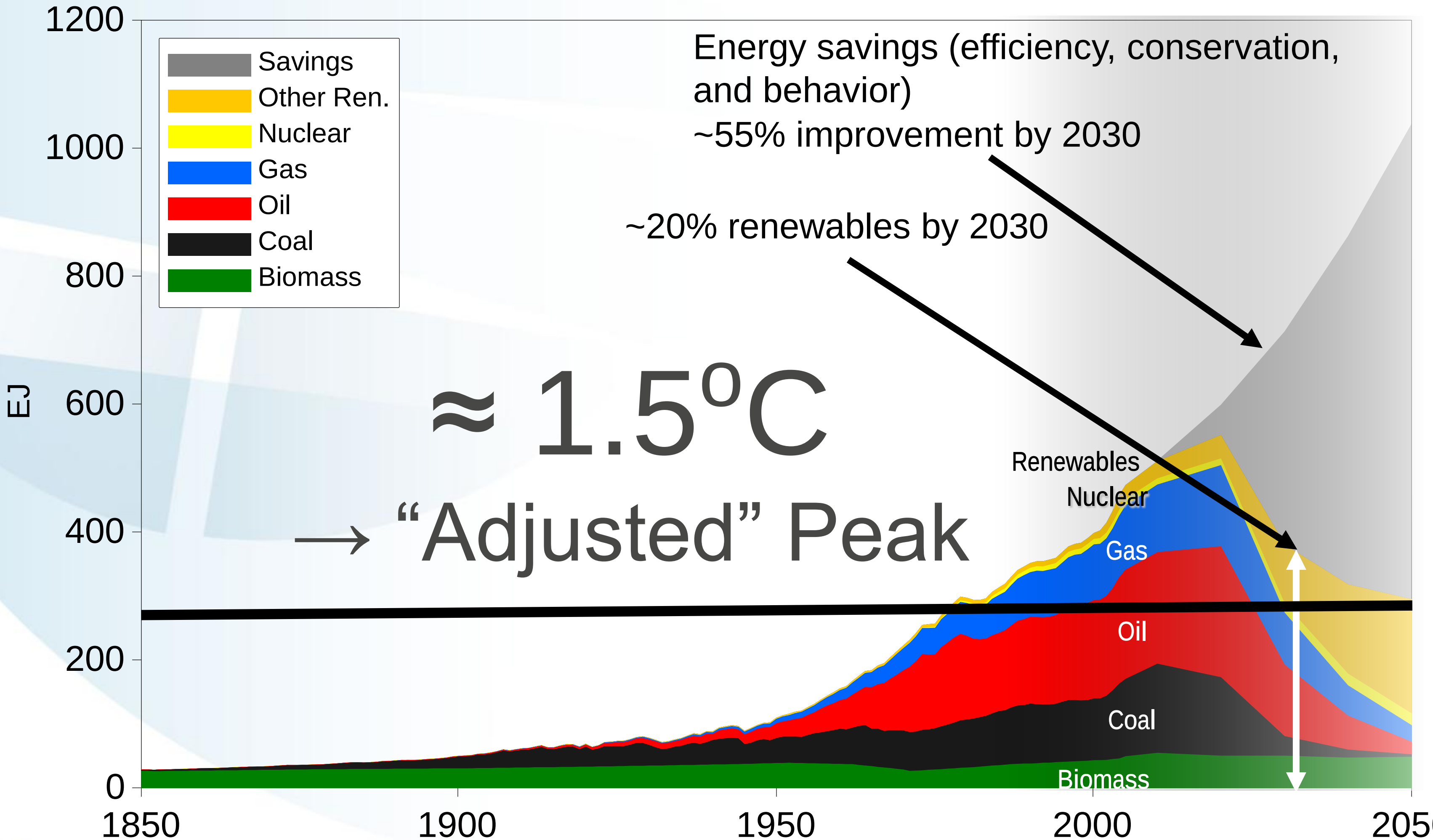
Zero Emissions by 2050



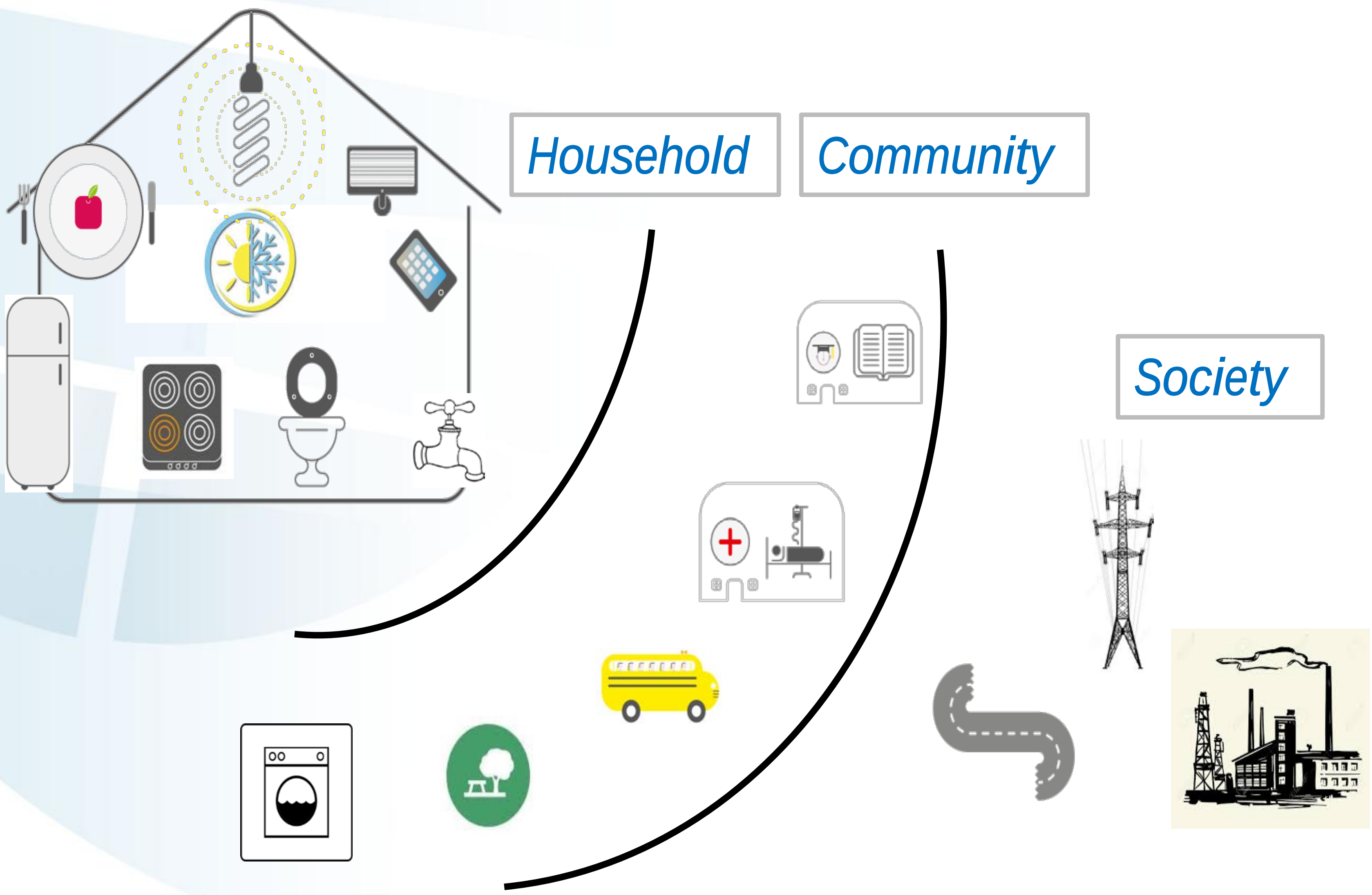


Global Primary Energy

ALPS Low Energy Demand (LED)



ALPS LED Energy for ‘Decent Living’



ALPS LED Decent Living (DL)

