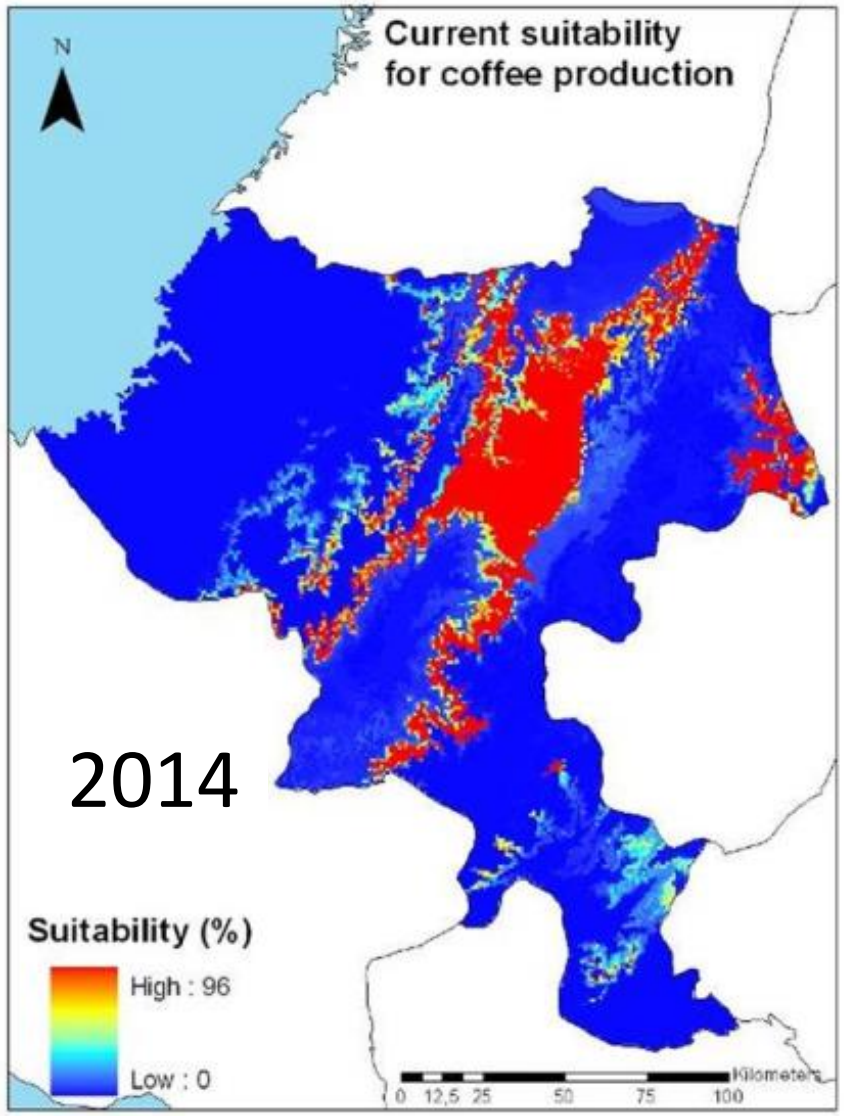
LanzaTech

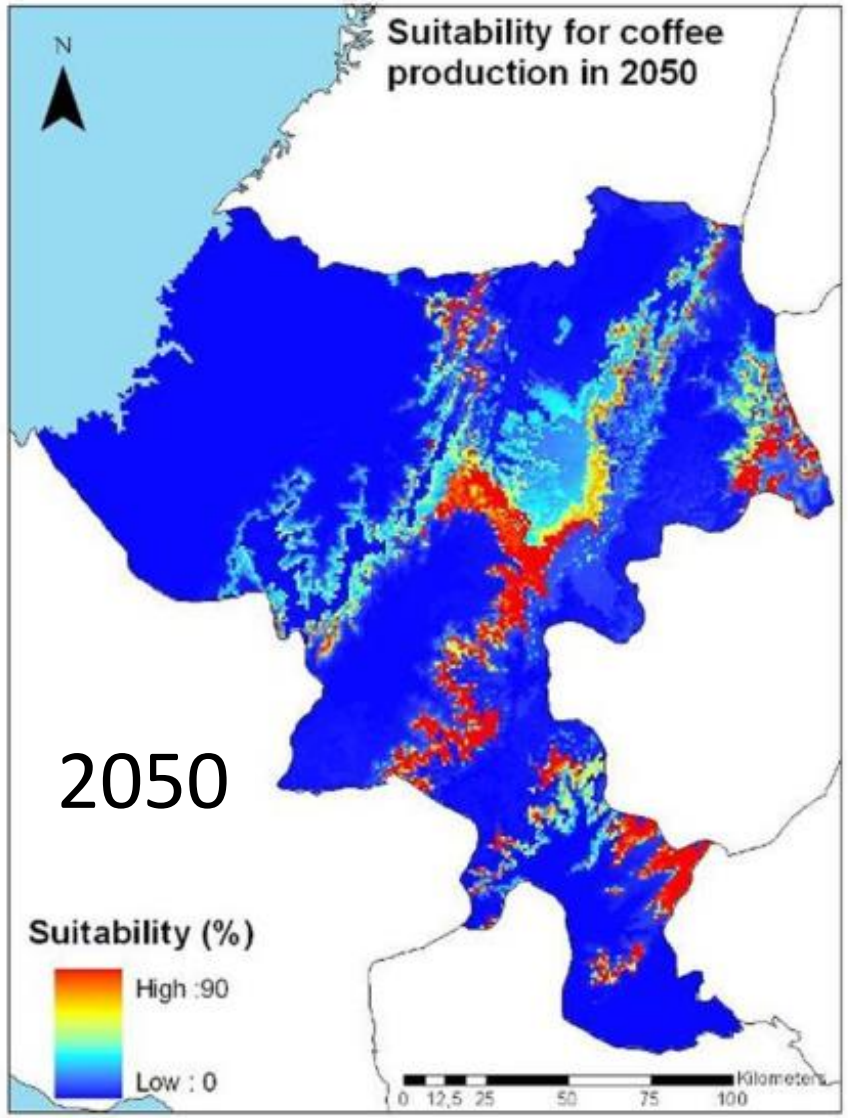
Creating a Carbon Smart Future

Dr. Jennifer Holmgren

Impact on Coffee Growing Areas of Colombia

Café de Colombia





Source: Jarvis, CIAT (2012)

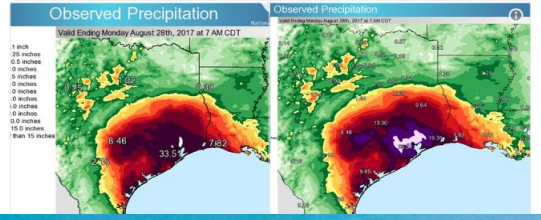
LanzaTech

AMERICA

National Weather Service Adds New Colors So It Can Map Harvey's Rains

August 28, 2017 · 1:50 PM ET

BILL CHAPPELL

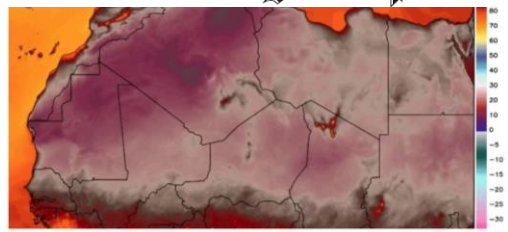


Capital Weather Gang

Africa may have witnessed its all-time hottest temperature Thursday: 124 degrees in Algeria

By Jason Samenow
July 6, 2018

The Washington Post



European model analysis of high temperatures in northern Africa on July 5. It shows maximum values over Algeria around 120 degrees. (WeatherBell.com)

