

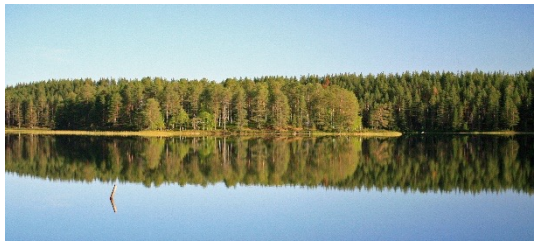

CARBON CAPTURE, UTILIZATION & STORAGE
ACCELERATING CCUS TOGETHER
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

Biomass Carbon Removal and Storage BiCRS

CEM CCUS Initiative Webinar, in collaboration with Innovation for Cool Earth Forum

Wednesday 16 June 2021, 14:00 – 15:00 CET

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

Innovation for Cool Earth Forum

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Some Housekeeping Items (continued)

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https://www.youtube.com/user/cleanenergypolicy

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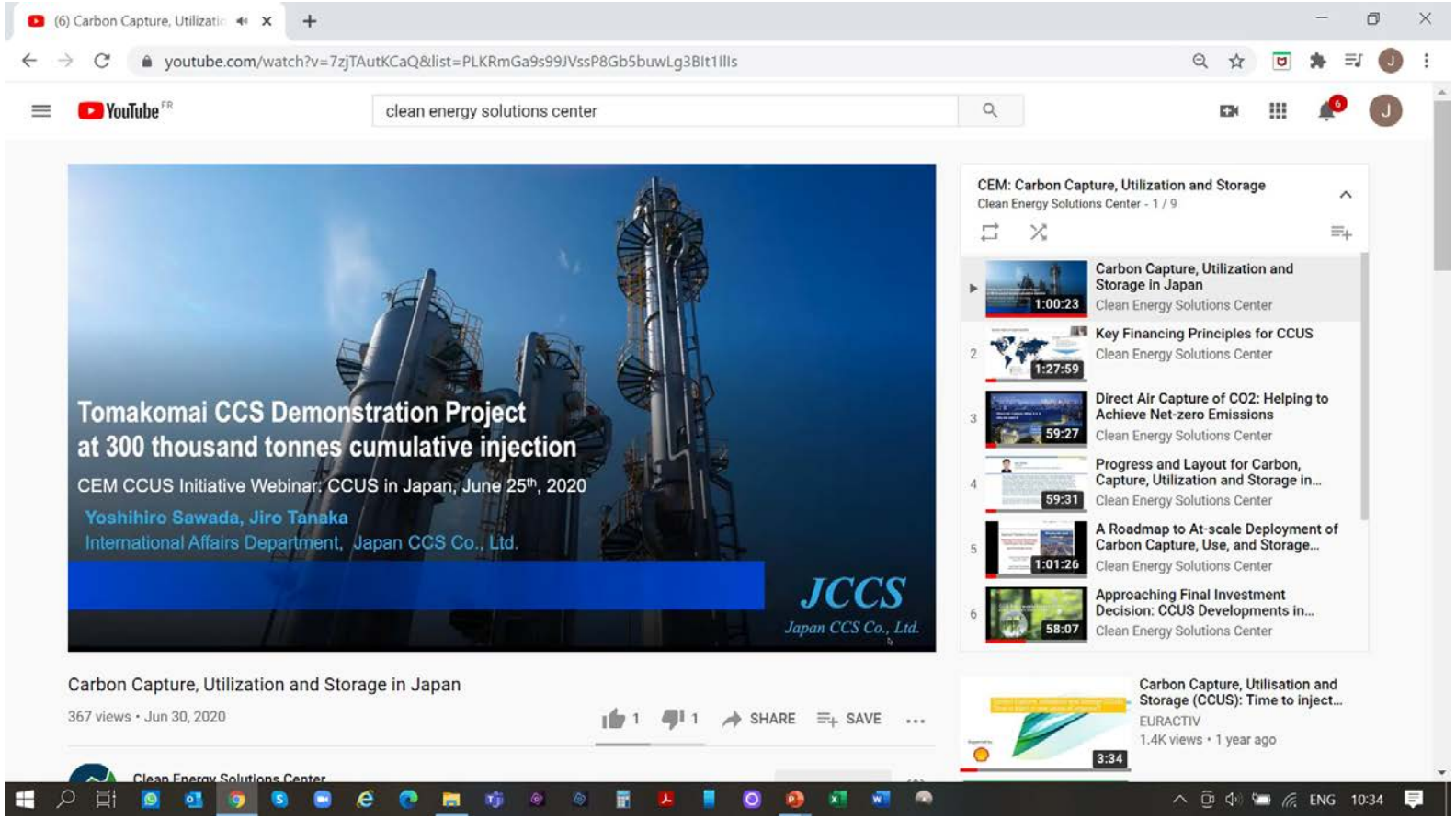
Webinars to disseminate country and sector experience



https://www.youtube.com/playlist?list=PLKRmGa9s99JVssP8Gb5buwLg3BIt1IlIs

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AGENDA

1

Welcome & Introductory Remarks

Welcome from CEM CCUS

- Jarad Daniels
  Director
  US Department of Energy

Background from ICEF:

- Nobuo Tanaka
  Special Advisor
  Sasakawa Peace Foundation

2

Biomass Carbon Removal and Storage

- David Sandalow
  Inaugural Fellow
  Center on Global Energy Policy
  Columbia University
- Julio Friedmann
  Senior Research Scholar
  Center on Global Energy Policy
  Columbia University
- Roger Aines
  Energy Program Chief Scientist
  Lawrence Livermore National Laboratory (LLNL)

3

Panel Discussion and Q&A Session

- All speakers

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Jarad Daniels
Director, Office of Strategic Planning, Analysis, and Engagement
U.S. Department of Energy

Jarad Daniels leads the Office of Strategic Planning, Analysis, and Engagement within the Department of Energy (DOE) Office of Fossil Energy, including domestic programs and international engagements conducted in close collaboration with industry, academia, and multi-lateral organizations.

Mr. Daniels has twenty-five years of experience with the DOE, managing advanced technology programs and working in several national laboratories throughout the United States. His expertise includes domestic and global energy and environmental technologies, policies, and programs.

Mr. Daniels holds a Master of Science degree in Chemical Engineering from the University of California at Berkeley.

Nobuo Tanaka
Special Advisor
Sasakawa Peace Foundation
Former IEA Executive Director

Nobuo Tanaka is former Chairman, and currently Special Advisor of The Sasakawa Peace Foundation. He is also the chairman of the Innovation for Cool Earth Forum (ICEF). As Executive Director of the International Energy Agency (IEA) from 2007 to 2011, he initiated a collective release of oil stocks in June 2011. He also played a crucial and personal role in the strengthening of ties with major non-Member energy players, including China and India.

He began his career in 1973 in the Ministry of Economy, Trade and Industry (METI), and has served in a number of high-ranking positions, including Director-General of the Multilateral Trade System Department. He was deeply engaged in bilateral trade issues with the US as Minister for Industry, Trade and Energy at the Embassy of Japan, Washington DC. He has also served twice as Director for Science, Technology and Industry (DSTI) of the Paris-based international organization, OECD.

David Sandalow
Inaugural Fellow
Center on Global Energy Policy
Columbia University

David Sandalow is the Inaugural Fellow at the Center on Global Energy Policy and co-Director of the Energy and Environment Concentration at the School of International and Public Affairs at Columbia University. He founded and directs the Center's U.S.-China Program and is author of the Guide to Chinese Climate Policy.

Mr. Sandalow also serves as chair of the ICEF Innovation Roadmap Project. In that capacity, he has led development of roadmaps on biomass carbon removal and storage, industrial decarbonization, direct air capture and carbon dioxide utilization, among other topics.

Mr. Sandalow has served in senior positions at the White House, U.S. State Department and U.S. Department of Energy. He played a central role in launching the Clean Energy Ministerial in 2010.

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Dr. Julio Friedmann
Senior Research Scholar
Center on Global Energy Policy
Columbia University

Dr. Julio Friedmann is a Senior Research Scholar at the Center for Global Clean Energy Policy at Columbia University, where he leads a new initiative in carbon management. He is also CEO of Carbon Wrangler, LLC. Julio has served as Principal Deputy Assistant Secretary for the Office of Fossil Energy at the Department of Energy, where he held responsibility for DOE's R&D program in advanced fossil energy systems, carbon capture, and storage (CCS), CO2 utilization, and clean coal deployment. He has also held positions at Lawrence Livermore National Laboratory, including Senior Advisor for Energy Innovation and Chief Energy Technologist, is a Distinguished Associate at the Energy Futures Initiative, and serves as a special advisor to Total SA and the Global CCS Institute. He was recently named as a Senior Fellow to the Breakthrough Institute and a Stanford Precourt Scholar.

Dr. Friedmann is one of the most widely known and authoritative experts in the U.S. on carbon removal (CO2 drawdown from the air and oceans), CO2 conversion and use (carbon-to-value), and carbon capture and sequestration. Dr. Friedmann received his Bachelor of Science and Master of Science degrees from the Massachusetts Institute of Technology (MIT), followed by a Ph.D. in Geology at the University of Southern California. He worked for five years as a senior research scientist at ExxonMobil, then as a research scientist at the University of Maryland.

Roger Aines
Energy Programme Chief Scientist
Lawrence Livermore National Laboratory

Roger Aines is the Chief Scientist of the Energy Program at Lawrence Livermore National Laboratory. He holds a Bachelor of Arts degree in Chemistry from Carleton College, and Doctor of Philosophy in geochemistry from the California Institute of Technology.

Roger leads the Carbon Initiative at LLNL, which aims to understand, develop, and implement technologies for the removal of carbon dioxide from the atmosphere, so-called negative emissions technologies. He has been at LLNL since 1984 working on nuclear waste disposal, environmental remediation, application of stochastic methods to inversion and data fusion, management of carbon emissions including separation technology, and monitoring and verification methods for sequestration. With Amy Aines he authored the recently released Championing Science, a book that helps scientists communicate more effectively with decision makers.

The Clean Energy Ministerial (CEM) is a global process

27 CEM Members

90%

Clean energy investments

75%

Global CO_2 emissions

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

The CEM CCUS Initiative

Lead countries: Norway, Saudi Arabia, the United States and United Kingdom

Participating CEM members: Canada, China, Japan, Mexico, Netherlands, South Africa and United Arab Emirates; in addition, the European Commission is an observer

Industry: oil and gas, cement, steel, …

Financial institutions: private banks, investment firms, multilateral banks (MDBs)

Organizations: Carbon Sequestration Leadership Forum (CSLF), International Energy Agency (IEA), IEA Greenhouse Gas R&D Programme (IEAGHG), Mission Innovation (MI), Global CCS Institute (GCCSI), and Oil and Gas Climate Initiative (OGCI)

CEM CCUS Initiative: accelerating CCUS together by:

1

Actively **including CCUS** within Clean Energy Ministerial agenda and global clean energy discussions.

2

Bringing **together** governments, the private sector and the investment community.

CARBON CAPTURE, UTILIZATION & STORAGE
ACCELERATING CCUS TOGETHER
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

3

Facilitating identification of both near and longer-term **investment opportunities**.

4

Disseminating **best practice** in CCUS policy, regulation and investment.

CEM12/MI·6
CHILE 2021

CCUS events at CEM-12

1. "ACCELERATING CCUS"
HIGH-LEVEL FIRESIDE CHAT

Monday 31 May

2. CCUS 101:
How is CO_2 captured and stored?

With:
IEA
IEAGHG
Global CCS Institute

3. Stakeholder testimonies: How can my organization accelerate CCUS?

With:
Asian Development Bank
International CCS Knowledge Centre
Global Cement and Concrete Association
Port of Rotterdam
BHP

Créditos o pie de la imágen

IN DOCUMENT LIBRARY: CSLF 2021 Technology Roadmap, GCCSI Global Status of CCS etc.!

Recordings available:
https://cem12mi6chile.com/

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

MISSION INNOVATION
accelerating the clean energy revolution

ICEF 2020 and Japan's Path toward Carbon Neutrality

2021-6-16 CEM

Nobuo TANAKA

Chairman of the Steering Committee

The Innovation for Cool Earth Forum (ICEF)

Innovation for Cool Earth Forum (ICEF)

- To raise awareness and promote discussion on innovations in energy and environmental technologies, ICEF started its activity in 2014.
- Gathering experts, the annual event in every October shares the latest topics and trends with 1,000 audiences from areas of business, policy making and academia.

