Realizing the Circular Carbon Economy
Charting a Course for Innovations in Agriculture and Energy

Biomass Research and Development Technical Advisory Committee Meeting

Arlington, VA

22 August 2018

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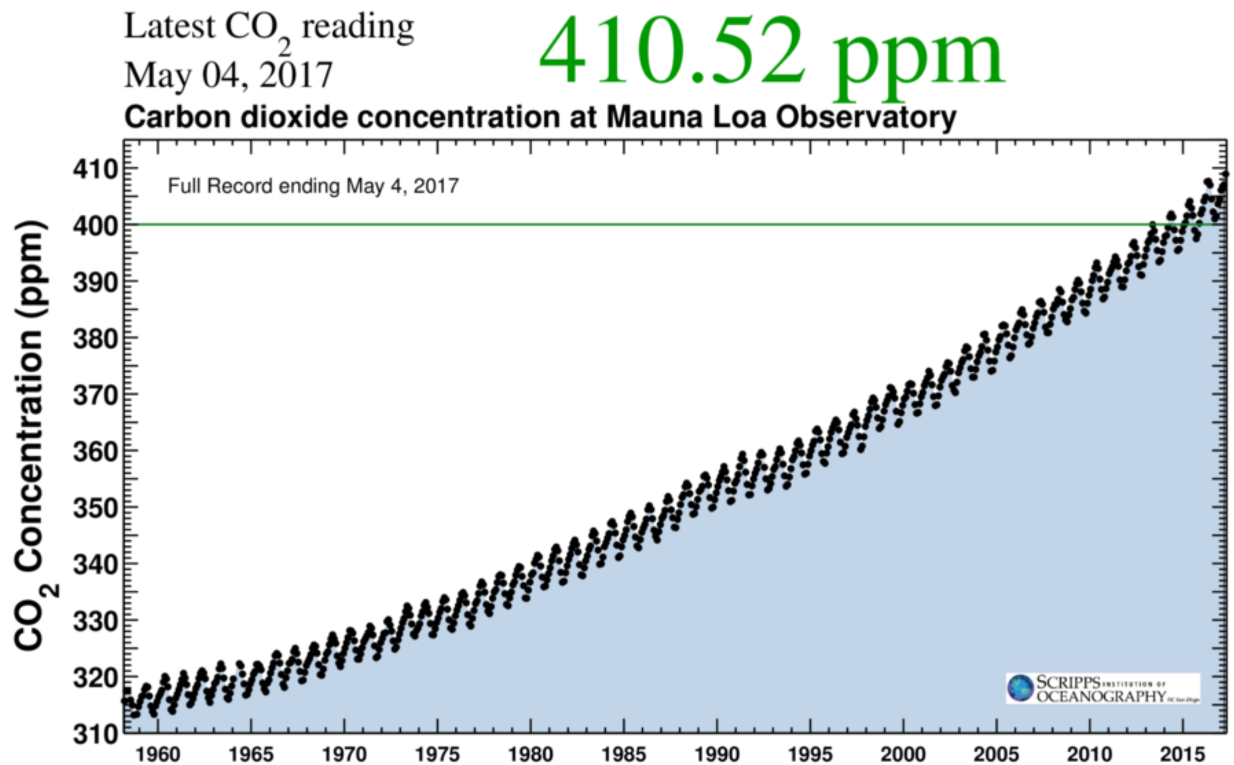
Renewable Energy, Natural Resources & Environment

U.S. Department of Agriculture

Global Challenges

The context for needing a sustainable bioeconomy and more broadly a renewable/circular "new" carbon economy

The amount of CO_2 in the atmosphere is increasing



The Keeling Curve

CO_2 from waste gas streams and the atmosphere is a cheap and abundant source of carbon.