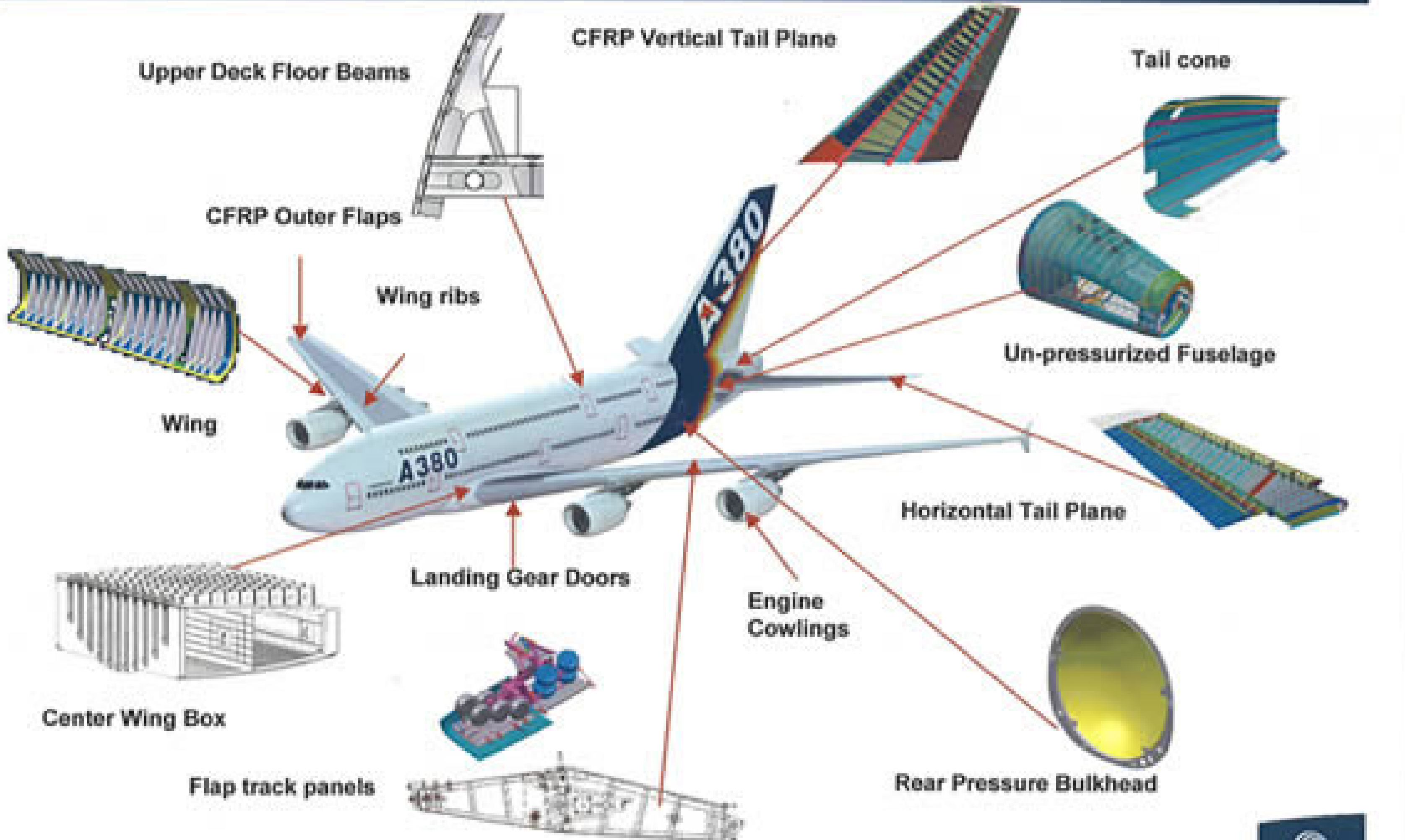
DL Indicator	Minimum DL
Food intake, *cal/day/capita*	2500
Shelter (residential), *m^2/capita*	10
Consumer goods, # of devices/Household *GJ/capita*	A/C, clean cooking, refrigeration, washing, TV, phone: >6 *3.5-4.1*
Mobility, *pass-km/yr/capita*	7000
Total DL Final Energy inputs, *GJ/capita*	*12-26* (today's technology, range India-Brazil)

DSL requirements ensure that people have the means to pursue a decent life, and avoid harm to their basic interests (Rao & Min, 2017). DSL requirements include amenities that ensure good health, quality of life, and those that enable people to engage with society. DSL energy requirements include "upstream" infrastructure and ancillary services (education, culture, materials, goods transport, etc.)