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NEWS

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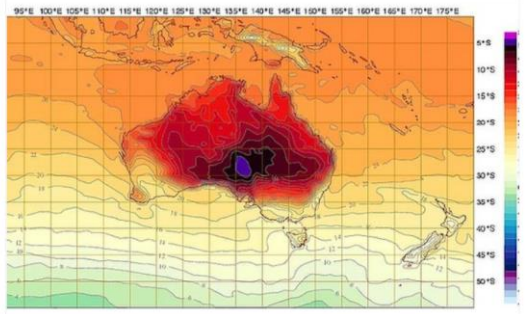
US & Canada

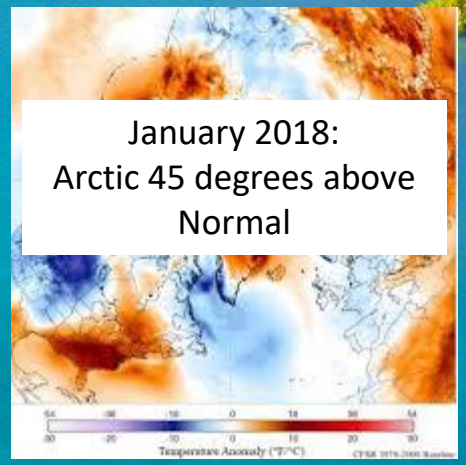
Phoenix flights cancelled because it's too hot for planes

20 June 2017 Share

It's So Hot in Australia That They Added New Colors to the Weather Map

This deep purple is a brand-new shade that the Australian bureau of meteorology was forced to add to its heat index because their country is, you know, kind of on fire.





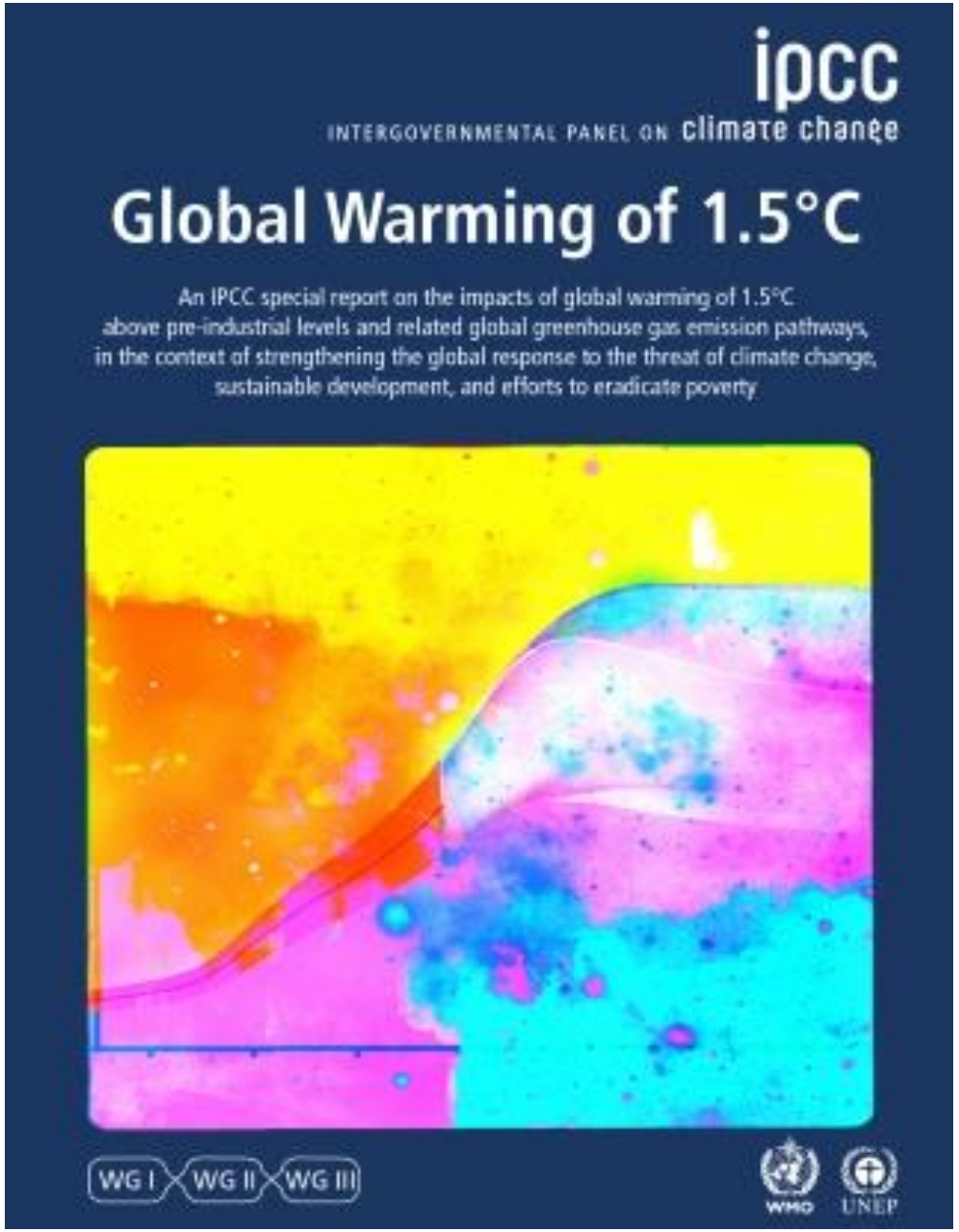
January 2018:
Arctic 45 degrees above Normal