ICEF Steering Committee Members: 2020-2021

Nobuo Tanaka(Chair)
Special Advisor, The Sasakawa Peace Foundation
Former Executive Director, International Energy Agency (IEA), Japan

David Sandalow
Inaugural Fellow, Center on Global Energy Policy, Columbia University, United States

Reiko Kuroda
Designated Professor, Institute of Science and Technology Research, Chubu University; Professor Emeritus, The University of Tokyo, Japan

Georg Erdmann
Retired Professor for Energy Systems, Berlin University of Technology, Germany

Vaclav Smil
Distinguished Professor Emeritus, University of Manitoba, Canada

Ismail Serageldin
Founding Director of the Library of Alexandria, Egypt

Valli Moosa
Head of the South African Presidential Climate Change Coordinating Commission, Republic of South Africa

Hoesung Lee
Chair of the IPCC; Endowed Chair Professor, Graduate School of Energy and Environment, Korea University, Korea

Richard K. Lester
Associate Provost, Massachusetts Institute of Technology, United States

Laurence Tubiana
CEO, European Climate Foundation; Chair of the Board of Governors, French Development Agency; Professor, Sciences Po Paris, France

Kenji Yamaji
Senior Vice President/Director-General, Research Institute of Innovative Technology for the Earth (RITE); Professor Emeritus, The University of Tokyo, Japan

Jon Moore
Chief Executive Officer, BloombergNEF, United Kingdom

Sally M. Benson
Professor, Department of Energy Resources Engineering, School of Earth Energy & Environmental Sciences, Stanford University, United States

Itaru Yasui
Honorary Adviser, National Institute of Technology and Evaluation (NITE); Professor Emeritus, The University of Tokyo, Honorary Adviser, Institute for Promoting Sustainable Societies, Japan

Eija-Riitta Korhola
Delegate of the Consultative Commission on Industrial Change; Advisor in the EU affairs, Finland

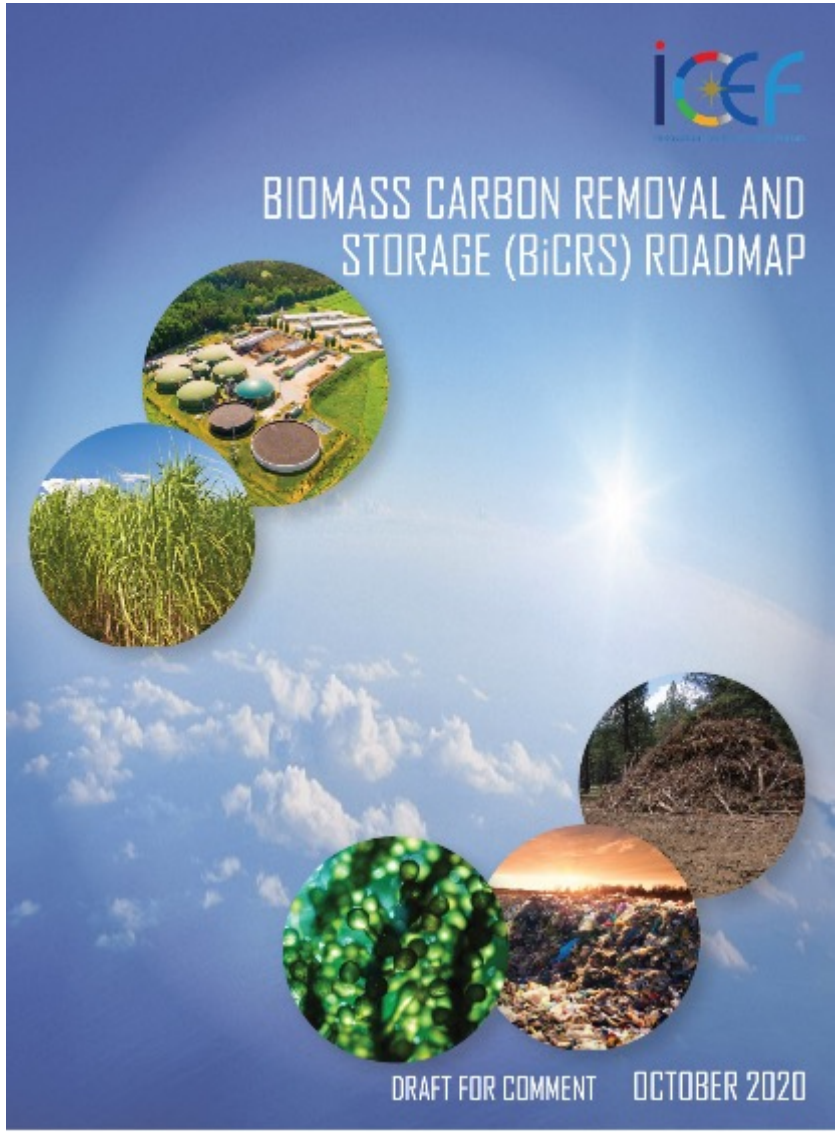
Nebojsa Nakicenovic
Executive Director, The World in 2050 (TWI2050)

Activities

- Choose topics for panel discussions that are relevant to technological and societal innovation on energy and environment.
- As one of out put, ICEF publishes Road Map on specific technology which are deemed to have impact on technological development

	Main theme	Road map topic
2014	The Role of Innovation for Addressing Climate Change	
2015	Principal Issues in the Future GHG Reduction	Distributed Solar and Storage
2016	Importance of Net Zero Emission of CO2 and Innovation for Realizing the Net Zero Anthropogenic Emission of CO2	CO2 Utilization and ZEB/ZEH
2017	Further Exploration of Innovations toward Achieving Global Net-Zero Anthropogenic Emissions of CO2	CO2 Utilization 2.0 and Energy Storage
2018	Driving Green Innovation	Direct Air Capture of Carbon Dioxide
2019	Bending down the emissions trajectory by Innovation and Green Finance	Industrial Heat Decarbonization
2020	Action toward “Beyond Zero” emission society in light of COVID-19; with a focus on gender equality	BiCRS : Biomass Carbon Removal and Storage

ICEF 2020 RoadMap Project



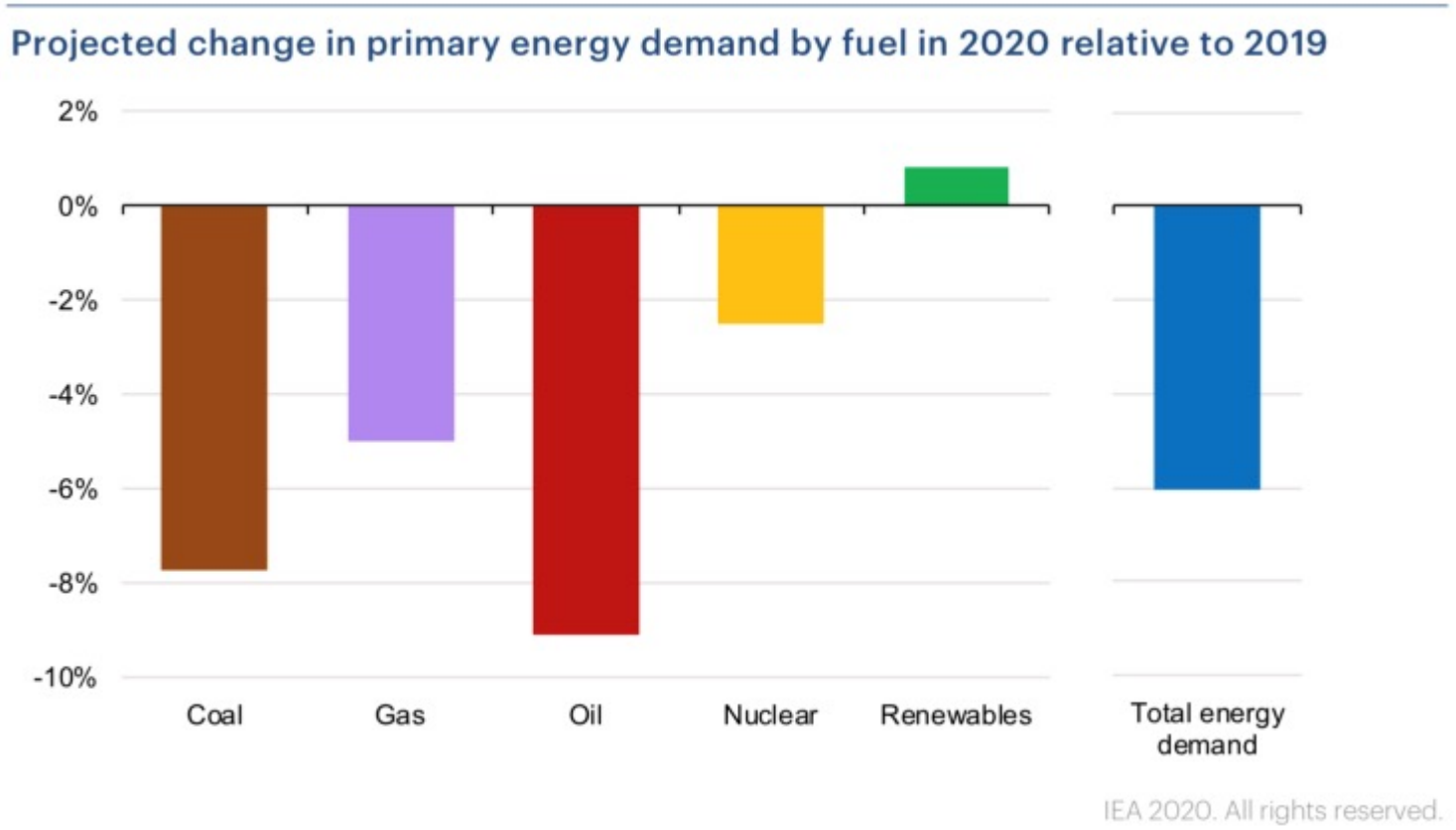
Leads to the new term: BIOMASS CARBON REMOVAL AND STORAGE

BECCS

BiCRS

BiCRS feedstocks are available for 2.5 to 5 GT CO2 removal/year by 2050

Dr. Fatih Birol, Executive Director of the International Energy Agency (IEA), said that COVID19 made for a historic "Black April" for the oil markets. **Renewable Energy is a sole WINNER!**



Global Energy Review 2020

But he recently said, "Today, I'm more optimistic than ever about the world's ability to reach the goals of the Paris agreement,,. Even the,,, 1.5 degrees seems less remote than it did a year ago." (2021-1-13)

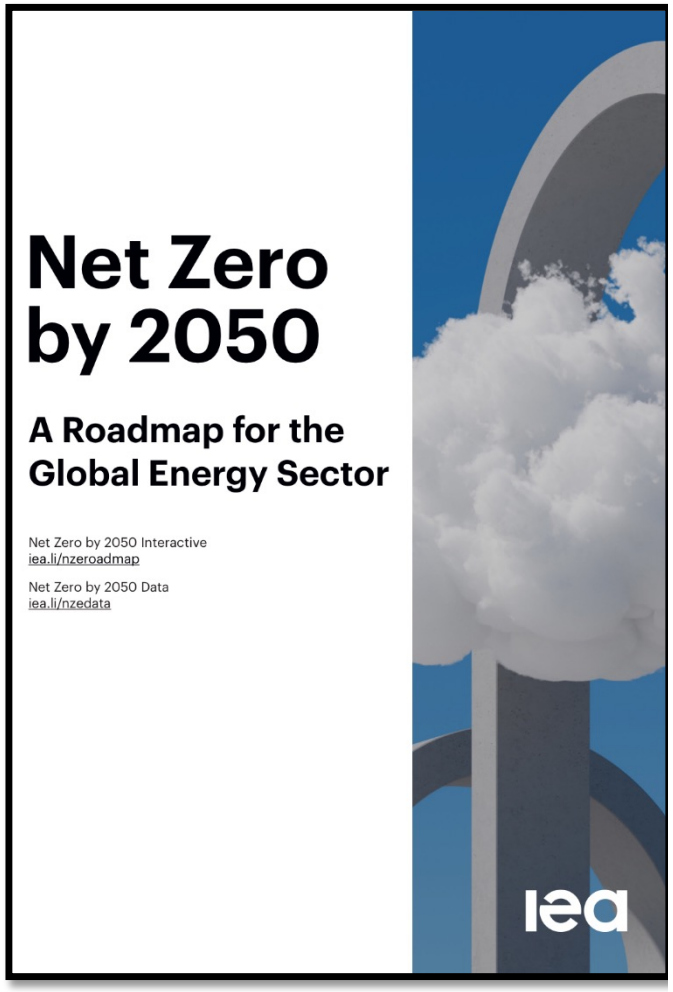
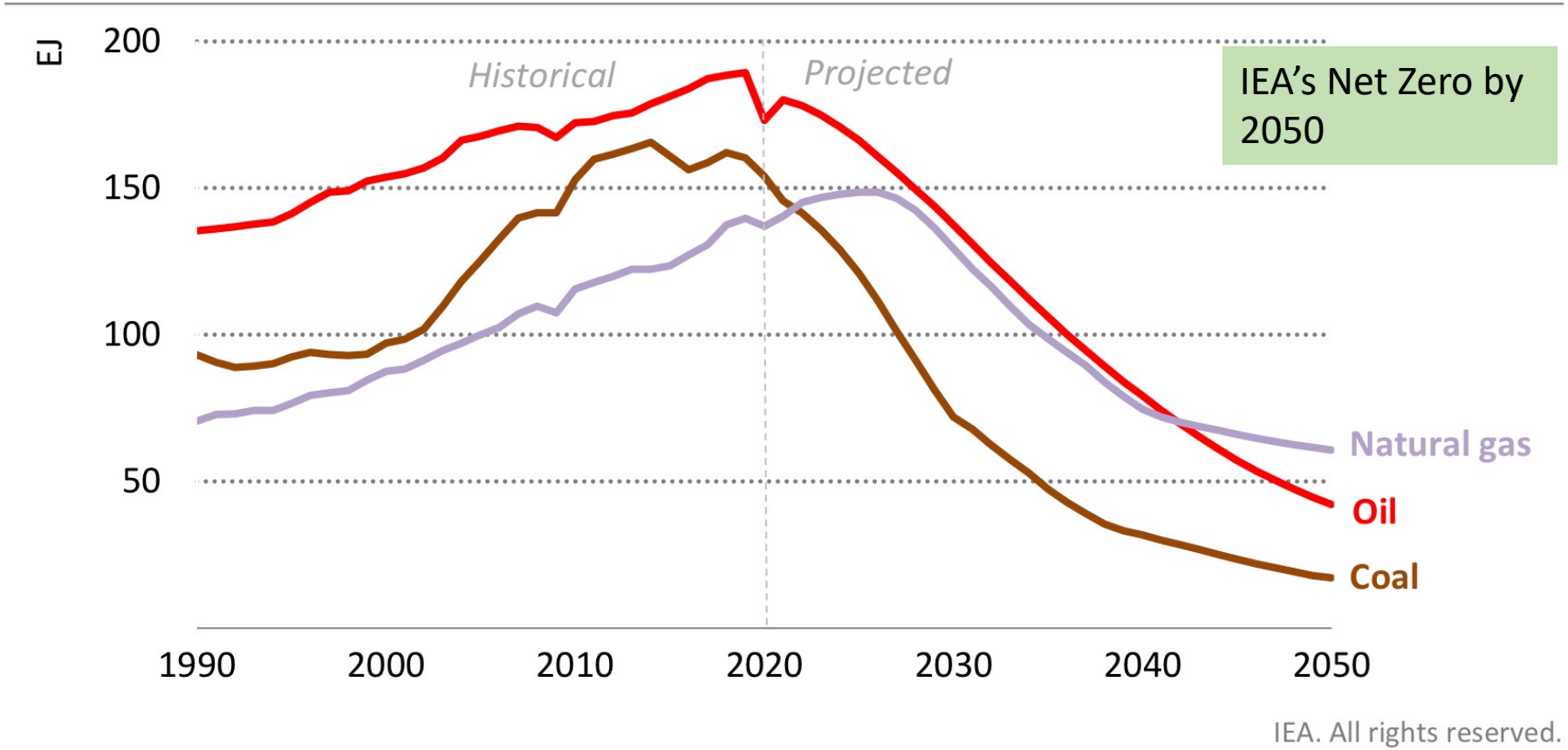