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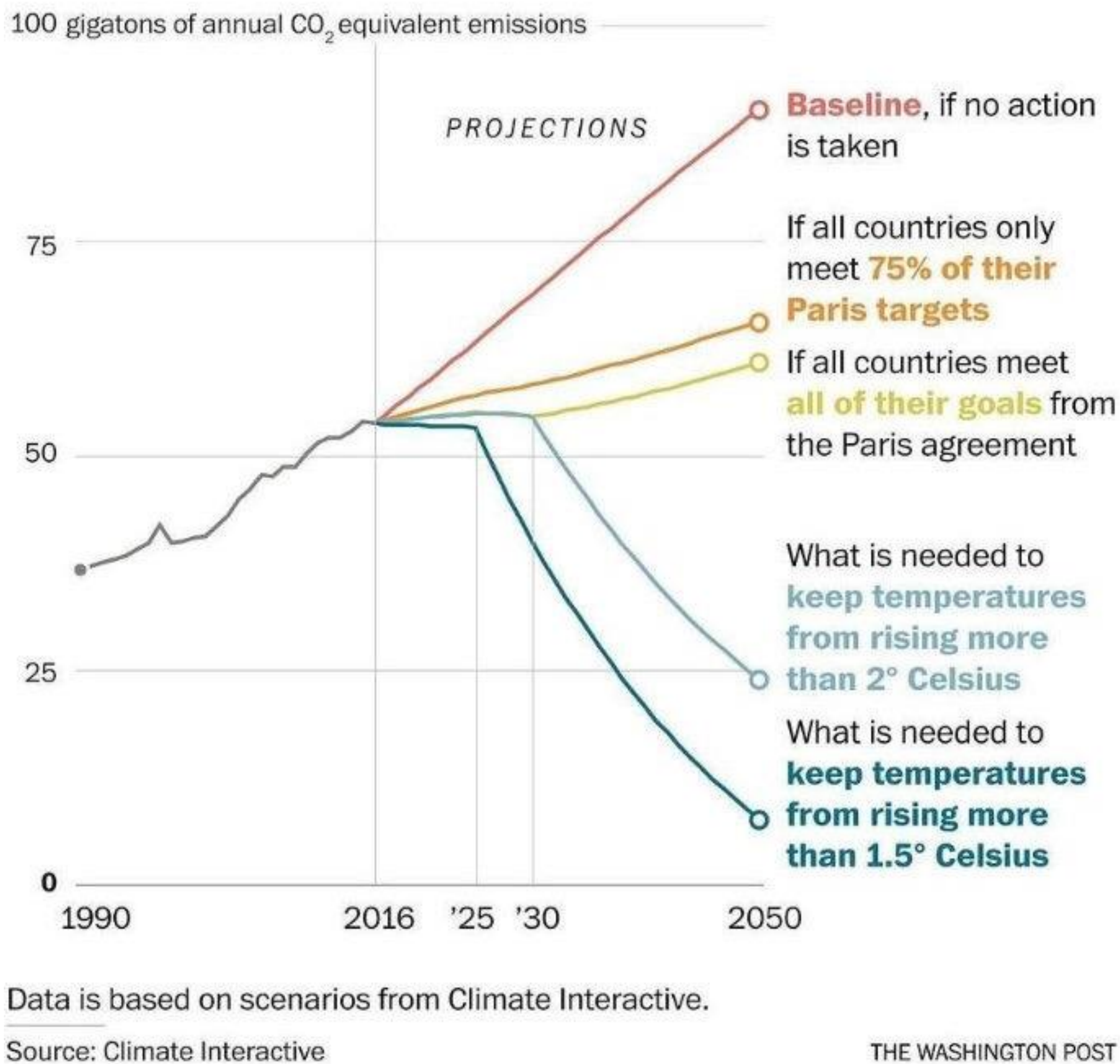
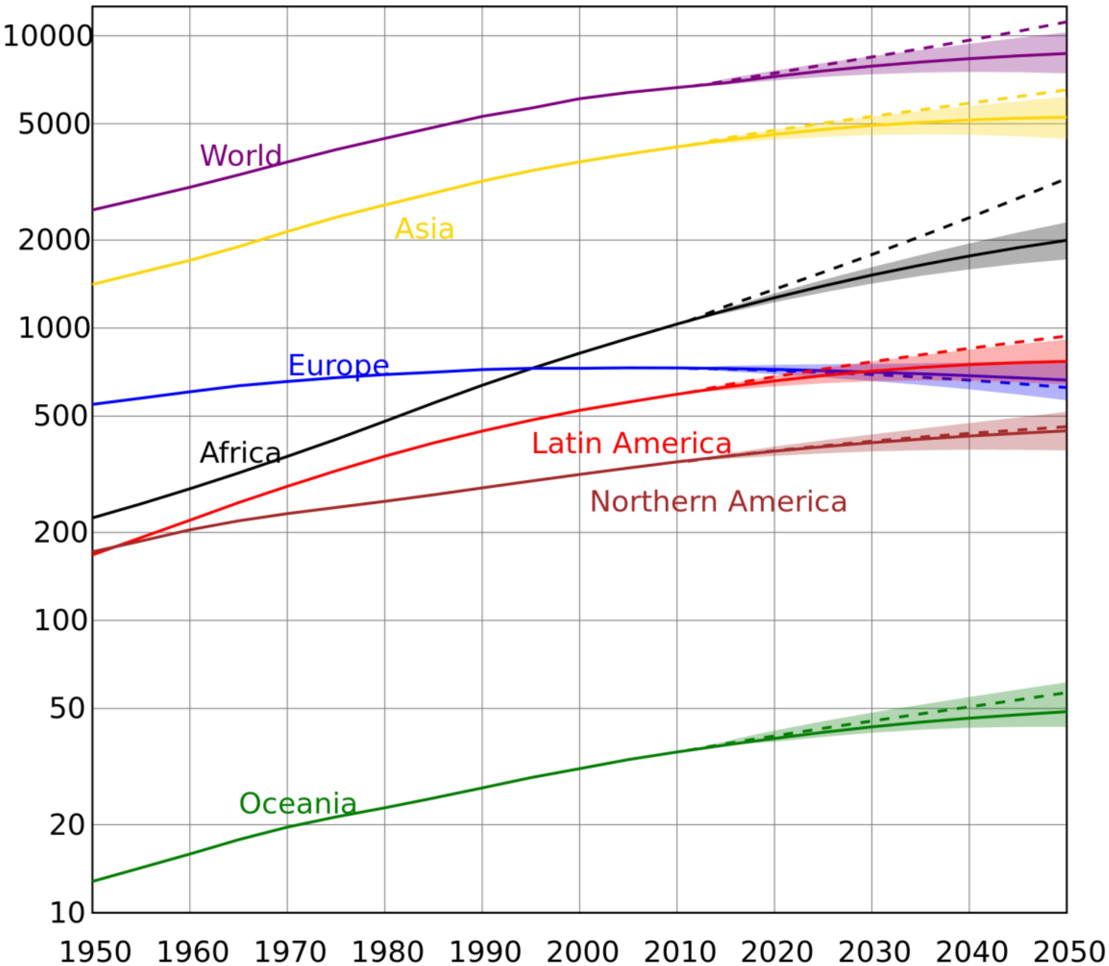
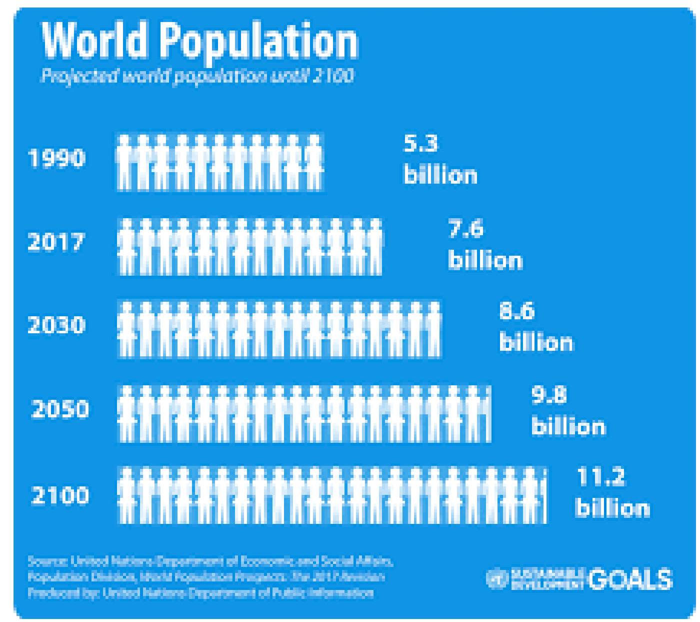
And CO_2 really needs to ***not*** be increasing.