350,228 views | Jan 29, 2019, 11:34am

Chicago Will Be Colder Than Mount Everest, Arctic Tomorrow

Trevor Nace Contributor
Science

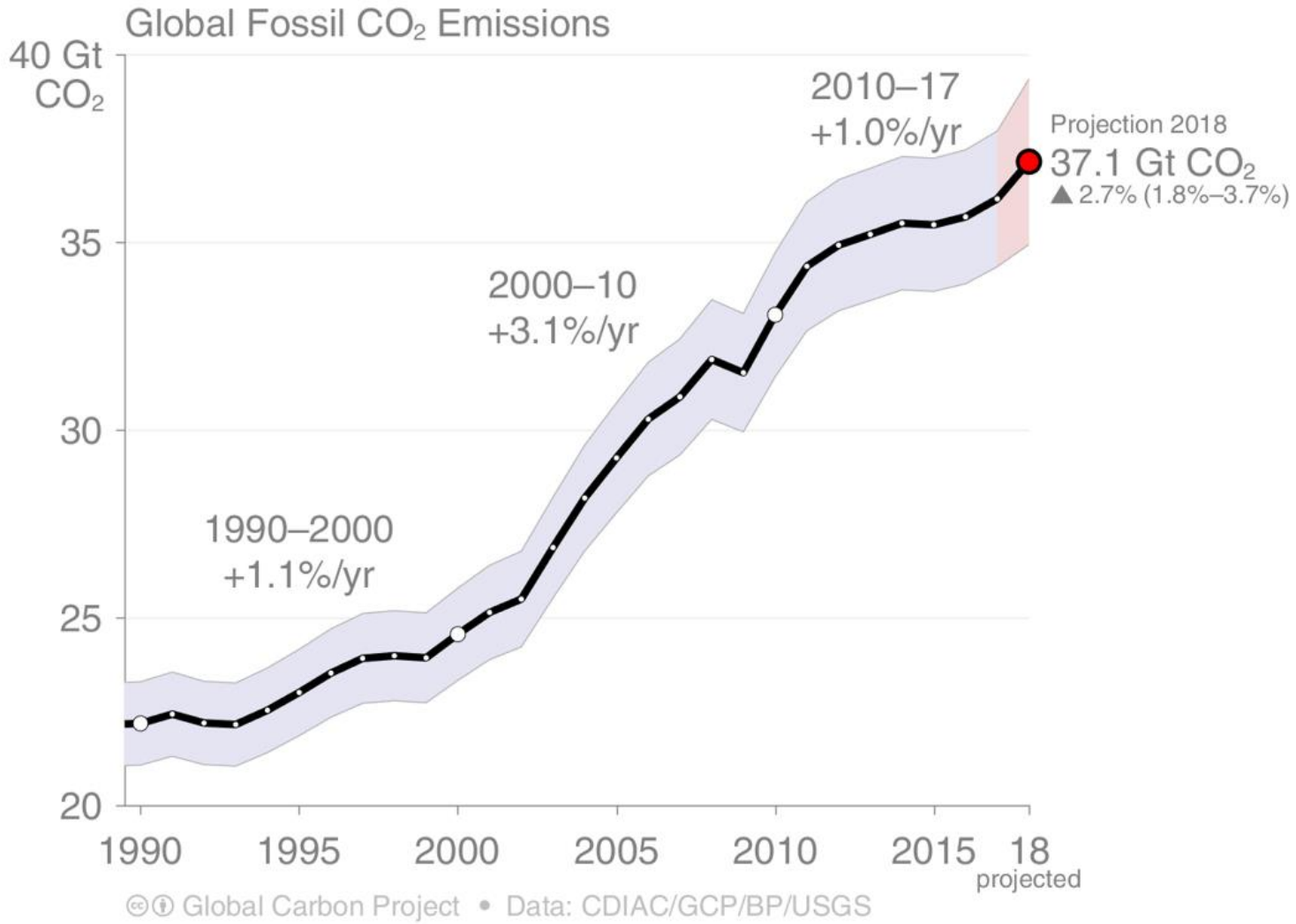
Forbes



Limiting Global Warming to 1.5°C compared to 2°C

"rapid and far-reaching" transitions in land, energy, industry, buildings, transport, and cities. Global net human-caused emissions of carbon dioxide (CO_2) would need to ***fall by about 45% from 2010 levels by 2030,*** *reaching 'net zero' around 2050. This means that any remaining emissions would need to be balanced by removing CO_2 from the air.*

Global Fossil CO_2 Emissions

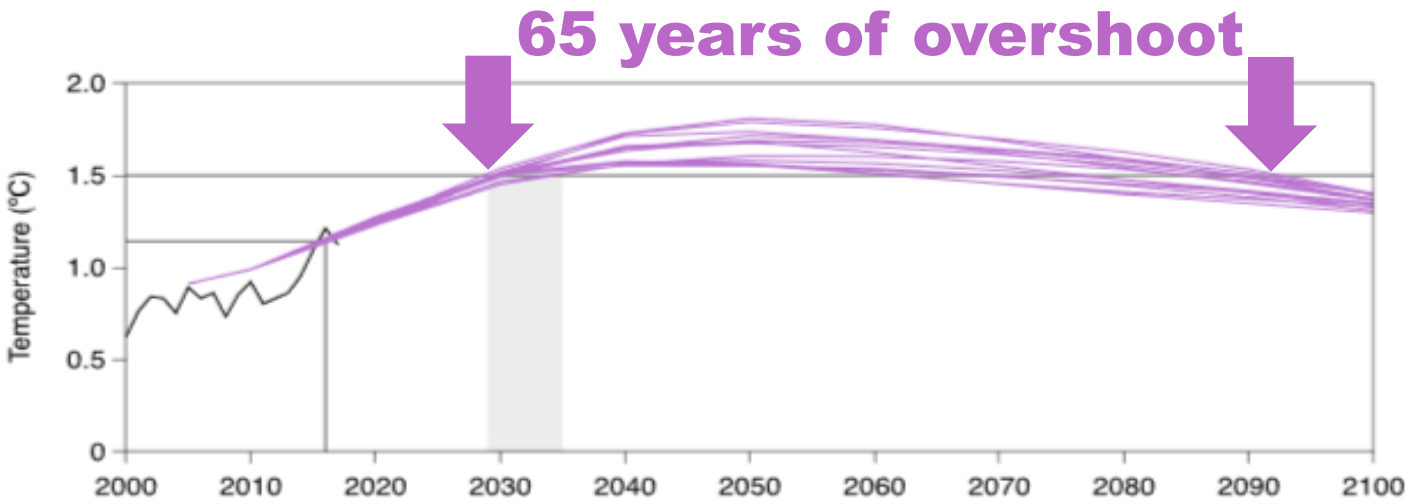


Global fossil CO_2 emissions have risen steadily over the last decades. The peak in global emissions is not yet in sight.

Source: CDIAC; Le Quéré et al 2018; Global Carbon Budget 2018

All 1.5°C Scenarios depend on Negative Emissions Technologies (NETs)