Figure 3.2 ▷ Coal, oil and natural gas production in the NZE

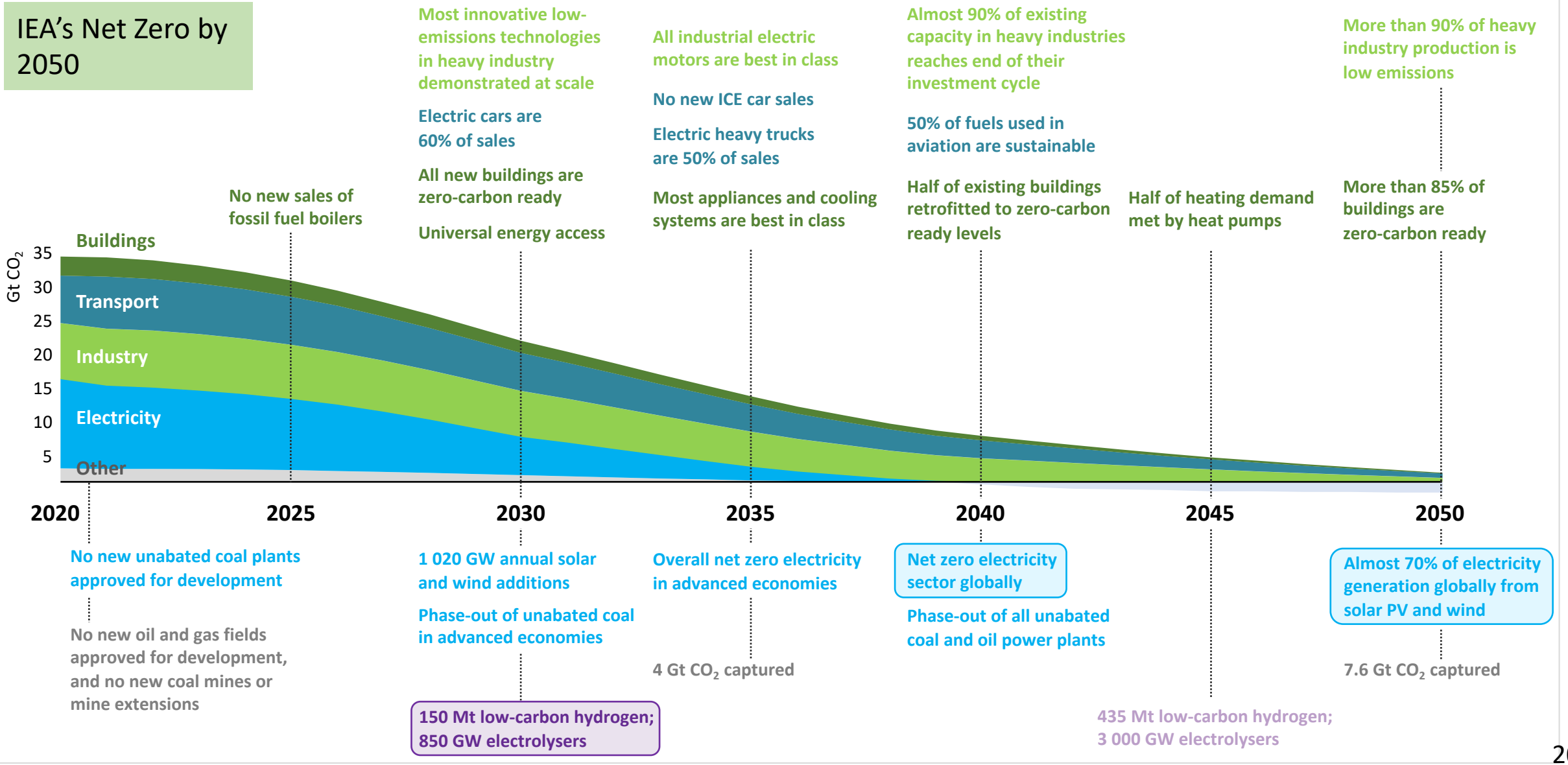


Between 2020 and 2050, demand for coal falls by 90%, oil by 75%, and natural gas by 55%

IEA's Faith BIROL said that Energy groups must stop all new oil and gas exploration projects from this year if NZ2050 should happen.

Set near-term milestones to get on track for long-term targets

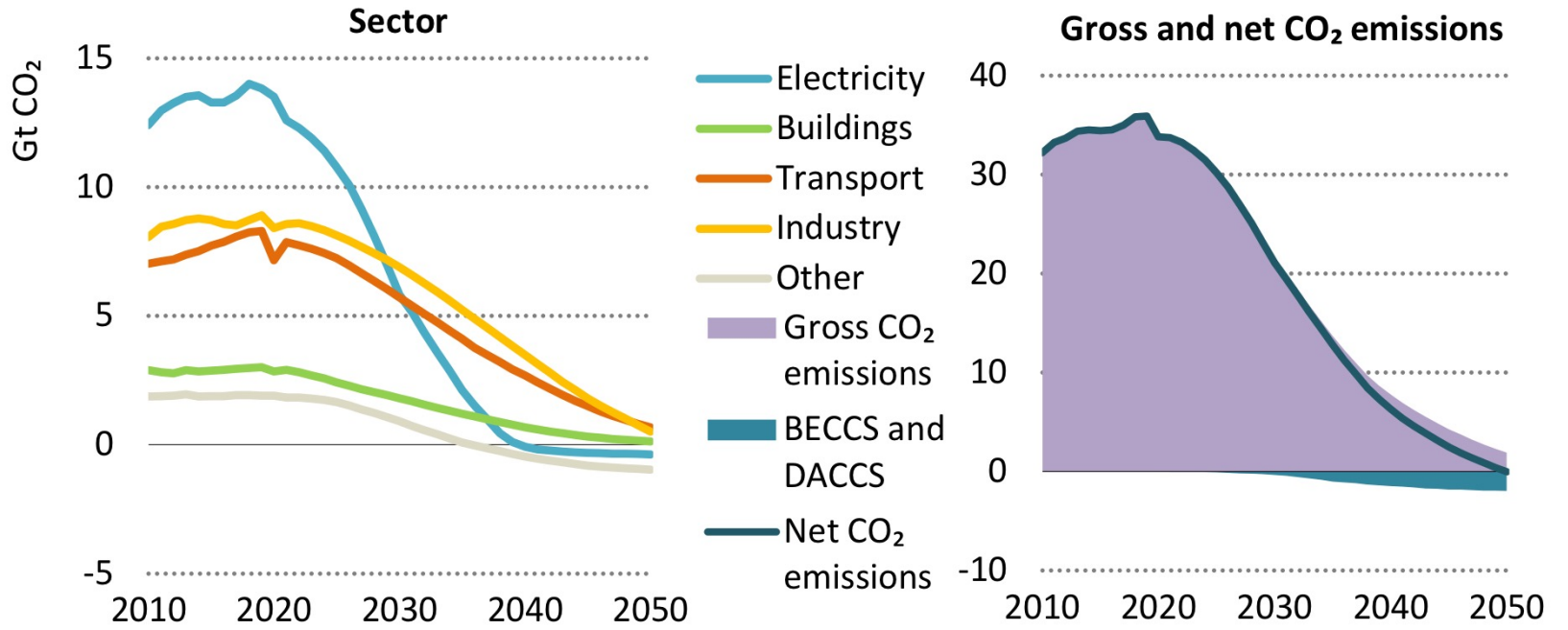
IEA's Net Zero by 2050



Emissions from electricity fall fastest, with declines in industry and transport accelerating in the 2030s. Around 1.9 Gt CO2 are removed in 2050 via BECCS and DACCS.

IEA's Net Zero by 2050

Figure 2.3 ▷ Global net-CO_2 emissions by sector, and gross and net CO_2 emissions in the NZE



Emissions from electricity fall fastest, with declines in industry and transport accelerating in the 2030s. Around 1.9 Gt CO_2 are removed in 2050 via BECCS and DACCS.

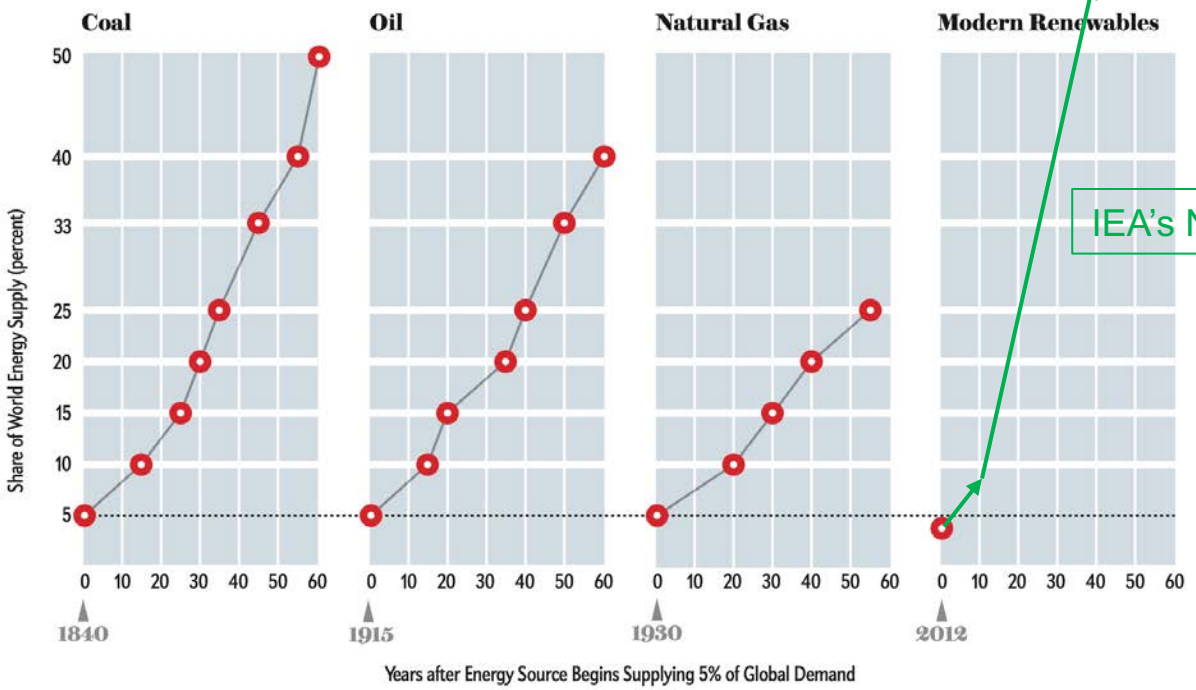
BiCRS feedstocks are available for 2.5 to 5 GT CO2 removal/ year by 2050

How fast is the coming energy transformation?

Vaclav Smil vs IEA's Net Zero by 2050

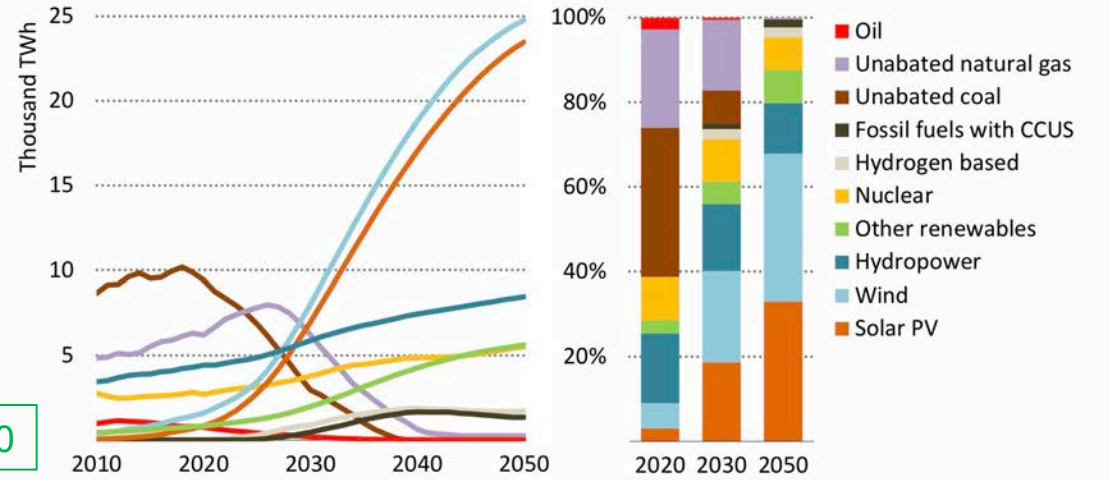
Many Years Needed to Take Over the Energy World

Each major energy source that has dominated world supply has taken 50 to 60 years to rise to the top spot. Coal reached 5 percent of global supply in 1840 (*bottom left*) and gradually took over from wood, reaching 50 percent some 60 years later, around 1900. Subsequent transitions to oil and natural gas have followed a similar pattern in reaching benchmark levels of supply (*vertical axis*), rising steadily after they achieve 5 percent. Oil has not yet reached 50 percent and may never. Natural gas is still partway along the path and is taking longer to ascend. The so-called modern renewable energy sources—wind, solar, geothermal and liquid biofuels—have hit only about 3.4 percent; unless a disruptive technology or revolutionary policy speeds up change, they, too, may be destined for a long transition.