Climate change is not abstract to USDA

A growing population





Global population to 9.7 billion by 2050

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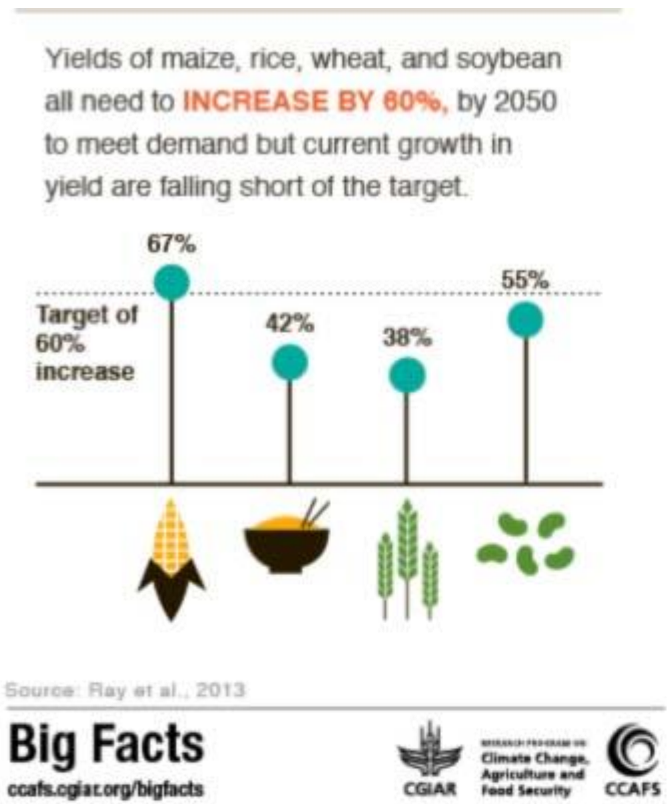
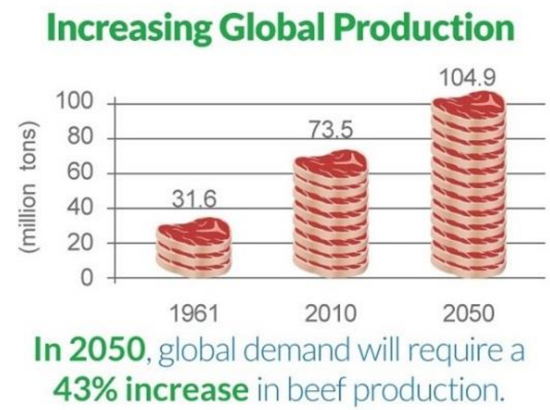
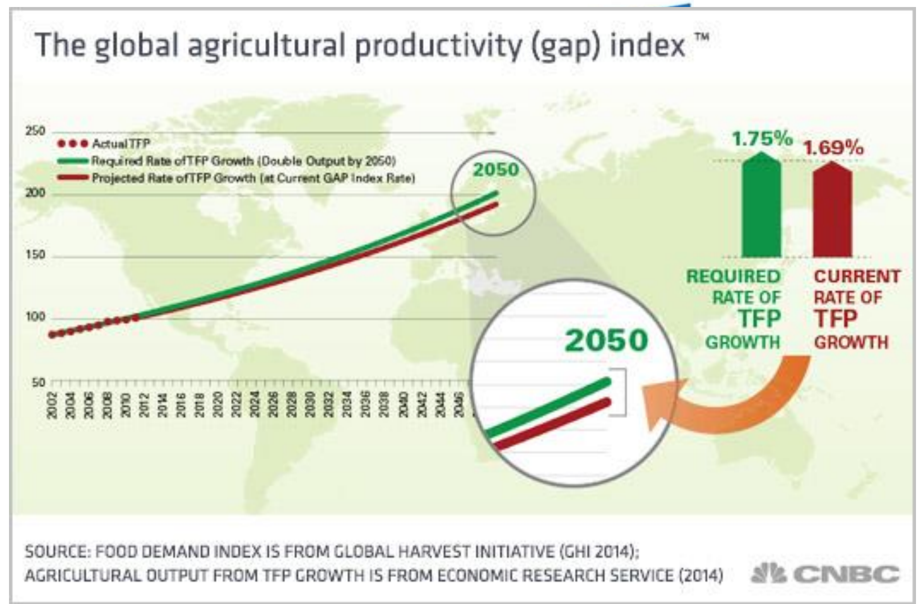
A larger more affluent population