All exceed 1.5°C in early 2030s

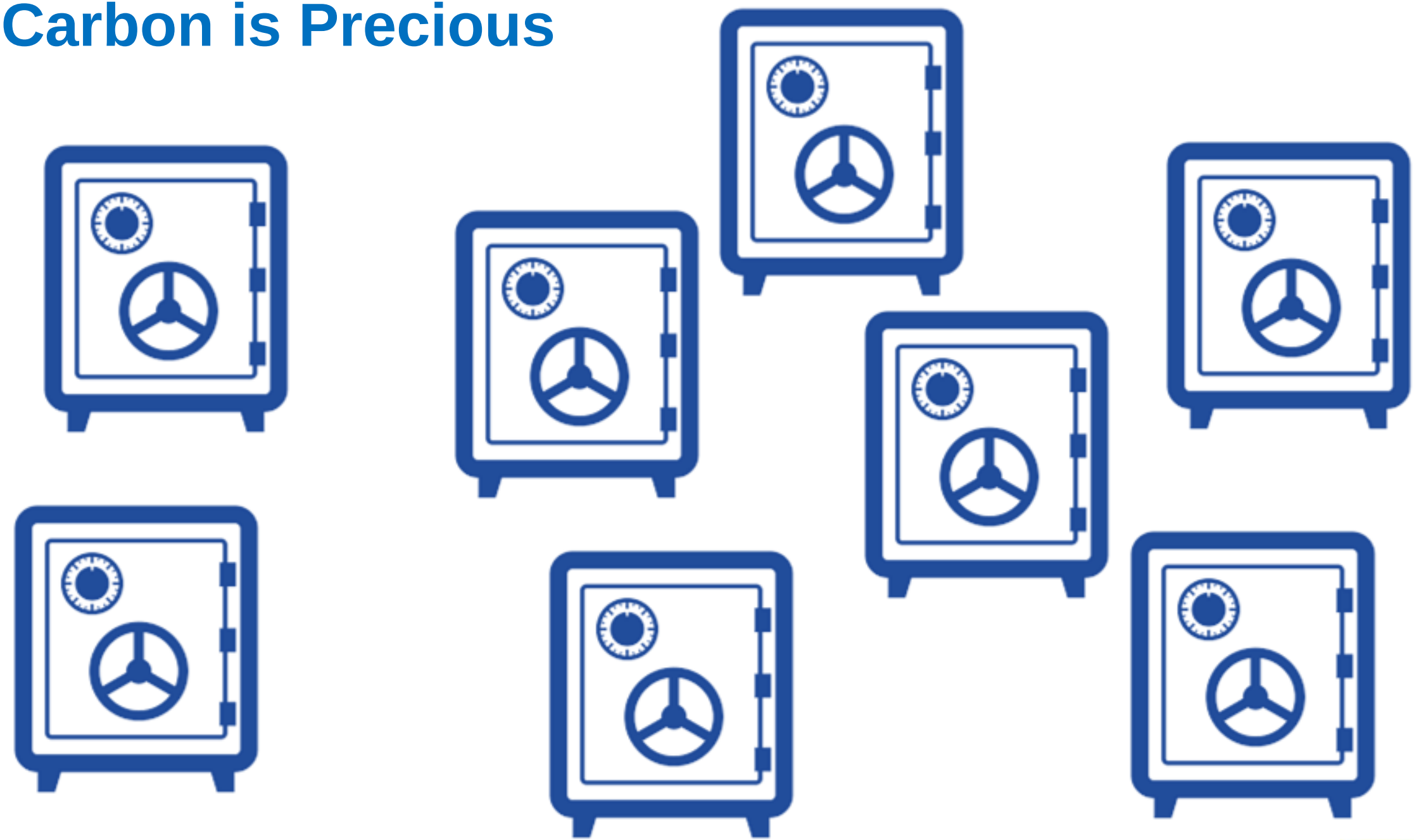


400 IPCC Scenarios with >50% meeting 2°C

344 Assume Largescale NET Deployment


SKOLSTREJK
FÖR
KLIMATET

All Carbon is Precious



Energy can be Carbon Free

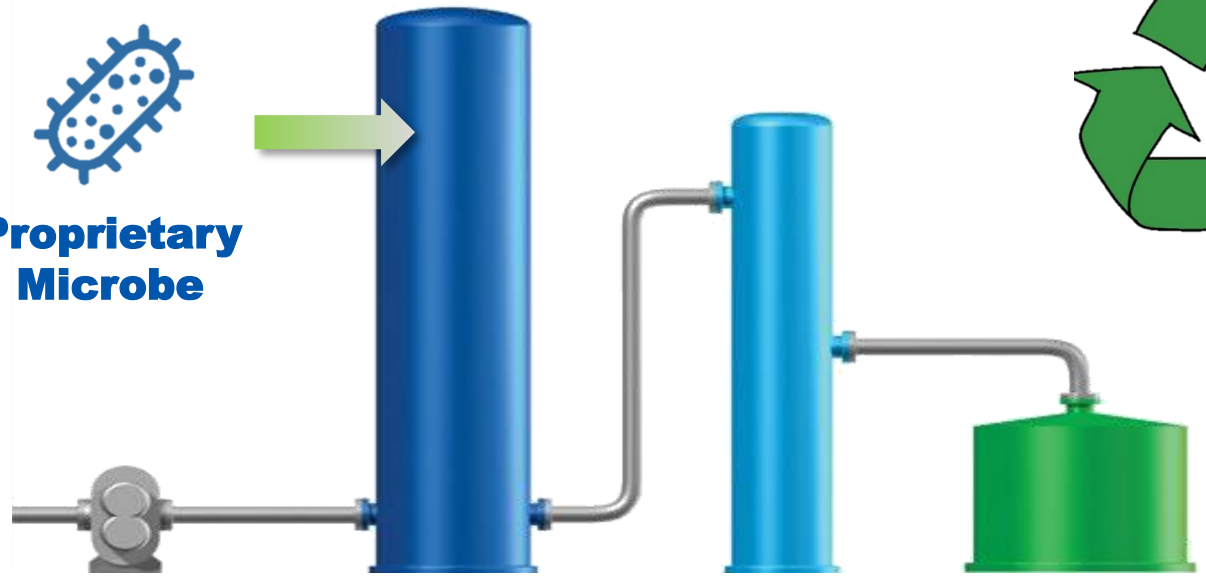
Chemicals for Everyday Products need Carbon

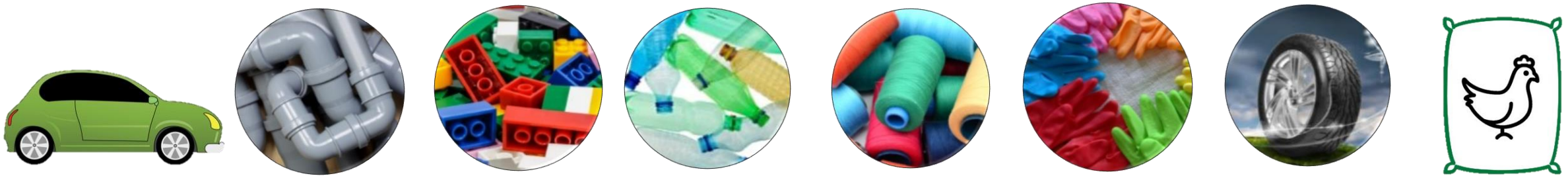
Aviation Fuel needs Carbon


C

Recycling Carbon

Industrial Off Gas
Biomass, MSW Syngas





>5 Million Gallons Ethanol Produced Since Start Up

It Takes…

Data

首钢朗泽
Shougang LanzaTech

Multiple Demo plants at various scales

80,000 operating hours

Time

LanzaTech

CELEBRATING
14 YEARS



Lab Pilot Demo

Commercial

Money

>$250M

khosla ventures
K1W1 K One W One Ltd.
CICC 中国国际金融有限公司 CHINA INTERNATIONAL CAPITAL CORPORATION LIMITED
MITSUI & CO.
IndianOil
QIMING VENTURE PARTNERS
NEW ZEALAND SUPERANNUATION FUND
BAOSTEEL
PETRONAS
SIEMENS
BASF We create chemistry
CITIC CAPITAL 中信資本
MLS Capital
SBCVC
SUNCOR ENERGY

Compelling Project Economics at 1st Commercial Plant

Production Levels that Enable Profitability

CapEx per Gallon of ~$3.25

Gas BTU Value

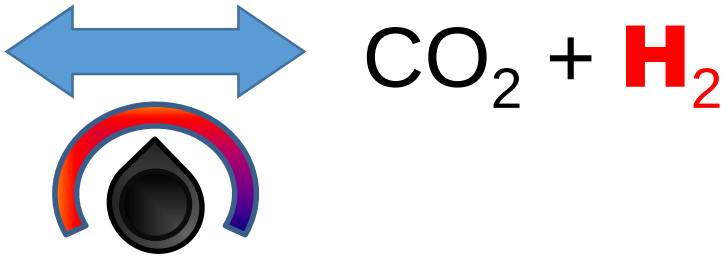
Payback Period ~3 Years

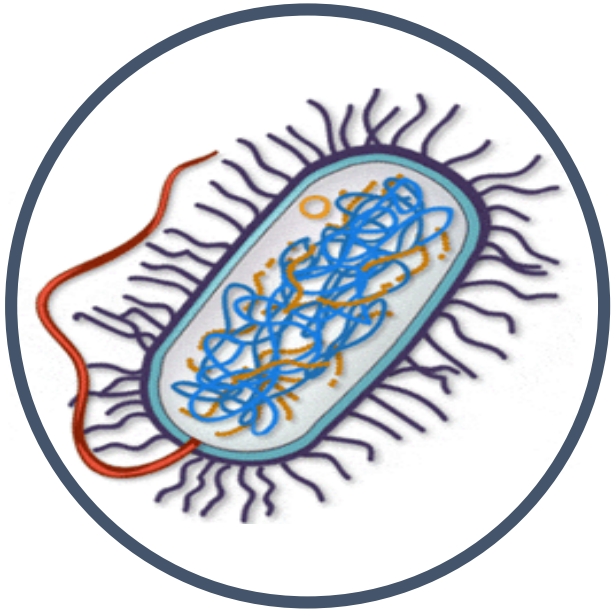
“…relevant scale”

“…relevant cost”

“…relevant adoption”

A Bacteria Which Does Water Gas Shift…





1. **Low H_2:** If H_2 is not available in the feed gas, the microbe can make H_2 from CO and H_2O as required
2. **High H_2**: Excess H_2 can be used to fix the carbon in CO_2
3. Higher carbon retention in presence of H_2