IEA's NZ2050

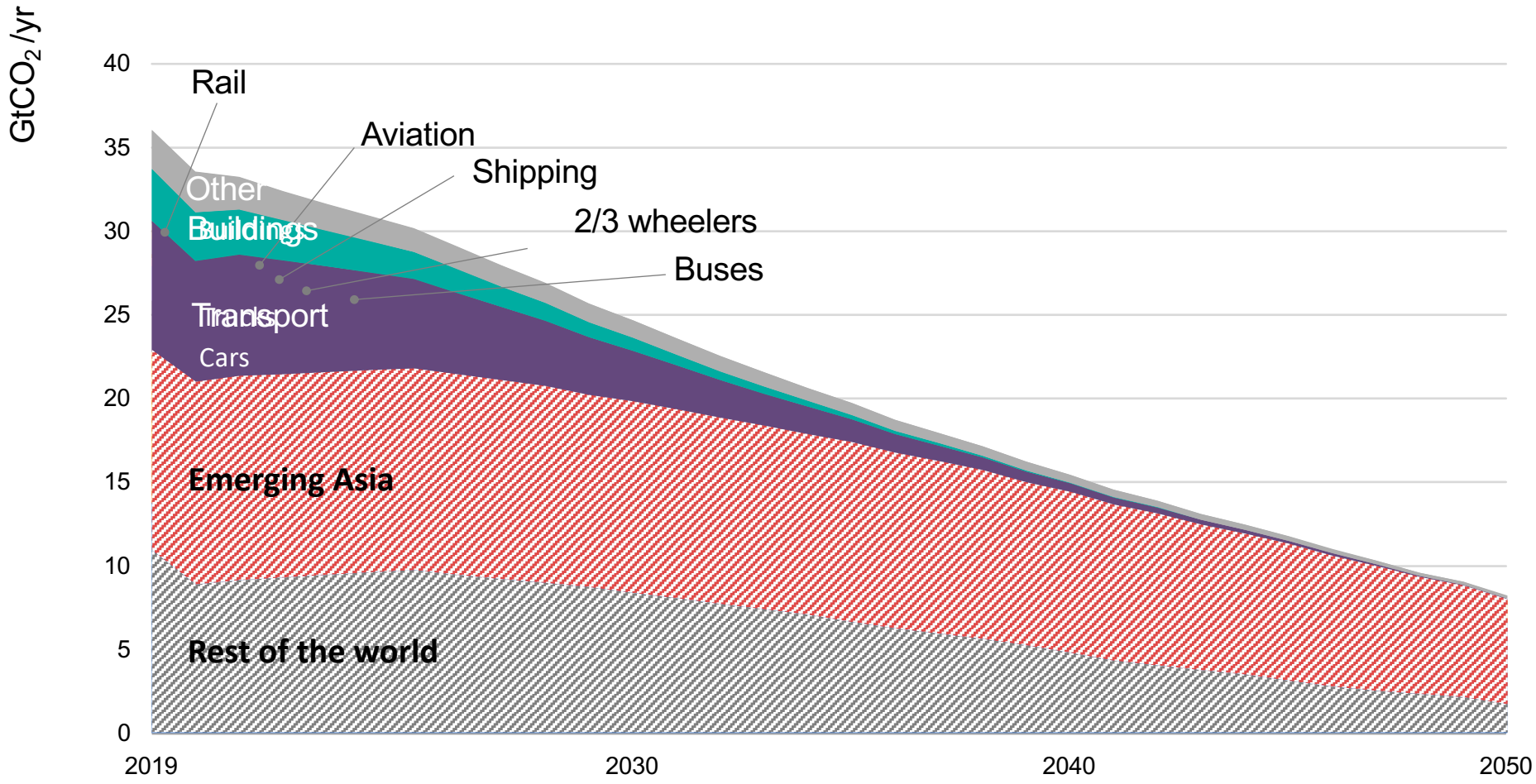
Figure 3.10 ▷ Global electricity generation by source in the NZE



Solar and wind power race ahead, raising the share of renewables in total generation from 29% in 2020 to nearly 90% in 2050, complemented by nuclear, hydrogen and CCUS

IEA's Net Zero by 2050

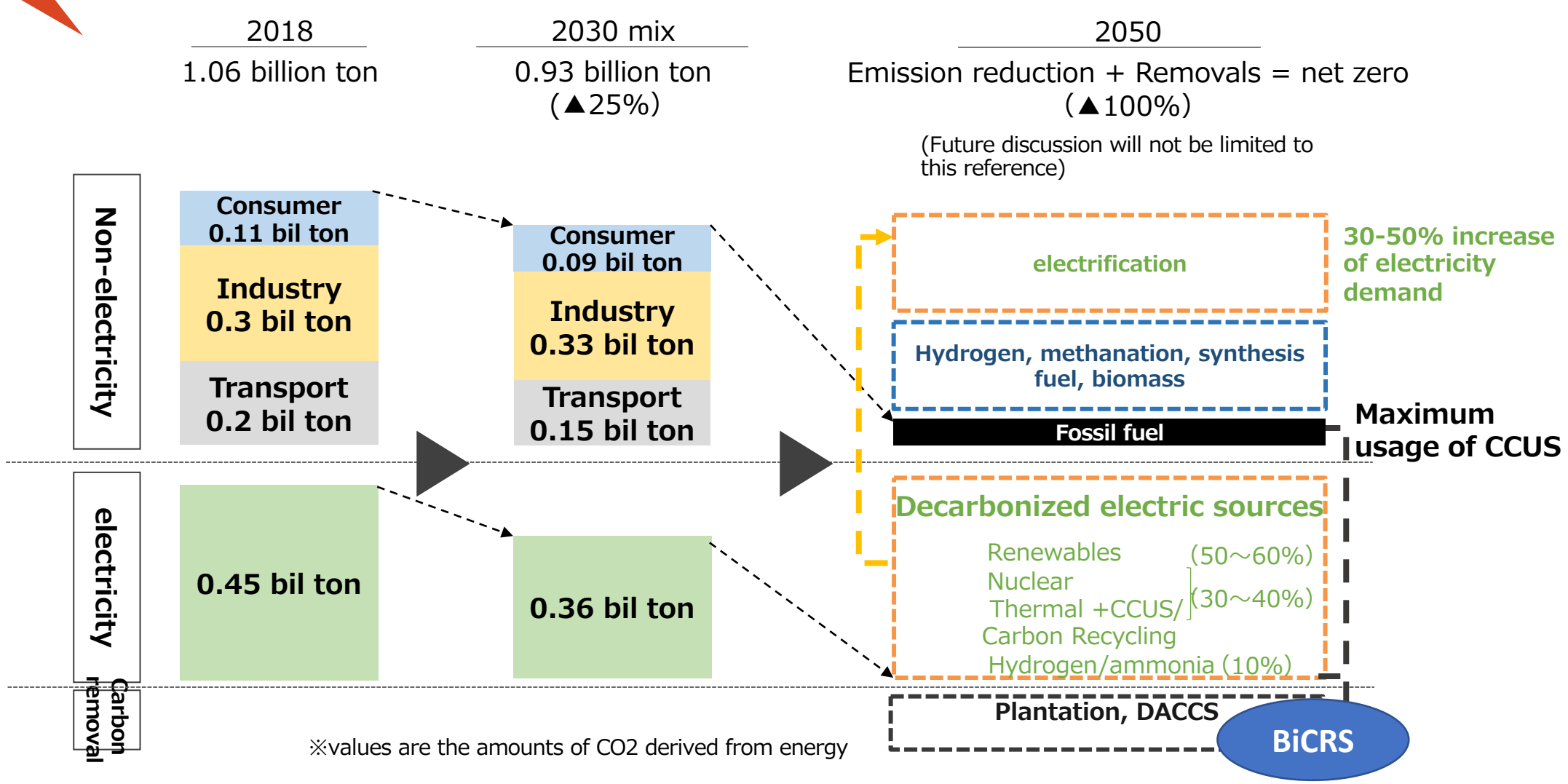
Our existing energy infrastructure is too big to ignore



Reaching net-zero emissions requires tackling emissions from long-lived assets in power generation and heavy-industries. In emerging Asia, 80% of existing coal power capacity was built in the past 20 years.

Japan's Pathway to Carbon Neutrality in 2050

(reference for a discussion purpose)



*Based on a material released by Ministry of Economy, Trade and Industry of Japan, presenter added information.

A Golden Age of Hydrogen is coming?

14 priority fields have set on the strategy

Energy

Offshore wind power
Windmill, parts, floating wind turbine

Fuel ammonia
Combustion burner
(as fuel in transition period to hydrogen society)

Hydrogen
Turbine for power generation,
hydrogen reduction steelmaking,
carrier ships, water electrolyzer

Nuclear power
SMR (Small Modular Reactor),
nuclear power for hydrogen production

Transport / Manufacturing

Mobility and battery
EV (electric vehicle), FCV (fuel cell vehicle),
next generation batteries

Semiconductor and ICT
Data center, energy-saving semiconductor
(demand-side efficiency)

Maritime
Fuel-cell ships, electric propulsion ships, gas-fueled ships

Logistics, people flow and infrastructure
Smart transportation, drone for logistics,
fuel-cell construction machine

Foods, agriculture, forestry and fisheries
Smart-agriculture, wooden skyscraper, blue carbon

Aviation
Hybrid electric, Hydrogen-powered Aircraft

Carbon Recycling
Concrete, biofuel, plastic materials

Home / Office

Housing and building, Next generation PV
(perovskite solar cell)

Resource circulation
Biomaterials, recycled materials, waste power generation

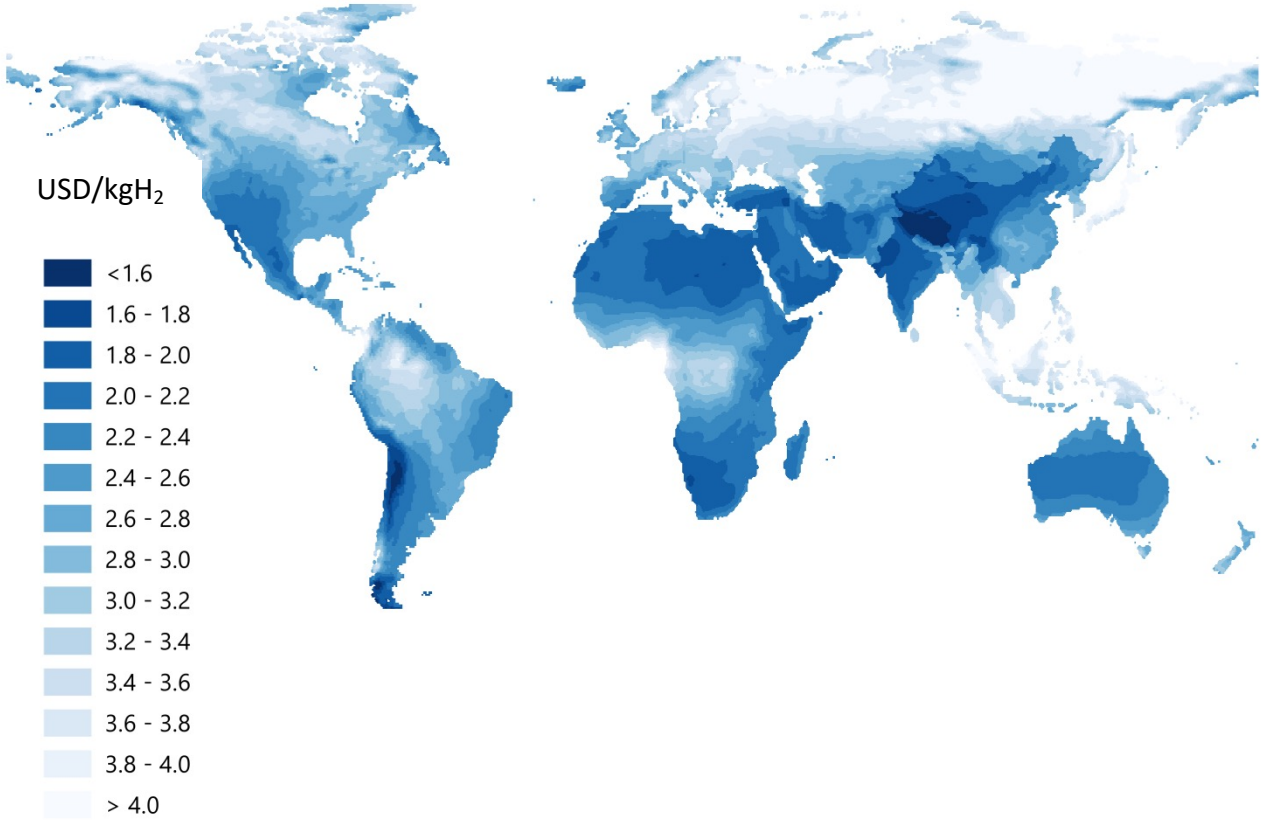
Lifestyle-related industry
Local decarbonization business