With increased population and affluence comes increased food demands

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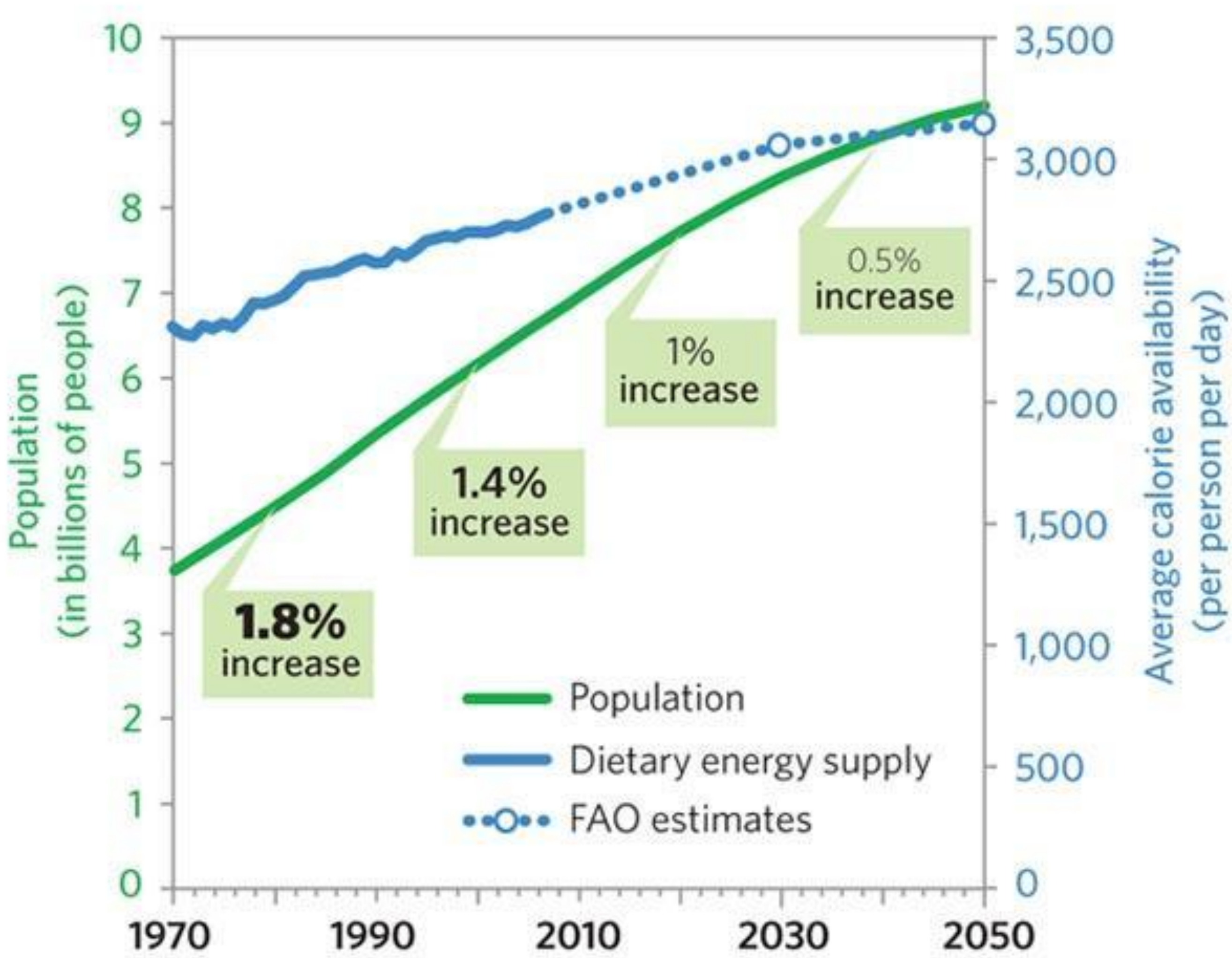
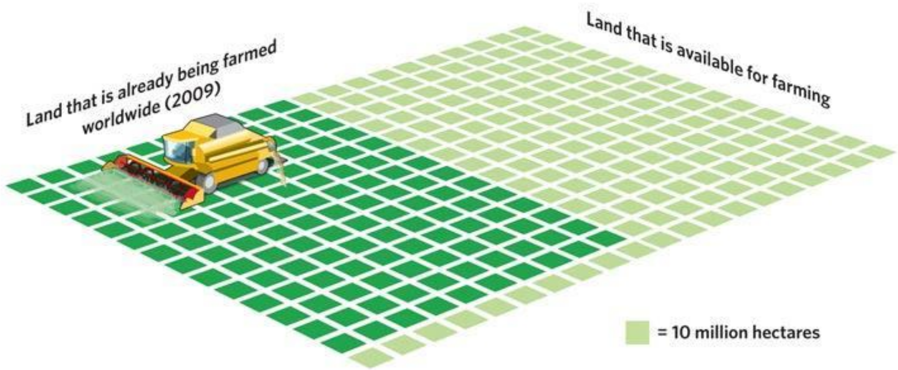
Keeping up with demand



Resource Limitation: land

- An estimated 10^9 ha of new land will be required to feed global population in 2050
- This is an area 20% larger than Brazil



- An FAO outlook says that current cropland could be more than doubled by adding 1.6 billion hectares
- Consensus advises against substantial increases that could tax natural resources and harm ecosystems.