Enables the use of any CO:H_2 Ratio

Stoichiometric Conversion of C, H -> Ethanol

		H_2:CO ratio
CO	$6\ CO + 3\ H_2O \rightarrow \underline{EtOH} + 4\ CO_2$	0:1
$CO + H_2$	$3\ H_2 + 3\ CO \rightarrow \underline{EtOH} + CO_2$	1:1
$CO + H_2$	$4\ H_2 + 2\ CO \rightarrow \underline{EtOH} + H_2O$	2:1
$CO + H_2 + CO_2$	$5\ H_2 + 1\ CO + 1\ CO_2 \rightarrow \underline{EtOH} + 2\ H_2O$	5:1

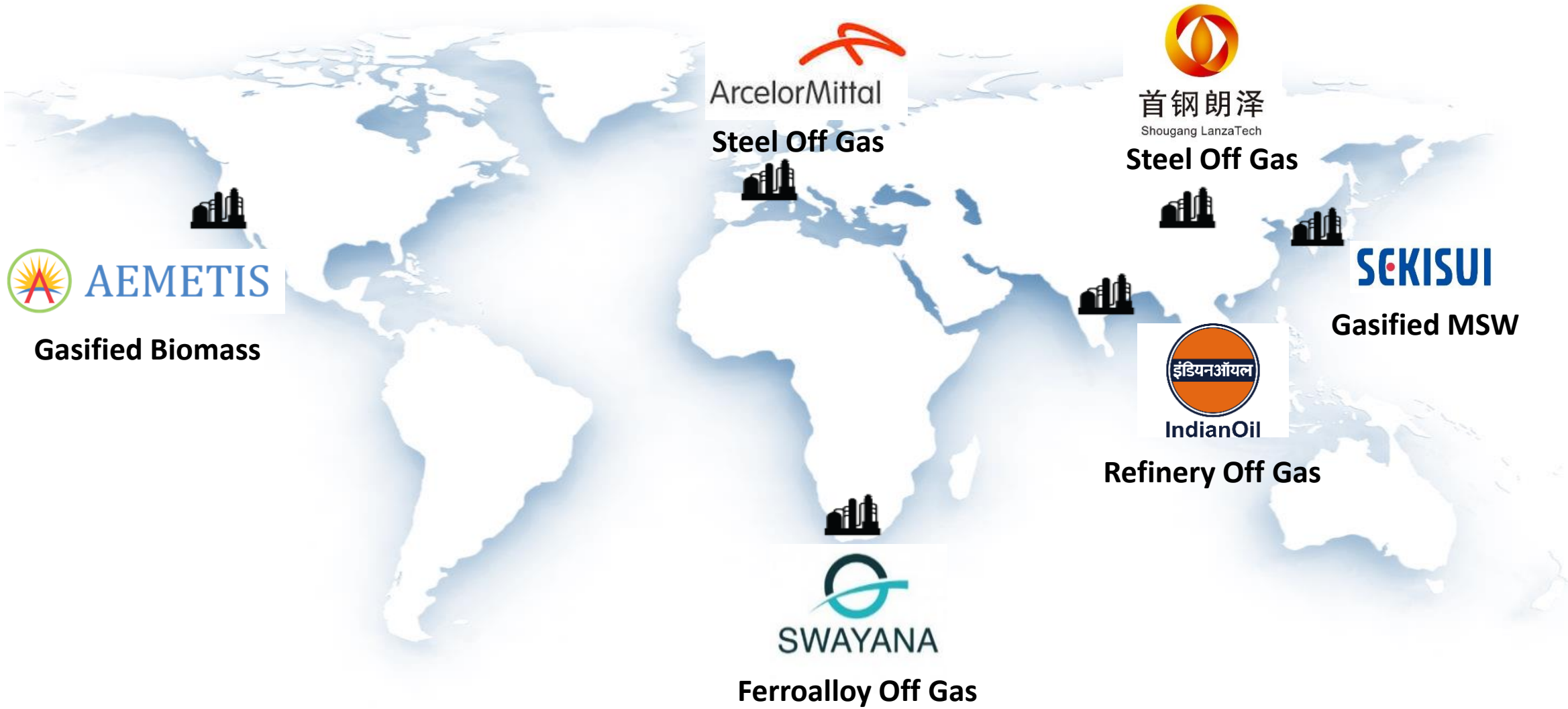
High CO off-gas (e.g. steel)
Demonstrated at scale

Syngas (e.g. MSW)
Demonstrated at scale

High H_2 off-gas (e.g. refinery)
Demonstrated at pilot, allows CO_2 fixing in products

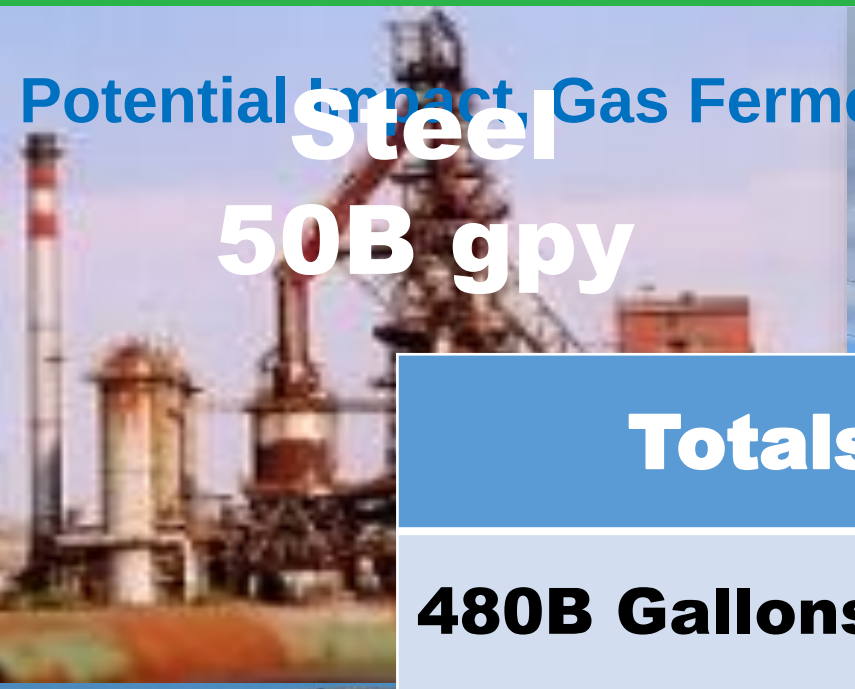
Any combination or interpolation of these can be used for ethanol production with only a change in operating conditions