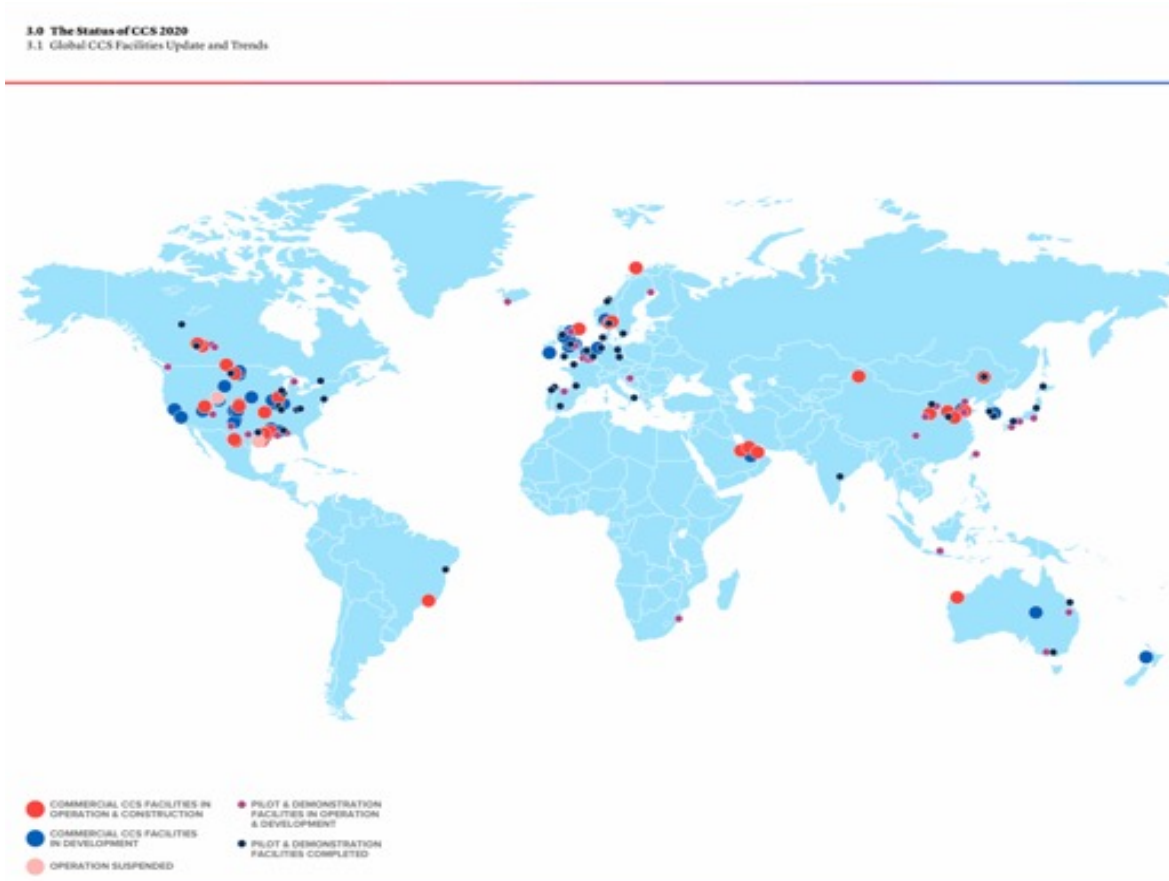
Dec, 2020. METI

Renewables (Green) hydrogen costs are set to decline

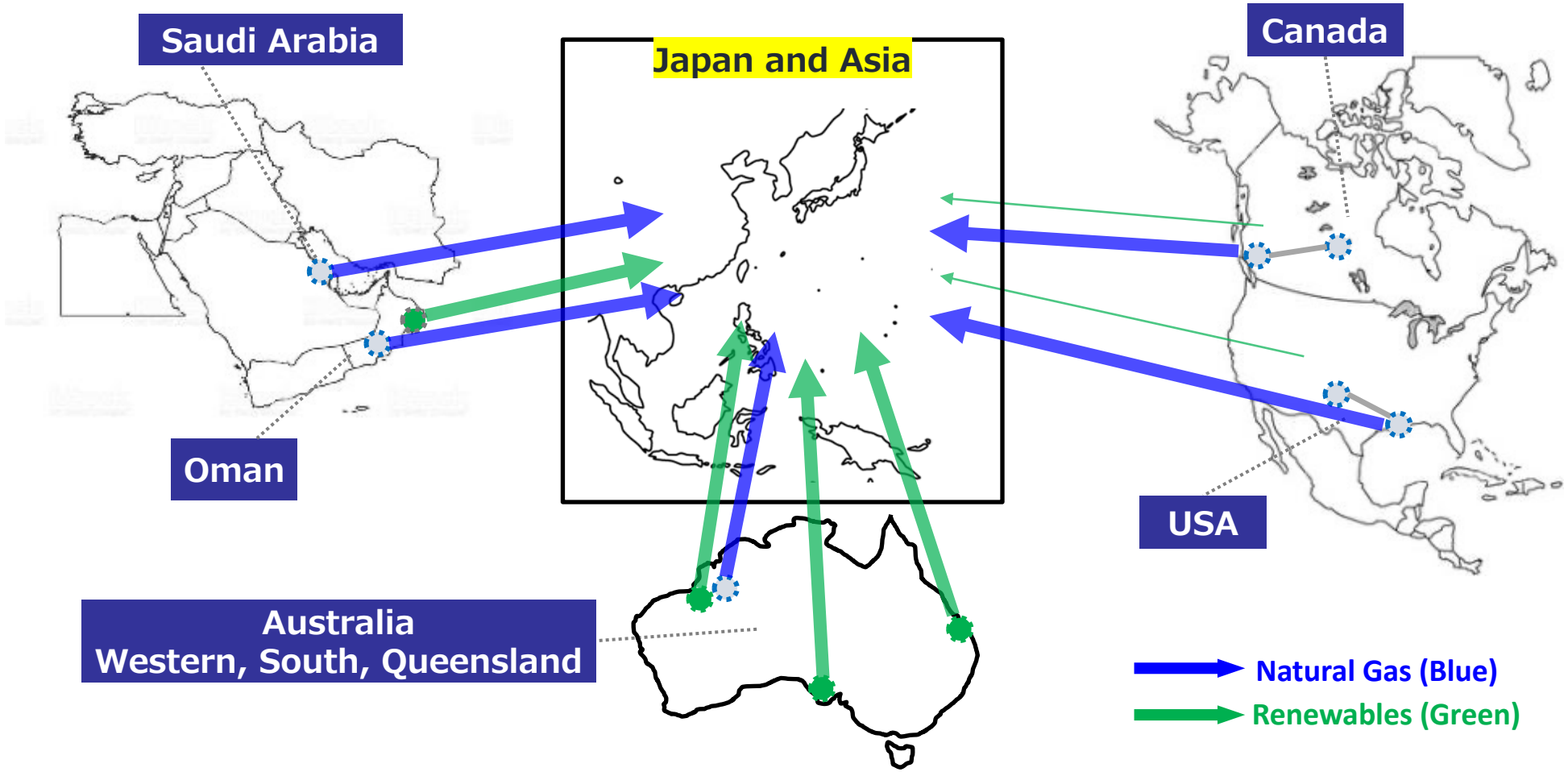
Blue Hydrogen with Carbon Capture &Storage (CCS)

Long-term hydrogen production costs from solar & wind systems





Potential Supplies of Blue and Green Ammonia. Organic Hydrate and Liquid Hydrogen are alternative modes of transportation.



THE GREEN AMMONIA CONSORTIUM

What Do Countries With The Best Coronavirus Responses Have In Common? Women Leaders

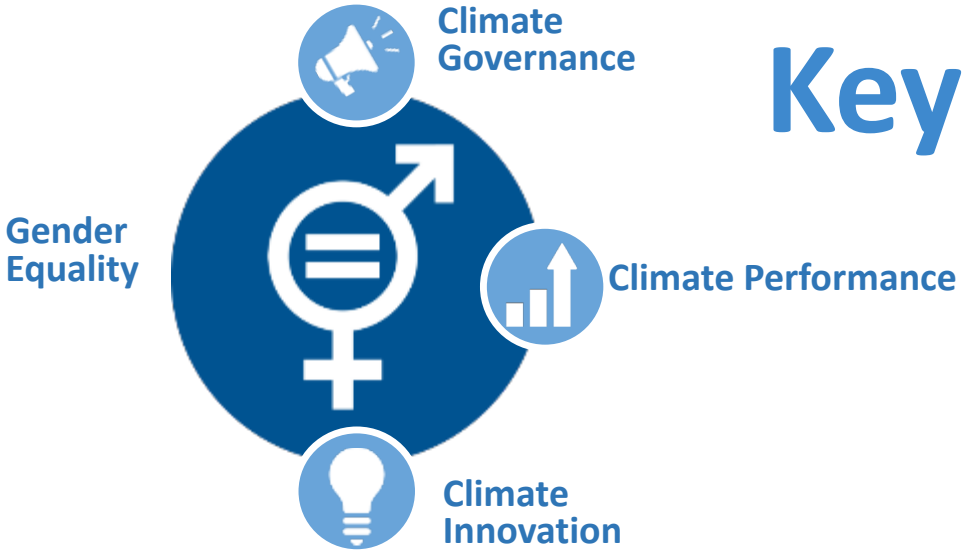
Avivah Wittenberg-Cox Contributor

Political Leaders Showing the Way 20-FIRST

The Forbes

A huge amount of evidence is emerging that the Coronavirus will have an outsized economic impact on women. So does Climate Change.

Climate Change is NOT Gender Neutral!



Key Findings

>30%

- Critical mass of >30% women on Board (WOB) makes difference.
  - Global Trends: >30% WOB threshold is growing 2% => 16% in 10 years.
  - More women in management reasonably correlates to % women in workforce
- International initiatives such as TCFD is key driver for better climate governance, and early adopters show better gender diversity.
- Legislation and reporting requirements accelerate disclosure.

Gender diversity positively correlates to better **climate governance** and **innovation**.

Study by the Sasakawa Peace Foundation and BNEF

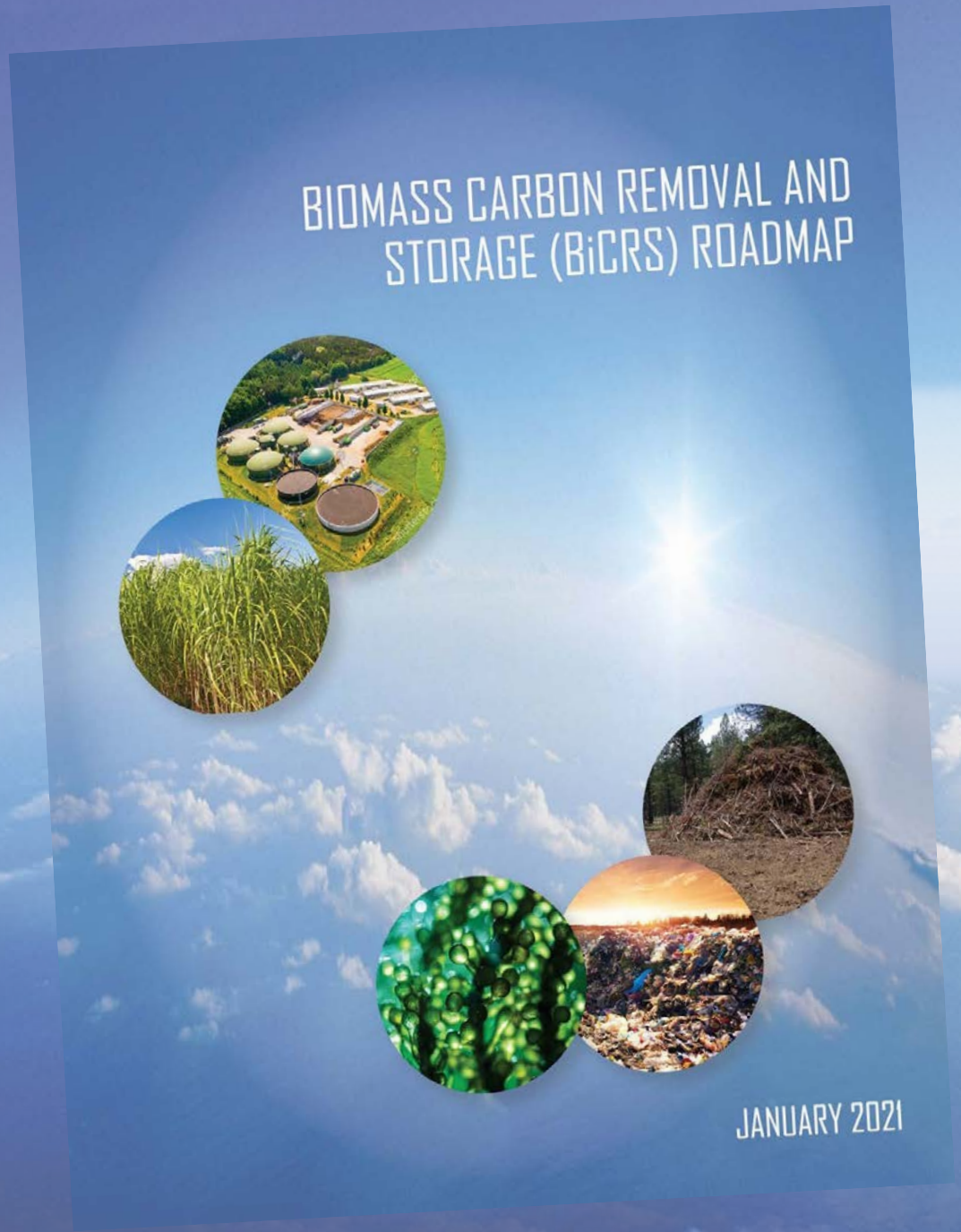

(Gt-CO2e)
60
40
20
10
0
2020
Inter nationalize
Inspire
Involve
BEYOND ZERO
H2
CCUS
SMR

Main theme：

Pathways to Carbon Neutrality by 2050;
Accelerating the pace of global decarbonization.