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Beyond the bioeconomy – the circular carbon economy

The Carbon Based Economy

A carbon conscious economy is not a *low-carbon economy* as much as it will be a *renewable carbon based economy*.

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The Carbon Based Economy

A carbon based economy is an opportunity. Engineering systems to use renewable carbon consistently and efficiently can enable an economy that functions as a tool to manage carbon on an industrial scale.

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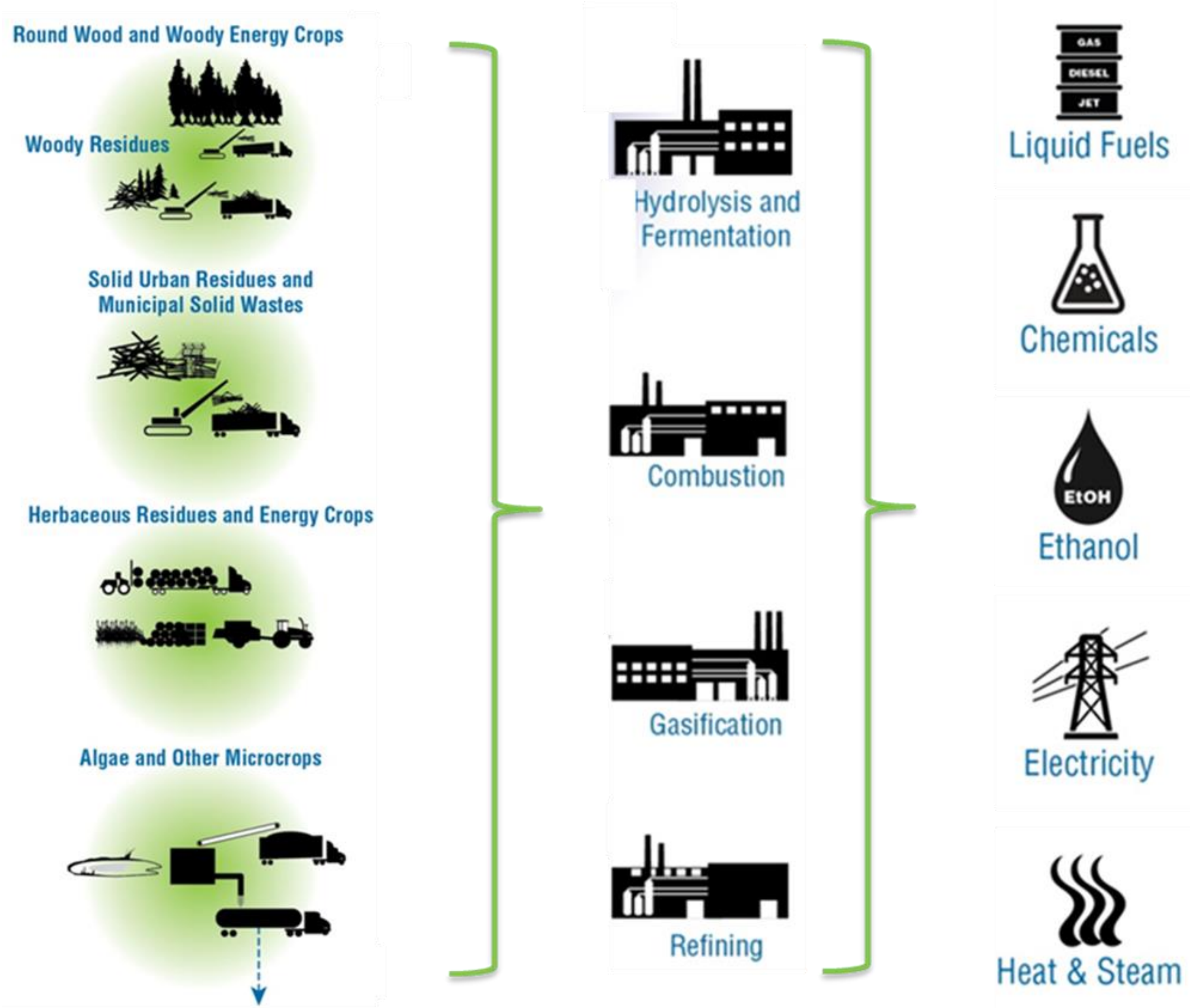
The Bioeconomy Concept



- Revenue and economic growth
- Broad spectrum of new jobs
- Rural development
- Advanced technologies and manufacturing
- Reduced emissions and Environmental Sustainability
- Export potential of technology and products
- Positive societal changes
- Investments and new infrastructure