ALPS LED Highlights

- Higher levels of energy services than GEA
- Decent living for all (well above poverty)
- “Peak” energy driven by (technological and service) efficiency
- Lowest demand scenario (<250EJ by 2050)
- End-use transformations (efficiency, electrification) lead to decarbonization
- Below 1.5^{o}C with no negative emissions
- Significant SDGs synergies (>6 SDGs)

Major monolithic Carbon Fiber Reinforced Plastic (CFRP) and Thermoplastics applications



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Varialift Airship

Varialift Airship

Carbon Composite BMW i3

Carbon Composite BMW i3 & i8

厦门甲壳虫复材有限公司

Xiamen Beatles Composite Material Co.,Ltd

Carbon Composite Train

 Source: CRRC Changchun Railway Vehicles Co

Carbon Composite Train

 Source: CRRC Changchun Railway Vehicles Co

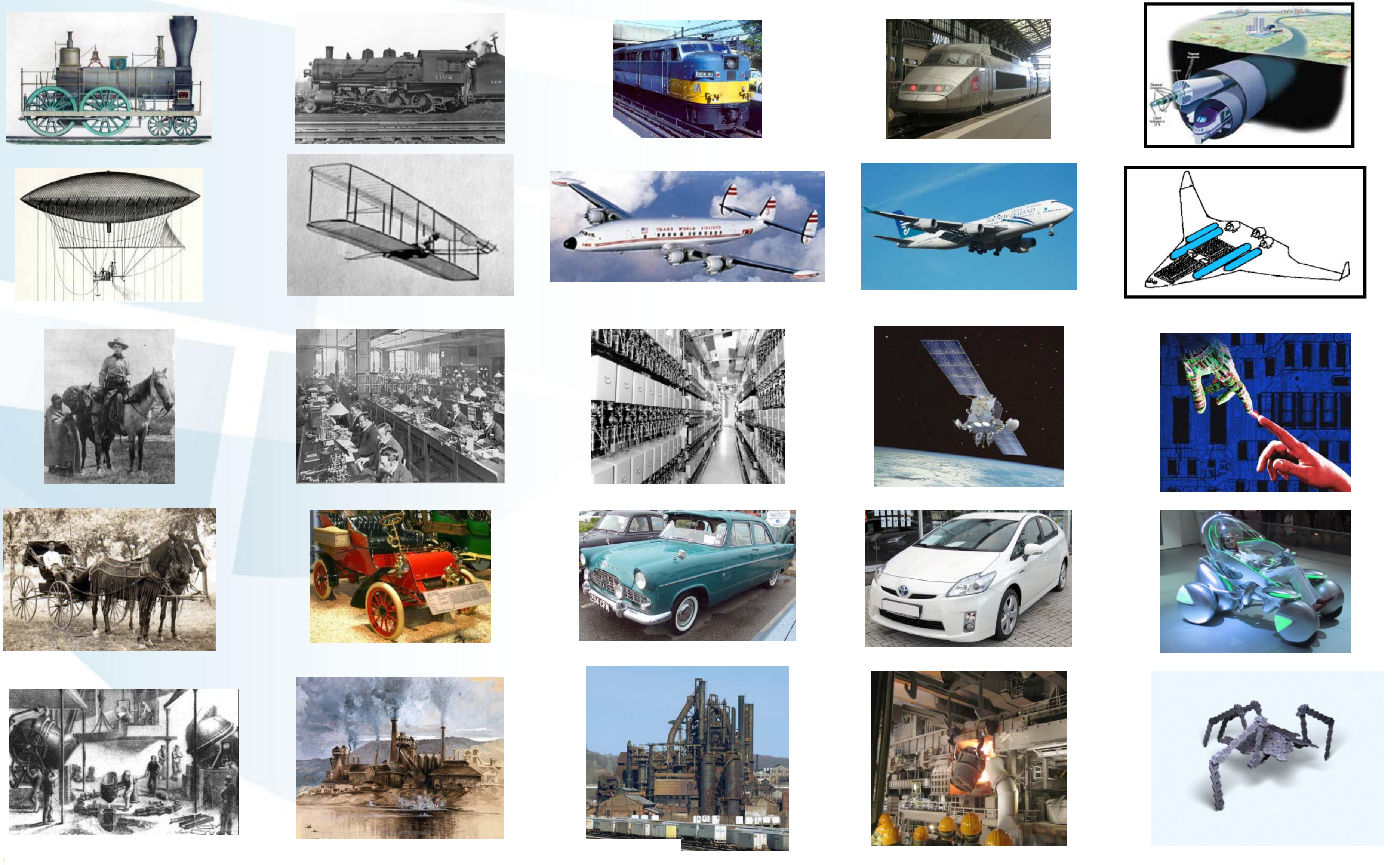
Carbon Composite Bridge in Madrid

Proposed Carbon Composite Bridge
Over I-5 at Northgate Seattle

Grand Transformation

Transformational Change

1850 1900 1950 2000 2050

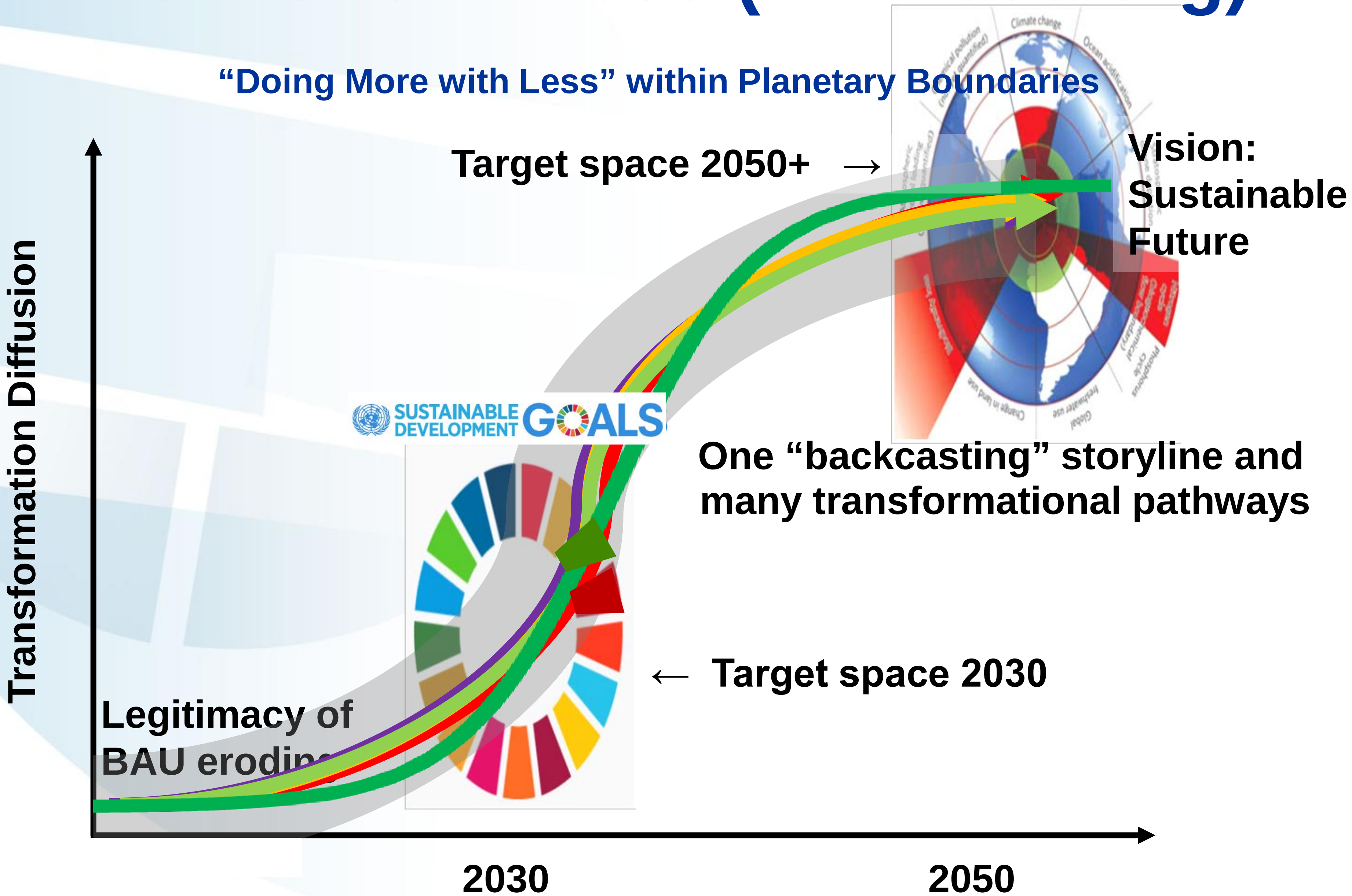


Source: After Granger Morgan, 2013

SUSTAINABLE DEVELOPMENT GOALS

The World in 2050 (TWI2050.org)

"Doing More with Less" within Planetary Boundaries



Disruptive Change

Sankt. Petersburg Airport Duty Free

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ありがとう

science for global insight

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