Road Map Project 2021：

Carbon Mineralization



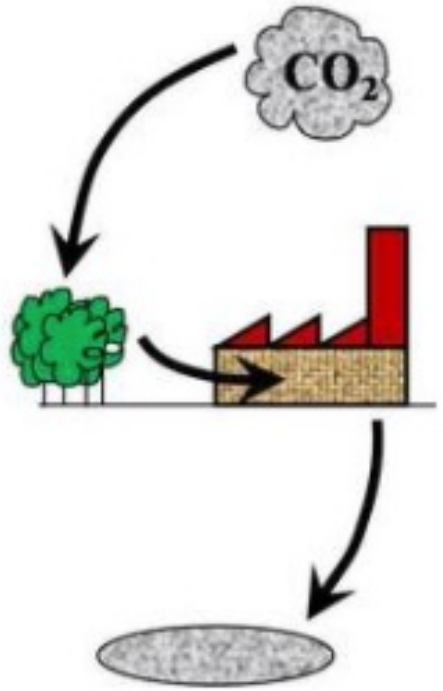
David Sandalow, Roger Aines,
Julio Friedmann, Colin McCormick
and Daniel Sanchez

Innovation for Cool Earth Forum

https://www.icef-forum.org/pdf/2020/roadmap/roadmap.pdf

We started out to write a roadmap on bioenergy with carbon capture and storage (BECCS)

- Part of the climate dialogue for decades
- Important role in many integrated assessment models



However the term “bioenergy with carbon capture and storage” (“BECCS”) misses two key points.

First, biomass can be used to capture and store CO_2 without energy production.

Second, the carbon removal value of biomass may exceed its energy value.

So we propose a new term: BIOMASS CARBON REMOVAL AND STORAGE

Also -- using biomass for carbon capture and storage creates risks.

- Higher food prices
- Ecosystem damage, including biodiversity loss
- Adverse impacts on rural livelihoods

And CO2 removal benefits may be reduced or eliminated by indirect land use change.

So we propose three guiding principles for BiCRS

- *First, do no harm.*
- *Second, social acceptability is key.*
- *Third, technology development should reflect social priorities.*

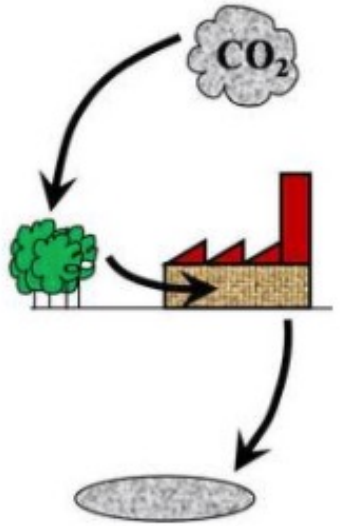
We define *biomass carbon removal and storage (BiCRS)* as…

A process that

a) uses biomass to remove CO_2 from the atmosphere,

b) stores that CO_2 underground or in long-lived products, and

c) does no damage to – and ideally promotes – food security, rural livelihoods, biodiversity conservation, and other important values.



BiCRS 2050: An Ideal Vision

UN Framework Convention on Climate Change
55th Conference of the Parties (COP 55)
December 2050

Address of the President,
Biomass Carbon Removal and Storage (BiCRS) Coalition

At this conference, we are celebrating the world achieving net-zero greenhouse gas emissions—a goal many once thought impossible. Today, let us also celebrate the important role that biomass carbon removal and storage (BiCRS) is playing in the world achieving that goal.

BiCRS Roadmap – KEY MESSAGES

1. Biomass carbon removal and storage (BiCRS) could deliver 2.5-5.0 Gt/y CO_2 removal and storage by mid-century.

2. Biggest issues to be addressed are institutional and political, not technical.

3. Wastes (agricultural, forestry and municipal) are attractive initial biomass sources. Microalgae and macroalgae could be significant in the long-term.

4. Using timber or dedicated energy crops for carbon removal and storage creates risks with respect to food security, rural livelihoods and biodiversity conservation.

BiCRS Roadmap – KEY MESSAGES
(cont.)

5. Widespread adoption of sustainable biomass standards will be needed to address these risks.

6. Technologies are available to monitor biomass production and help ensure good practices.

7. We recommend a core principle: Do no harm

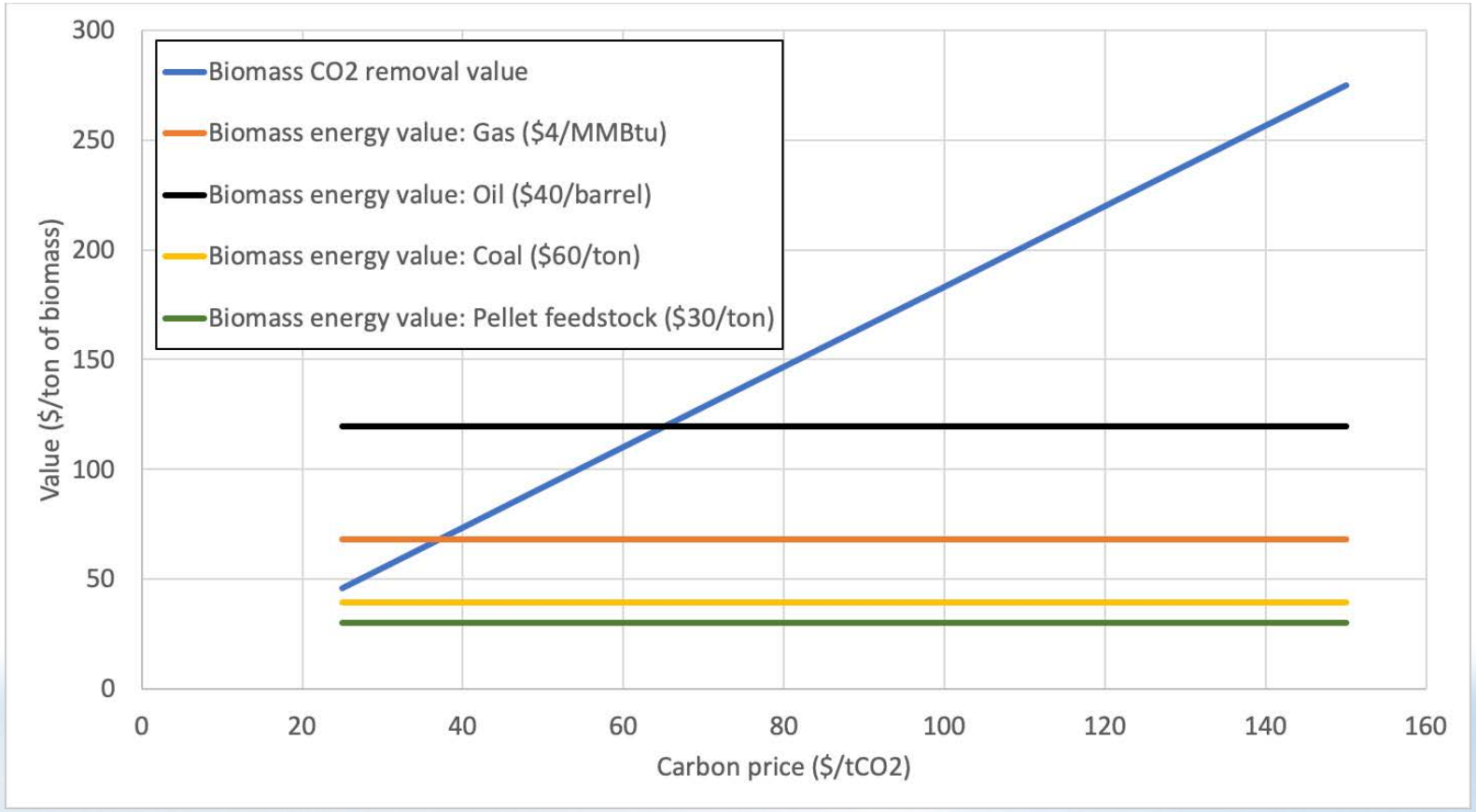
Background

BIOMASS CAN BE USED FOR CARBON REMOVAL WITHOUT ENERGY PRODUCTION

- Biochar from thermochemical biomass processing for soil improvements
- Engineered wood products for the construction market
- Bio-liquid production and direct injection to the subsurface
- Marine macroalgae production and abyssal dispatch
- Biofiber entombment in concrete

CARBON REMOVAL VALUE OF BIOMASS MAY EXCEED ITS ENERGY VALUE

- Biomass is half carbon. One ton of biomass produces 1.8 tons of CO_2.
- The value of this CO_2 depends on the carbon price.
- One ton of biomass (oven-dry) contains appr. 18 GJ of energy.
- This energy value is low compared to the CO_2 value in many cases.

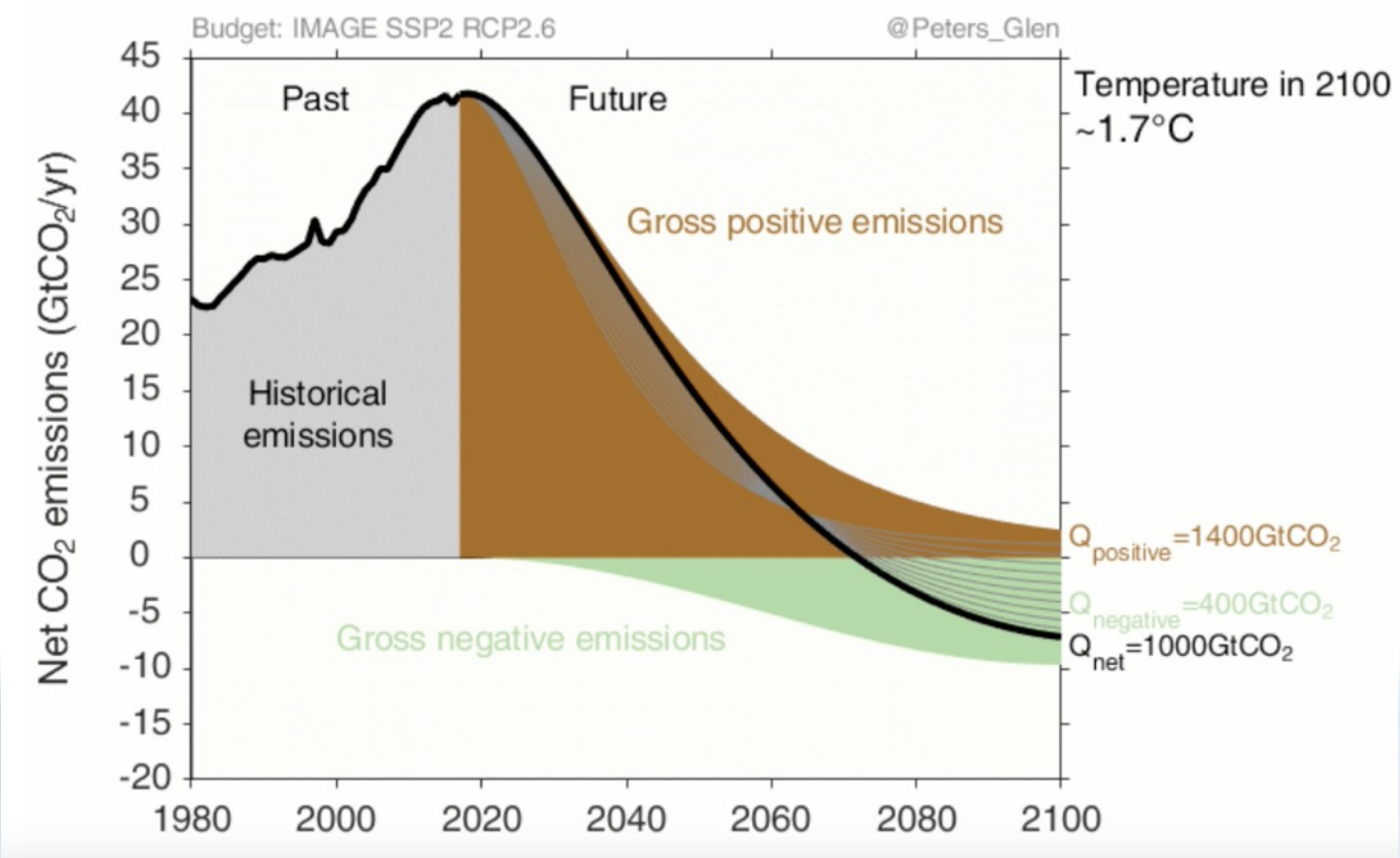


Leads to the new term: BIOMASS CARBON REMOVAL AND STORAGE

Rationale and Risks

CARBON DIOXIDE REMOVAL (CDR) ESSENTIAL FOR MEETING CLIMATE GOALS

- CDR is additional and complementary to conventional mitigation



"All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100–1000 $GtCO_2$ over the 21st century."

— IPCC 1.5°C Report (2018)

Using biomass for carbon capture and storage creates risks.