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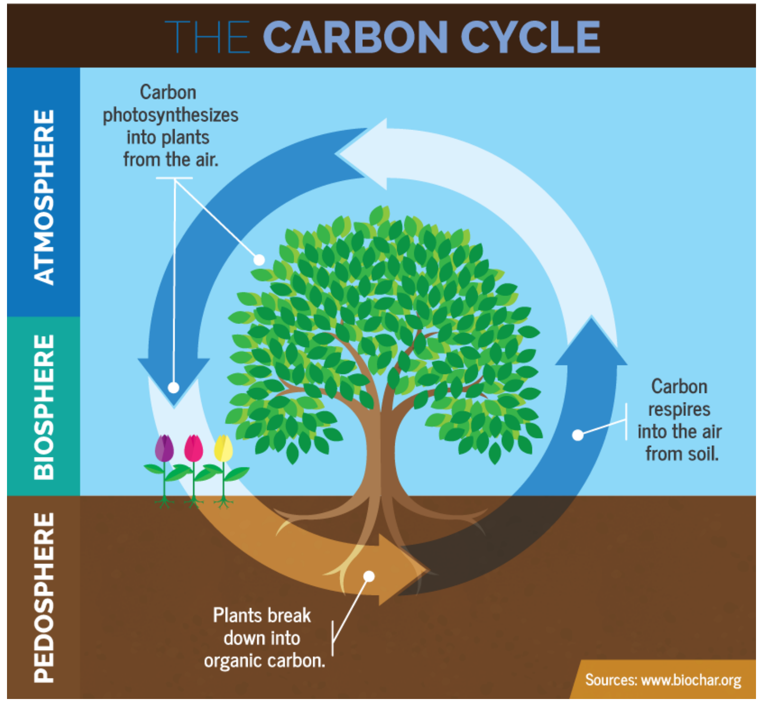
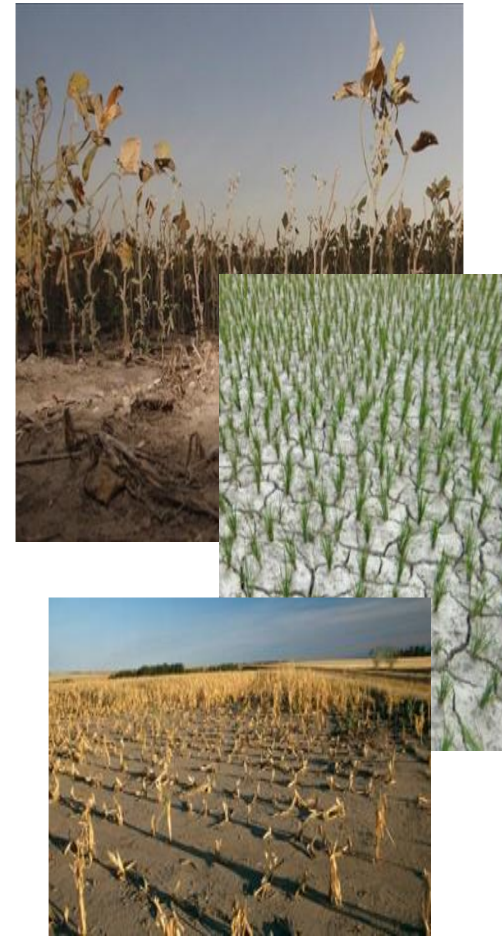
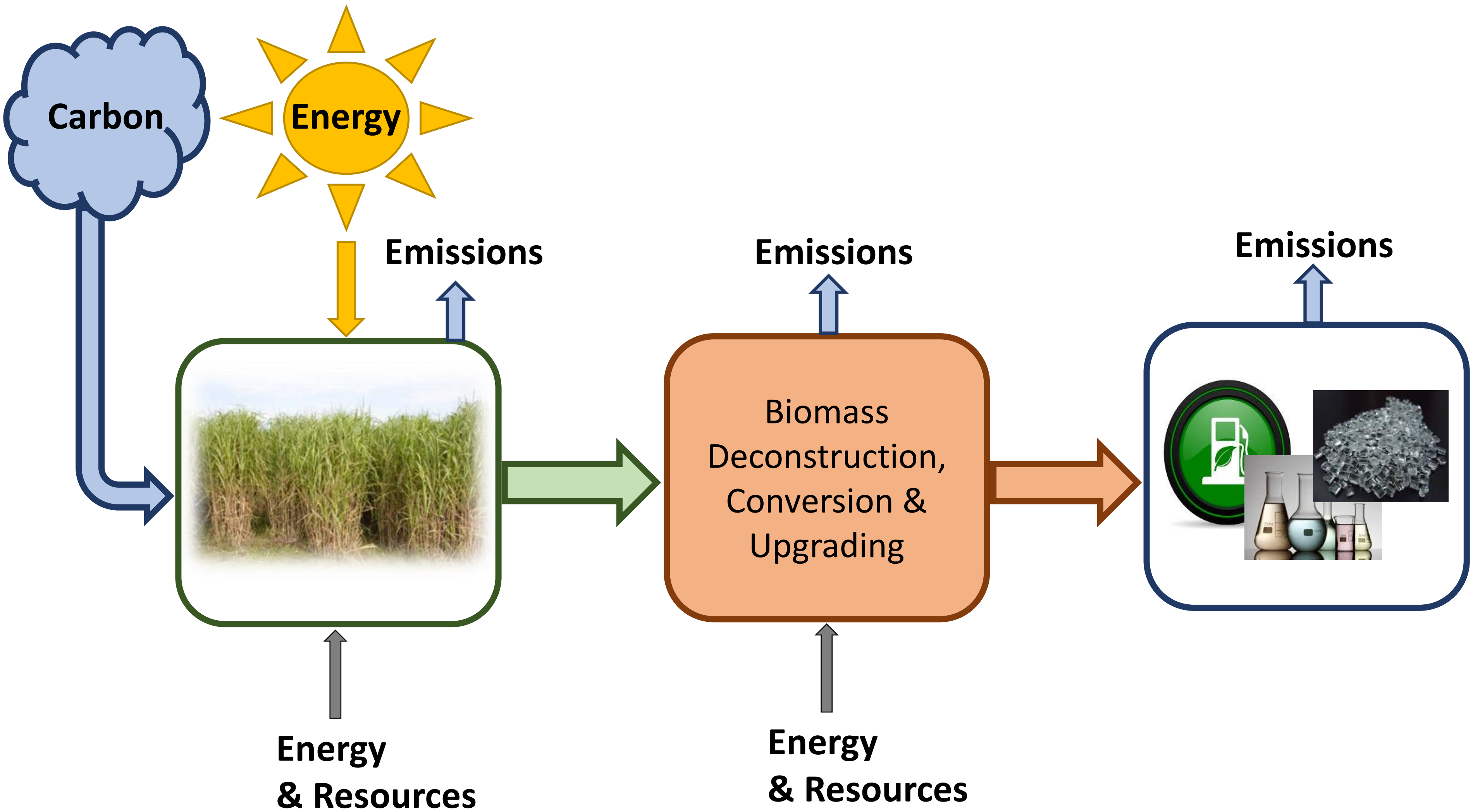
Maintain Economic Prosperity with Renewable Carbon