Ethanol Build Out



Global Deployment using Multiple Feedstocks

Potential Impact, Gas Fermentation



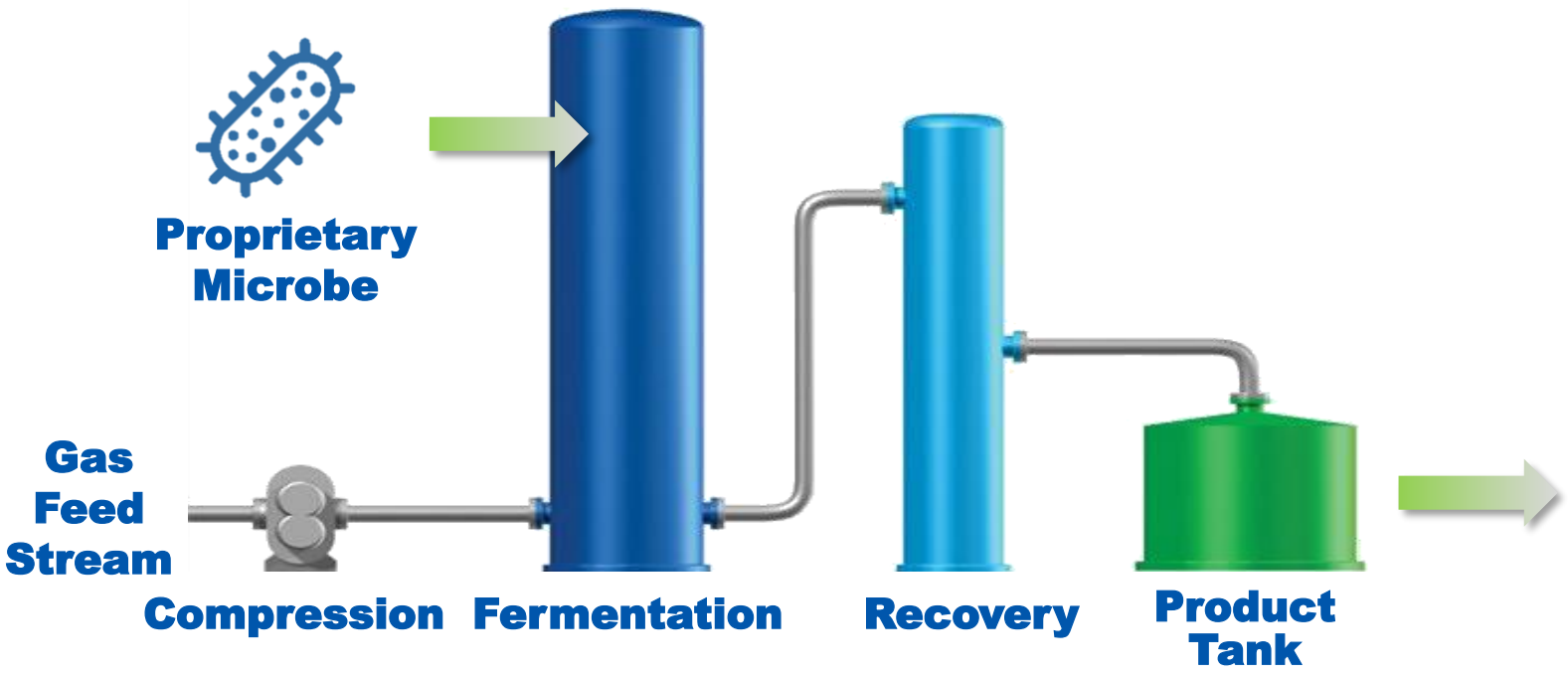
Totals/year	Relative to Today
480B Gallons	~35% of transport fuel
705M Cars off the road	~75% of passenger cars
2.6M mt CO_2	~7% of Global CO_2

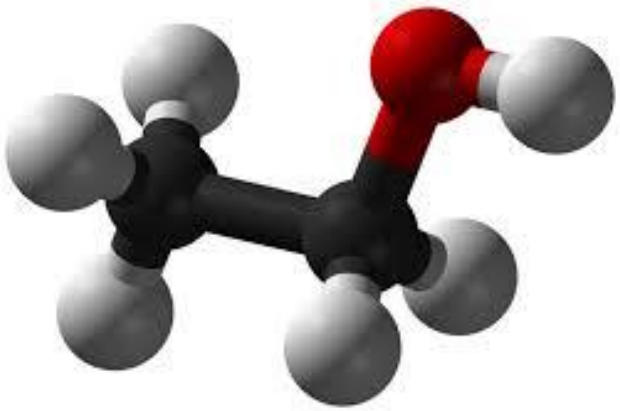
nput

Global Impact

Significant Global Potential

Recycling Carbon to Ethanol

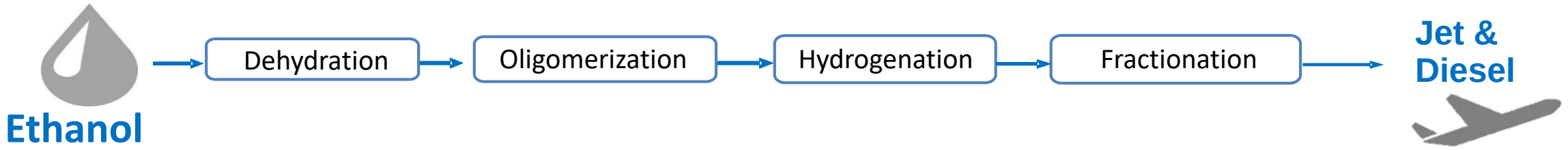


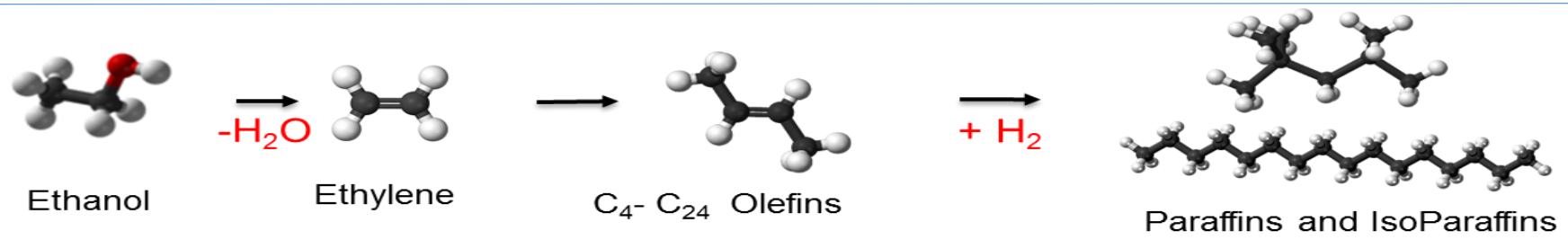


Ethanol

Excellent Substrate
Building Block of the Future

Alcohol-to-Hydrocarbons





Pacific Northwest NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

DARPA DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

FEDERAL AVIATION ADMINISTRATION

BOEING

首钢朗泽 Shougang LanzaTech

RSB Roundtable on Sustainable Biomaterials www.rsb.org

virgin atlantic

HSBC

Alcohol-to-Jet: Taking Off

✓ 4,000 gallons Jet
✓ 600 gallons Diesel
Waste Gas Ethanol from RSB Certified Facility
Grain Ethanol

Fuel Property	Jet A Spec	LanzaTech ATJ-SPK	50/50% v with Jet A
Freeze Point, °C	-40 max	-61	-54
Energy Density, MJ/kg	42.8 min	44.4	43.8
Thermal Stability	Baseline	Excellent	Excellent
Viscosity @ -40 °C mm^2/sec	12 max	7.0	9.3
Hydrogen %	13.4 min	15.1	14.5
Aromatics %	8 min, 25 max	Nil	8.8
Sulfur, total mass %	0.30 max	<0.001	0.02

ASTM INTERNATIONAL


Standard Specification for
Aviation Turbine Fuel Containing Synthesized Hydrocarbons

April 1, 2018
D7566 ATJ SPK Annex A5
✓ Ethanol feedstock
✓ Final blend ratio to max 50 %