- Higher food prices
- Ecosystem damage, including biodiversity loss
- Adverse impacts on rural livelihoods

Biomass Potential

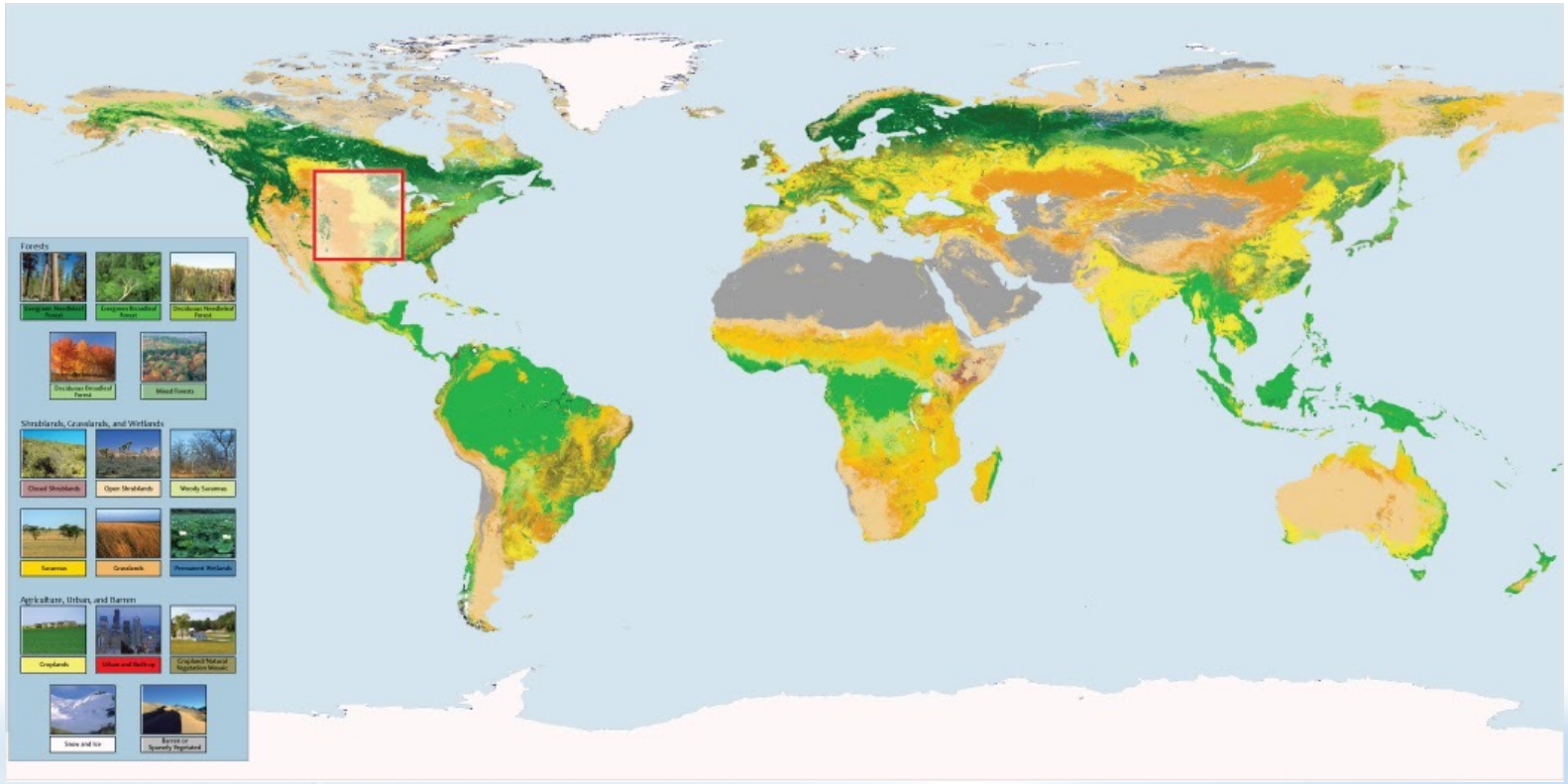
THERE ARE MANY POTENTIAL SOURCES OF FEEDSTOCK FOR BiCRS

- *Waste biomass* is preferred
  - low impacts on food and fiber production
  - includes agricultural, forestry, industrial and municipal wastes.
- *Dedicated crops* may be used in limited amounts.
  - constrained by land availability for food and fiber production.
- *Managed forests* may provide limited biomass.
  - must be carefully monitored and managed
- *Micro- and macro-algae (seaweed)* may provide increasing amounts of feedstock.




BiCRS FEEDSTOCKS ARE AVAILABLE FOR 2.5 TO 5 $GTCO_2$ REMOVAL/YEAR BY 2050

- No comprehensive analysis of BiCRS feedstock has yet been performed.
- Combining biofuel feedstock estimates with “capturable carbon” fraction gives a functional estimate.
- Realistic projections that preserve food and fiber production and ecosystem protection give 2.5 – 5.0 Gt/y of CO_2 removal.
- Higher estimates rely on large, unrealistic land-use change.

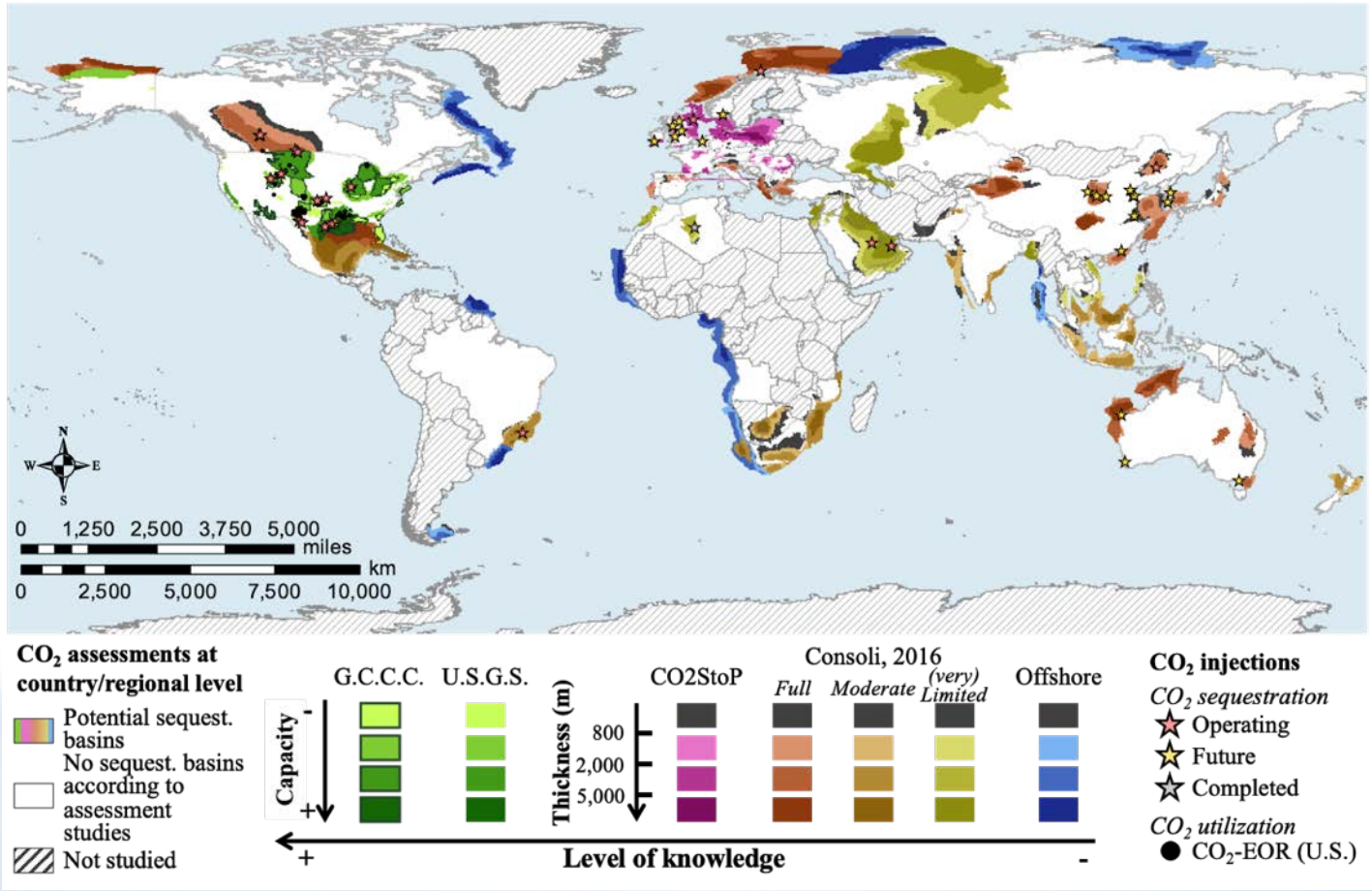


*Red square: 500 Mha, the area proposed for dedicated biomass crops by **unrealistically high** biofuel feedstock estimates.*


Carbon Capture
and Storage

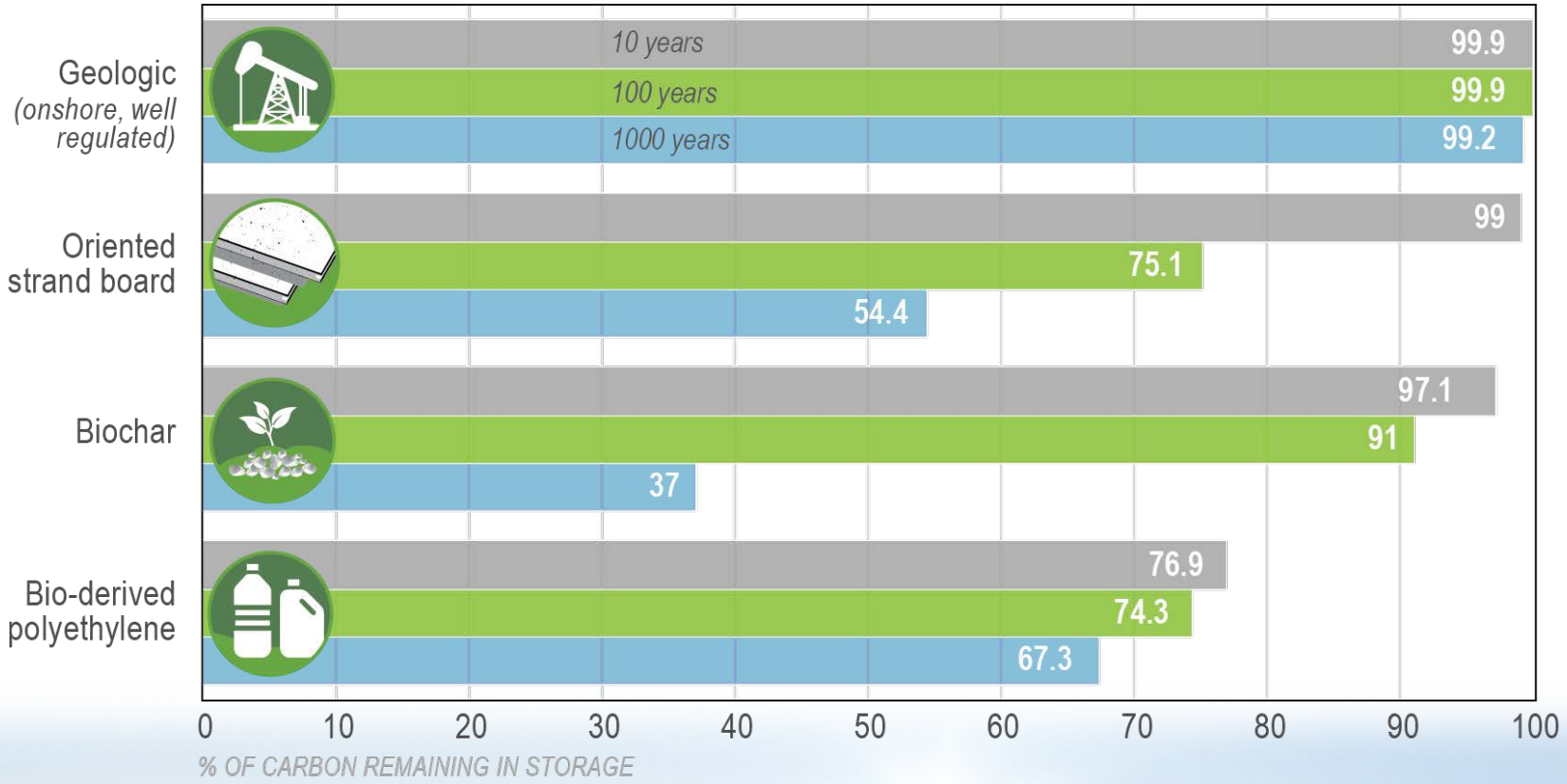
BiCRS REQUIRES CARBON STORAGE.
GEOLOGICAL STORAGE IS THE MOST DEVELOPED AND READY APPROACH.

- Good CO_2 storage options near both production and consumption centers
  - Southern US, SE Asia, Brazil
  - EU-North Sea, Canada, Brazil
- Co-location of conversion and storage provides job and climate benefits
  - Upgrade to higher value products
  - Potential CO_2 removal revenue
- Two jobs to maximize opportunity
  - Infrastructure: pipelines and well assessed storage
  - Characterization: especially in developing nations



STORAGE IN LONG-LIVED PRODUCTS

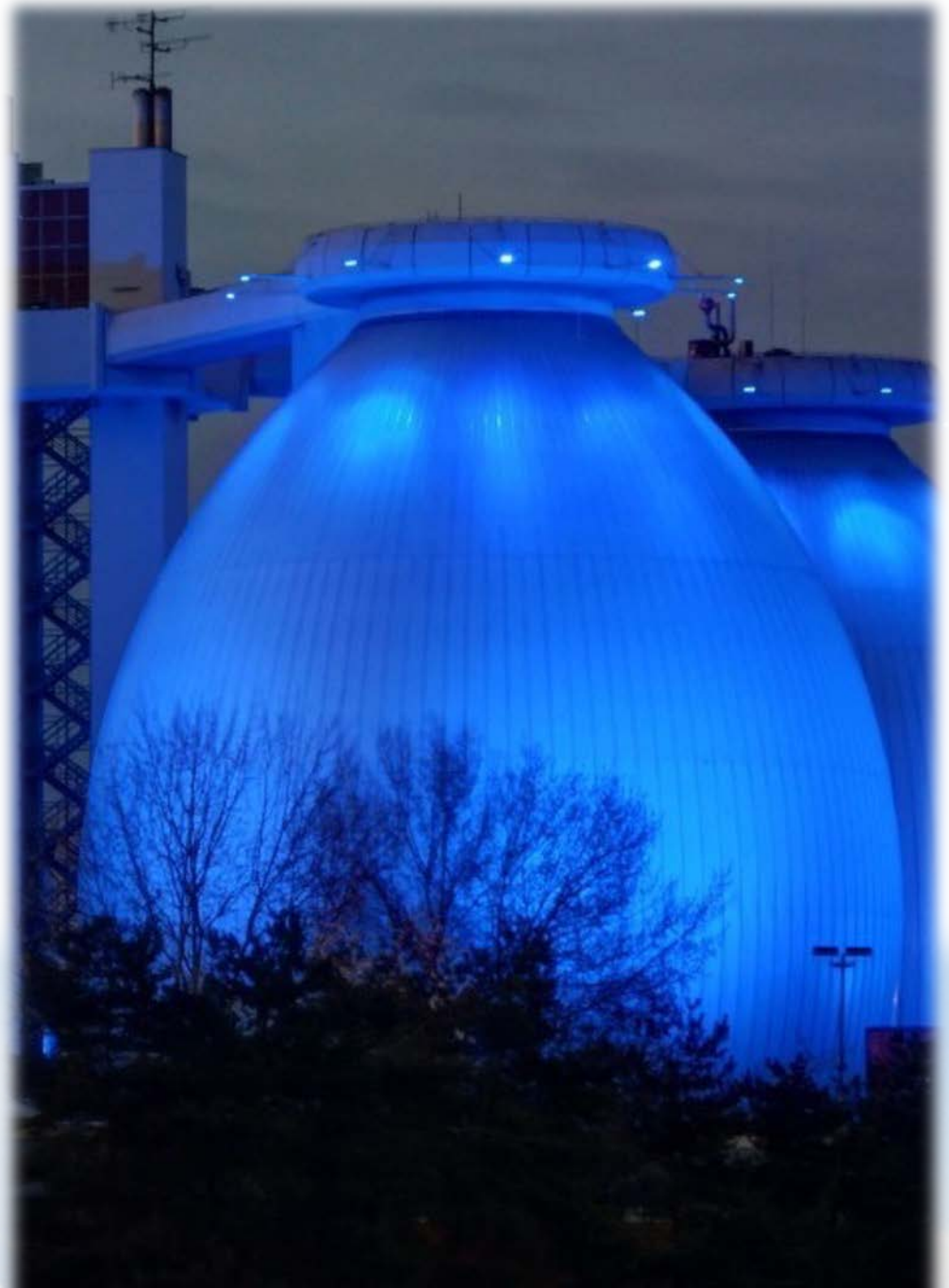
- Biochar
- Engineered wood products, like Oriented Strand Board (OSB)
- Bioplastics like bio-derived polyethylene
- Biofiber entombment in concrete