Greater yields and new sources of renewable carbon are needed to maintain a growing carbon-based economy.

Carbon Lifecycle in the Bioeconomy



New economy; not like the old one

Vertical to horizontal integration

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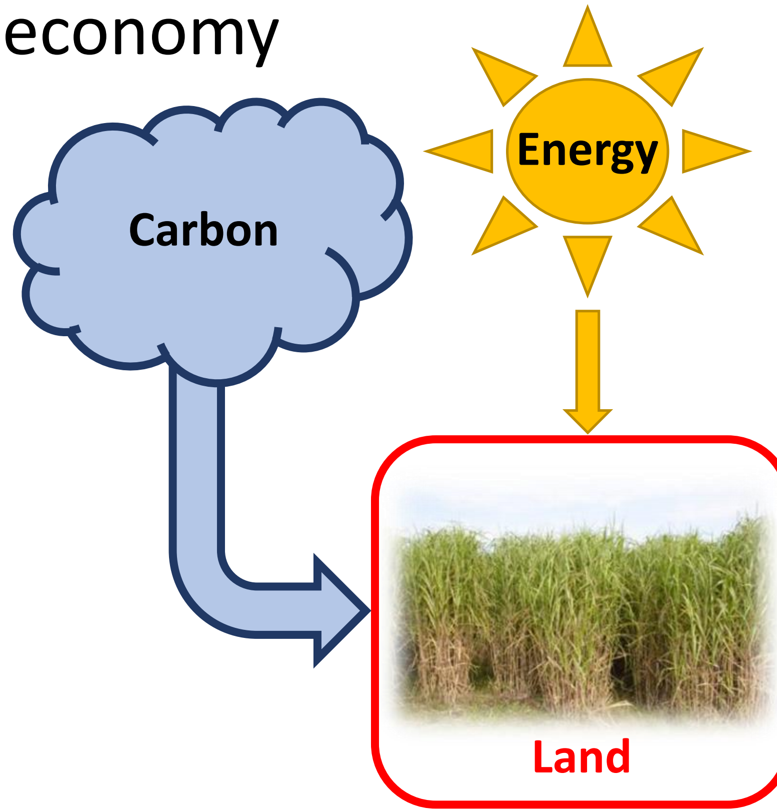
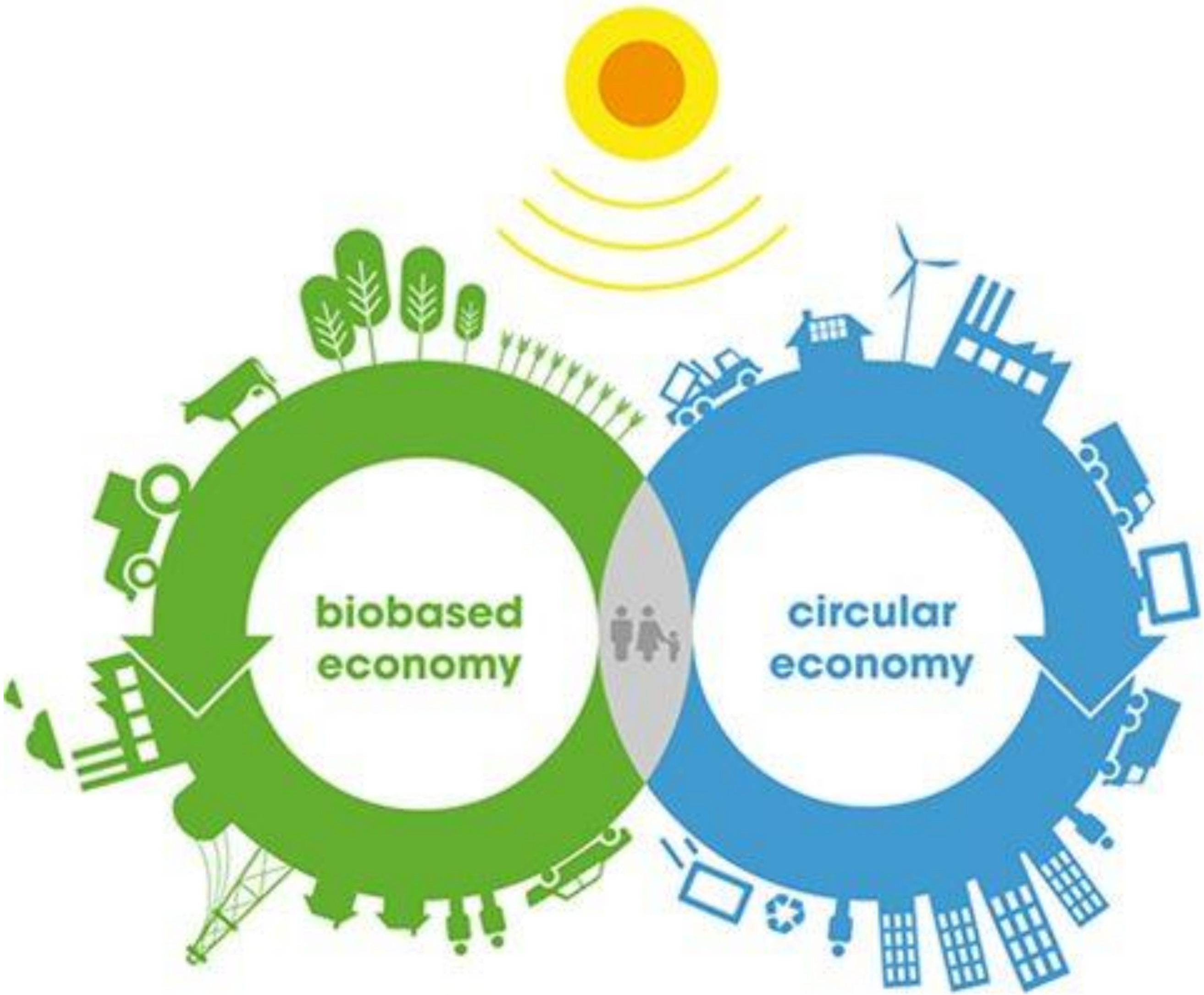
Need to address land limits