National Research Council Canada
Conseil national de recherches Canada

Carbon Smart™

LanzaTech

LanzaJet Path to Economic Volumes

2015
Lab Scale

2016
Pilot Scale

2020
10MGY

2022
90MGY

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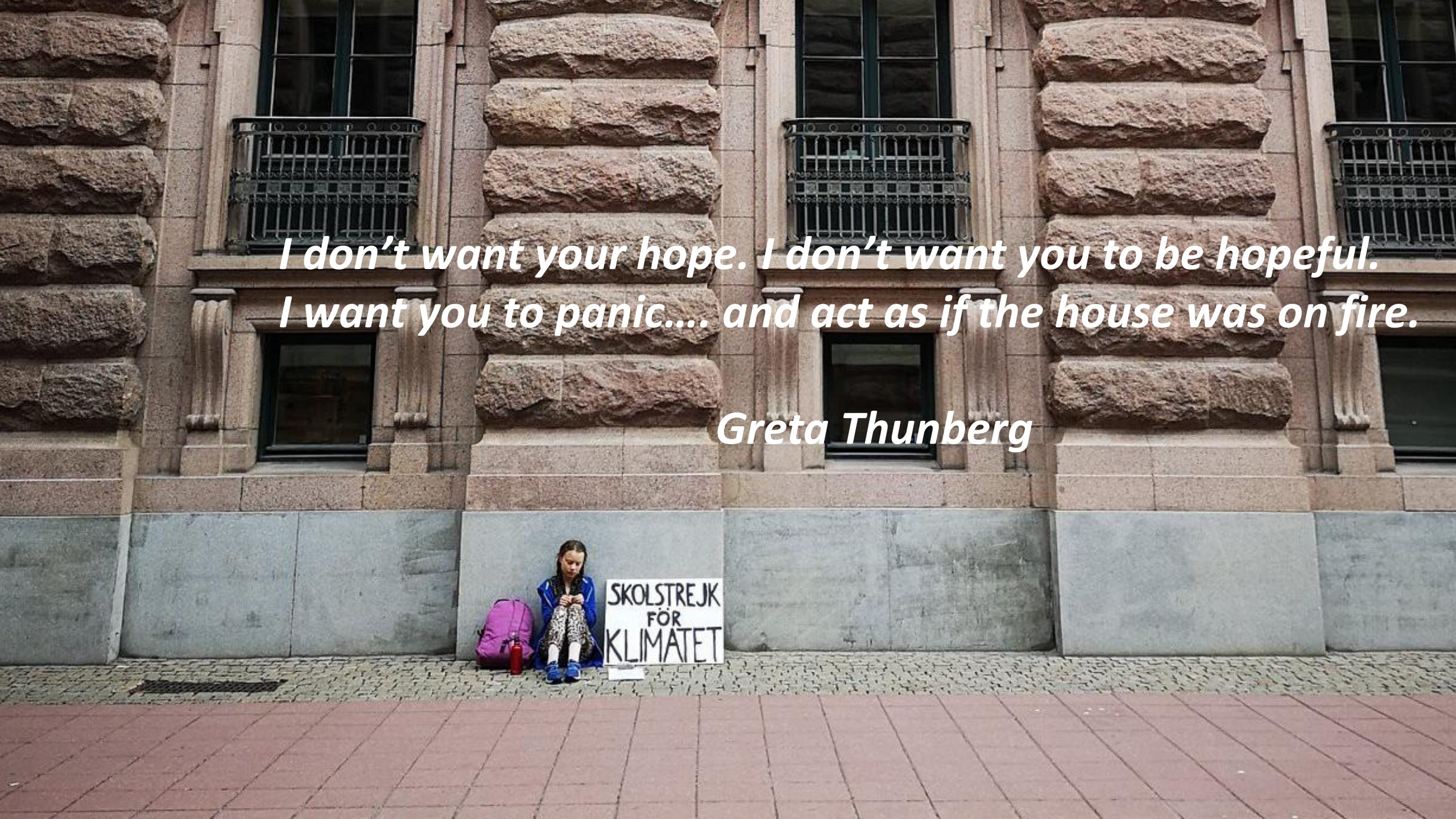
U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy



I don't want your hope. I don't want you to be hopeful.
I want you to panic…. and act as if the house was on fire.

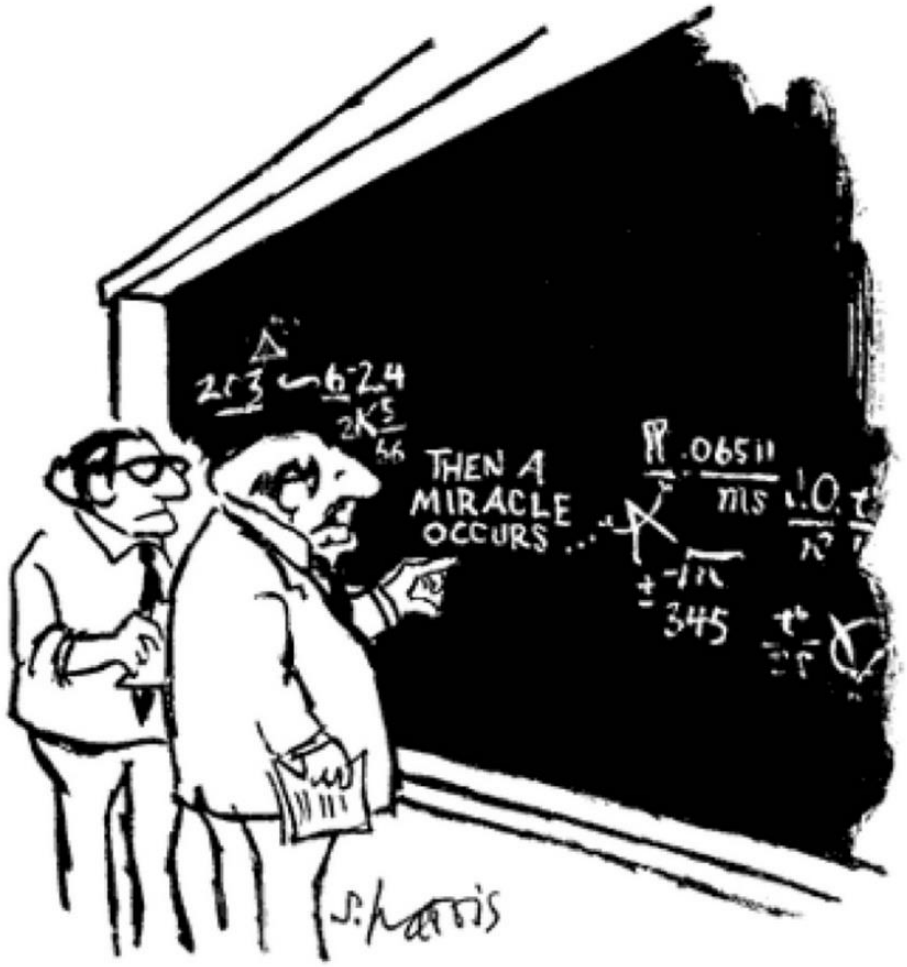
Greta Thunberg

We must adopt technology neutral positions and support all solutions.

We must fail quickly and move on.

We must collaborate to address environmental concerns and get new fuels to market quickly.

We need funding for every scale of commercialization from proof of concept through to first commercial units.



"I think you should be more explicit here in step two."

Need to Ensure all Solutions can Contribute Quickly

Share Print

GENERATION

Solar Panels Don't Work. And No One Knows.

By RAY BURGESS
on October 07, 2011 at 6:00 AM

Solar panels do not work that well. Often far below expectations.

The Economist explains

Explaining the world, daily

Previous | Next | Latest The Economist explains | All latest updates

The Economist explains

Why is renewable energy so expensive?

Jan 5th 2014, 23:50 BY M.J.

…rbon emissions from power stations are a significant cause of
…s a fiercer argument is over what to do about it. Many
…noney into renewable sources of electricity, such as wind

Special Reports

Solyndra Scandal

Key coverage of the investigation into Solyndra, the Silicon Valley startup that collapsed, leaving taxpayers liable for $535 million in federal guarantees .

Documents show politics infused Obama 'green' programs

Joe Stephens and Carol D. Leonnig DEC 25, 2011

Since the failure of solar-panel company Solyndra, President Obama's $80 billion clean-technology program has begun to look like a political liability.