Research Agenda

RESEARCH AGENDA

- Technology
- Social sciences
- Integrated analysis
- Timeline



TECHNOLOGY DEVELOPMENT

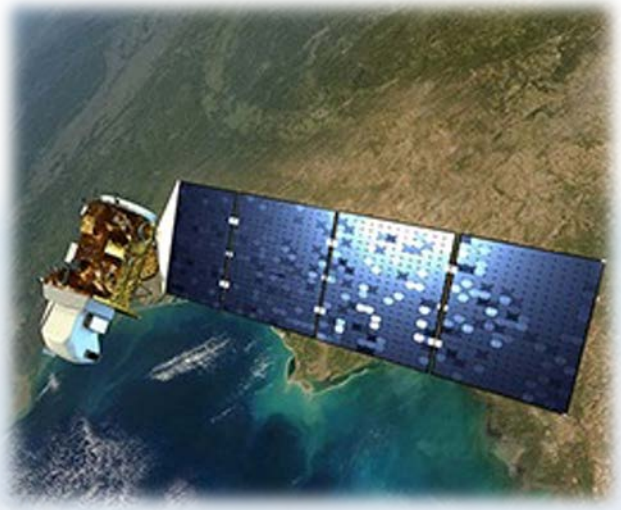
Hydrogen – Develop biomass supply chain that recovers all carbon for storage

New Pathways – Biochar, engineered wood, direct biomass storage, enhanced concrete

Fast Pyrolysis – Scale-up and processing to liquid transportation fuels

Satellite Monitoring – Allow purchasers to ensure land use and land cover compliance

Plant Breeding – Improve soil carbon (perennials and rootstock) and processability



SOCIAL SCIENCES

- The most important issue is the biomass supply chain:
  - Who **controls** it?
  - Who **benefits**?
  - **Where** are those benefits found?

Opportunities and **risks** for local communities must be clearly determined.

SOCIAL SCIENCE RESEARCH PRIORITIES

- Draw from multiple disciplines including economics, political science and sociology
- Draw on related fields including agronomy, nutrition, hydrology and engineering
- Focus on characterizing and increasing "social demand" for BiCRS and other forms of CO_2 removal

1. Synthesis research that looks at lessons on carbon sink enhancement, scaling up biofuels / the bioeconomy, and past and present energy transitions, including on the investment gap with CCS and clean energy technologies;
2. Regional and landscape-level analysis of carbon removal technologies;
3. Analysis of policymaker and citizen demand for and knowledge of negative emissions; and
4. Work on technology diffusion, adoption, and transfer into different socio-economic contexts.

INTEGRATED ANALYSIS

- BiCRS is a worldwide issue.
- Evaluating BiCRS requires balanced assessment of impacts over the full

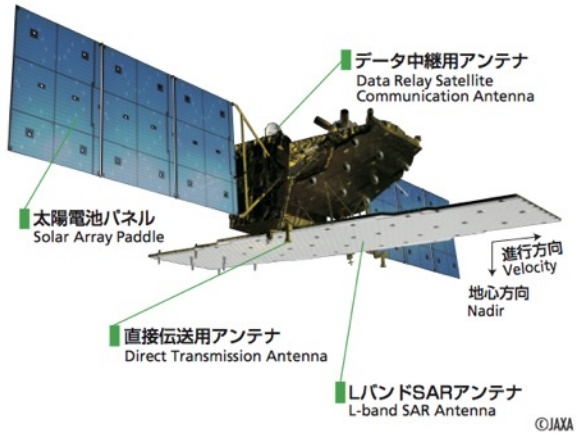
Social,

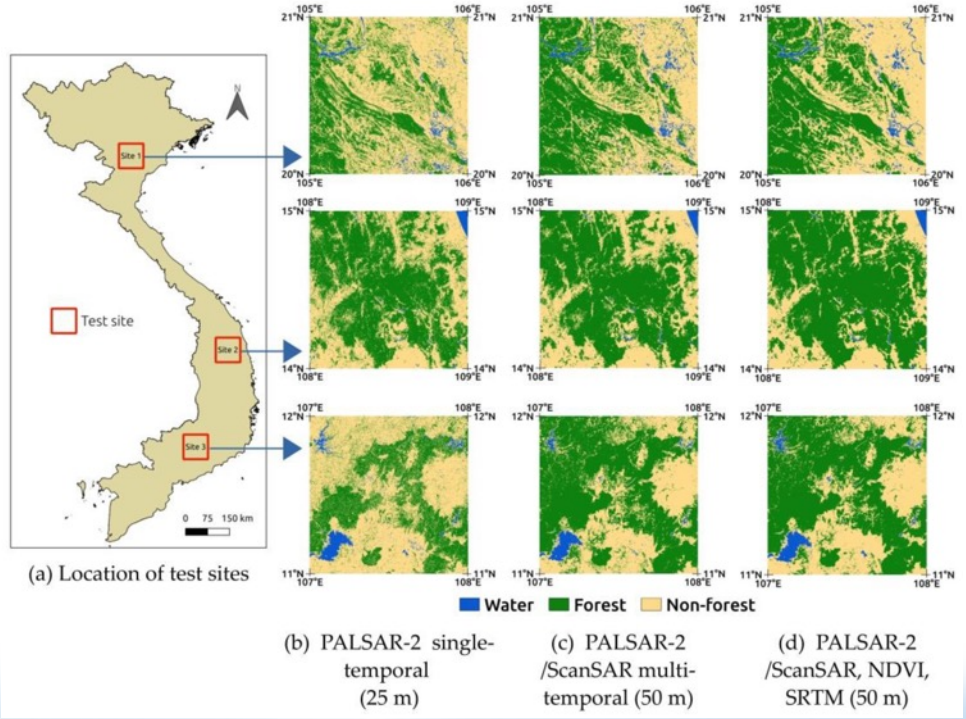
Economic, and

Environmental life

NEW SATELLITE APPROACHES: Continuous, Near-real-time Deforestation Monitoring

- Synthetic aperture radar (SAR): tree canopy at high resolution
- Rapid data processing: near-real-time monitoring for deforestation
- AI and machine learning: improve accuracy and precision





Left: ALOS-2 satellite (JAXA) with PALSAR-2 instrument
Right: Example of forest cover monitoring using SAR data (Truong2019)

Government support for flagship satellite missions is essential

Policy

POLICY SUPPORT IS ESSENTIAL

1. Incentives for removing carbon from the atmosphere
   - Emissions trading programs
   - Tax policy
   - Mandates
2. Support for RD&D
   - R&D: government spending
   - Deployment: tax incentives, grants, loan guarantees, procurement
3. Standard-Setting
   - Measuring, reporting and verification; accounting; life-cycle emissions; time frames; leakage
   - UNFCCC BiCRS Platform?

Findings and Recommendations

BiCRS ROADMAP – KEY MESSAGES

1. Biomass carbon removal and storage (BiCRS) could deliver 2.5-5.0 Gt/y CO_2 removal and storage by mid-century.

2. Biggest issues to be addressed are institutional and political, not technical.

3. Wastes (agricultural, forestry and municipal) are attractive initial biomass sources. Microalgae and macroalgae could be significant in the long-term.

4. Using timber or dedicated energy crops for carbon removal and storage creates risks with respect to food security, rural livelihoods and biodiversity conservation.

BiCRS ROADMAP – KEY MESSAGES
(cont.)

5. Widespread adoption of sustainable biomass standards will be needed to address these risks.

6. Technologies are available to monitor biomass production and help ensure good practices.

7. We recommend a core principle: Do no harm

ICEF INNOVATION ROADMAP PROJECT

SOLAR AND STORAGE ROADMAP (2015)

ZERO ENERGY BUILDINGS ROADMAP (2016)

CARBON DIOXIDE UTILIZATION ROADMAP (2016)

CARBON DIOXIDE UTILIZATION ROADMAP 2.0 (2017)

DIRECT AIR CAPTURE ROADMAP (2018)

INDUSTRIAL HEAT DECARBONIZATION ROADMAP (2019)

This roadmap was prepared to facilitate dialogue at the Seventh Innovation for Cool Earth Forum (October 2020), for final release in January 2021. We are deeply grateful to the Ministry of Economy, Trade and Industry (METI) and New Energy and Industrial Technology Development Organization (NEDO), Japan, for launching and supporting the ICEF Innovation Roadmap Project of which this is a part.

Roger Aines contributed to the technical evaluations in this document.
The policy recommendations were prepared by other contributors.

Biomass Carbon Removal and Storage

Discussion and Q&A

Panel host:

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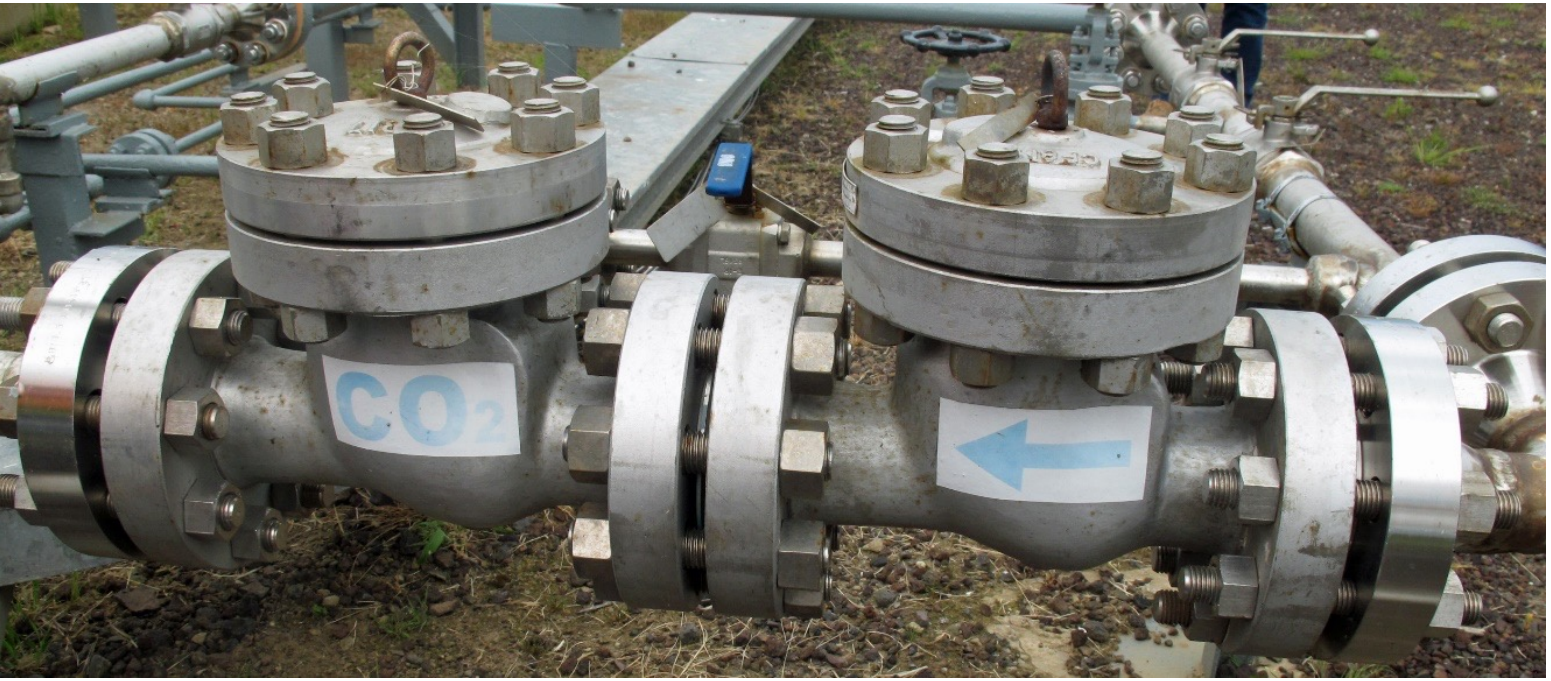
Innovation for Cool Earth Forum

CARBON CAPTURE, UTILIZATION & STORAGE
ACCELERATING CCUS TOGETHER
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL



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