AB InBev Gets $2.9 Billion Offer for Europe Brands

Coca-Cola Fights for 'Zero' Trademark

Time Warner Outlook Solid; Revenue Misses

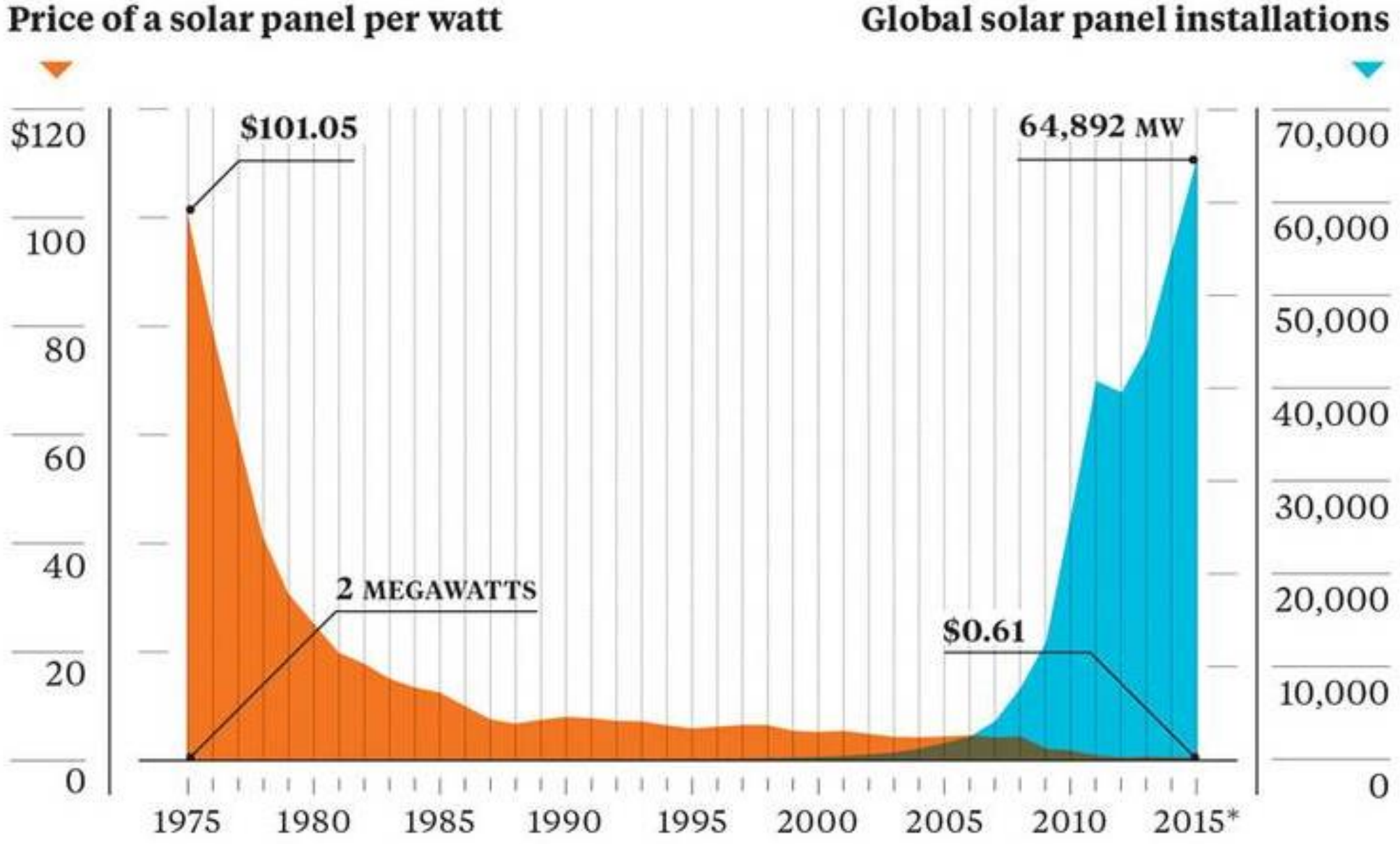
Uber Gears Up for French Court Battle

BUSINESS

Evergreen Solar to Abandon Massachusetts Factory

2010

Image: REUTERS/Jean-Paul Pelissier



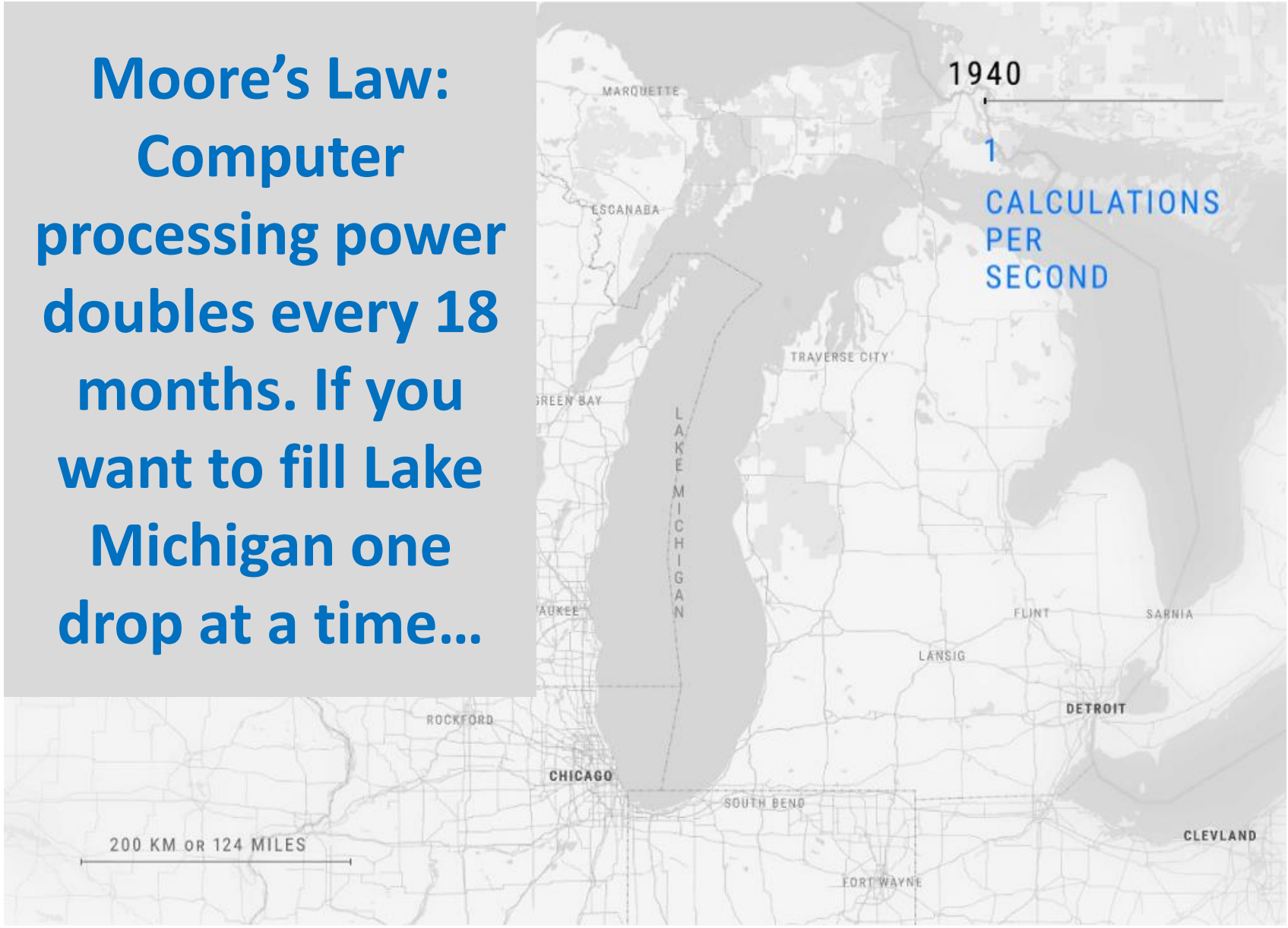
2017
98,000

2017
$0.37

Earth Policy Institute 2015/Bloomberg

Exponential Growth

Moore's Law: Computer processing power doubles every 18 months. If you want to fill Lake Michigan one drop at a time…



"The fight is won or lost far away from witnesses - behind the lines, in the gym and out there on the road, long before I dance under those lights."

Muhammad Ali