(Growing) demands on the land

Land *could be* a limiting factor in a new carbon economy



Do more and make more with less land



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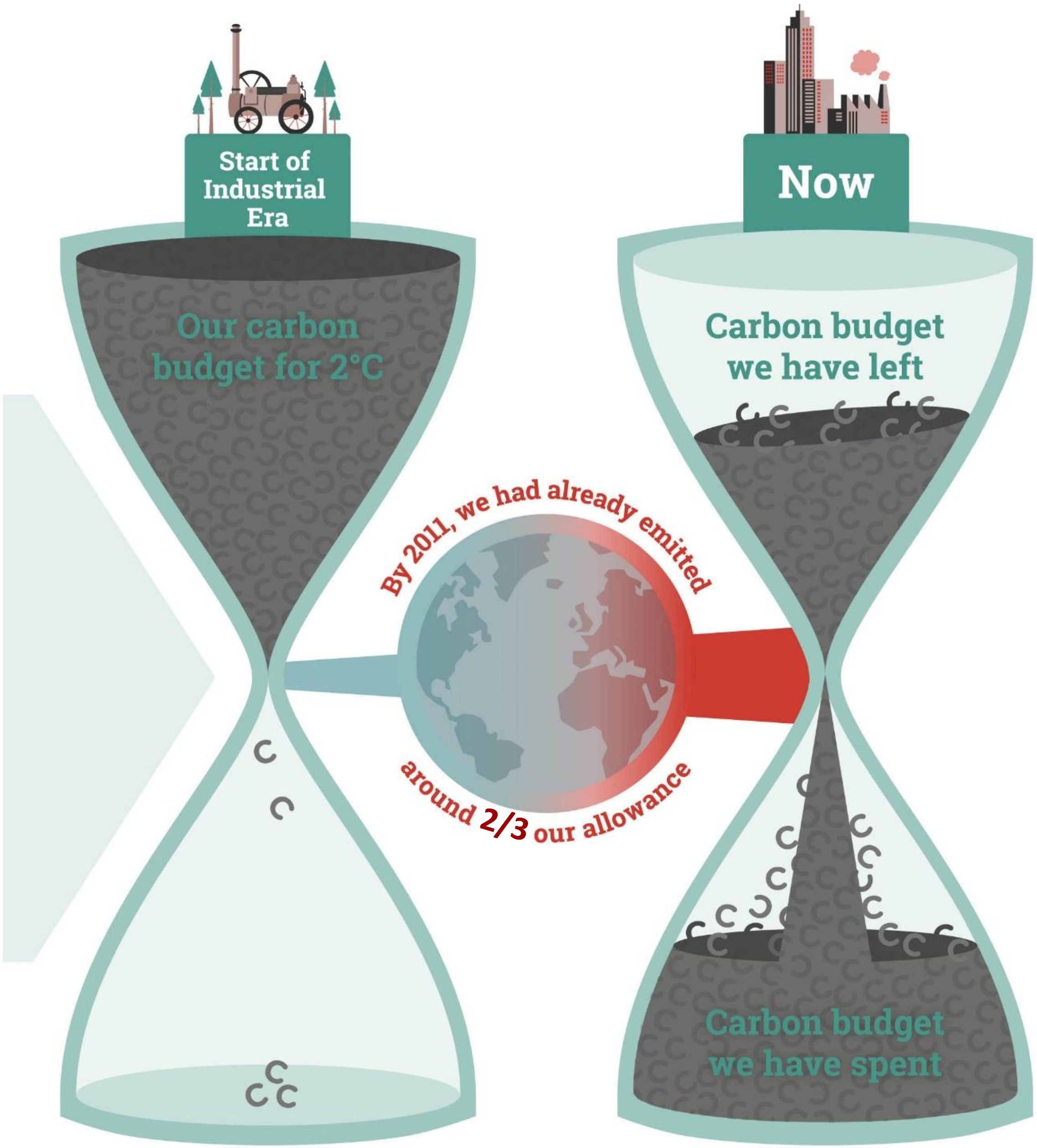
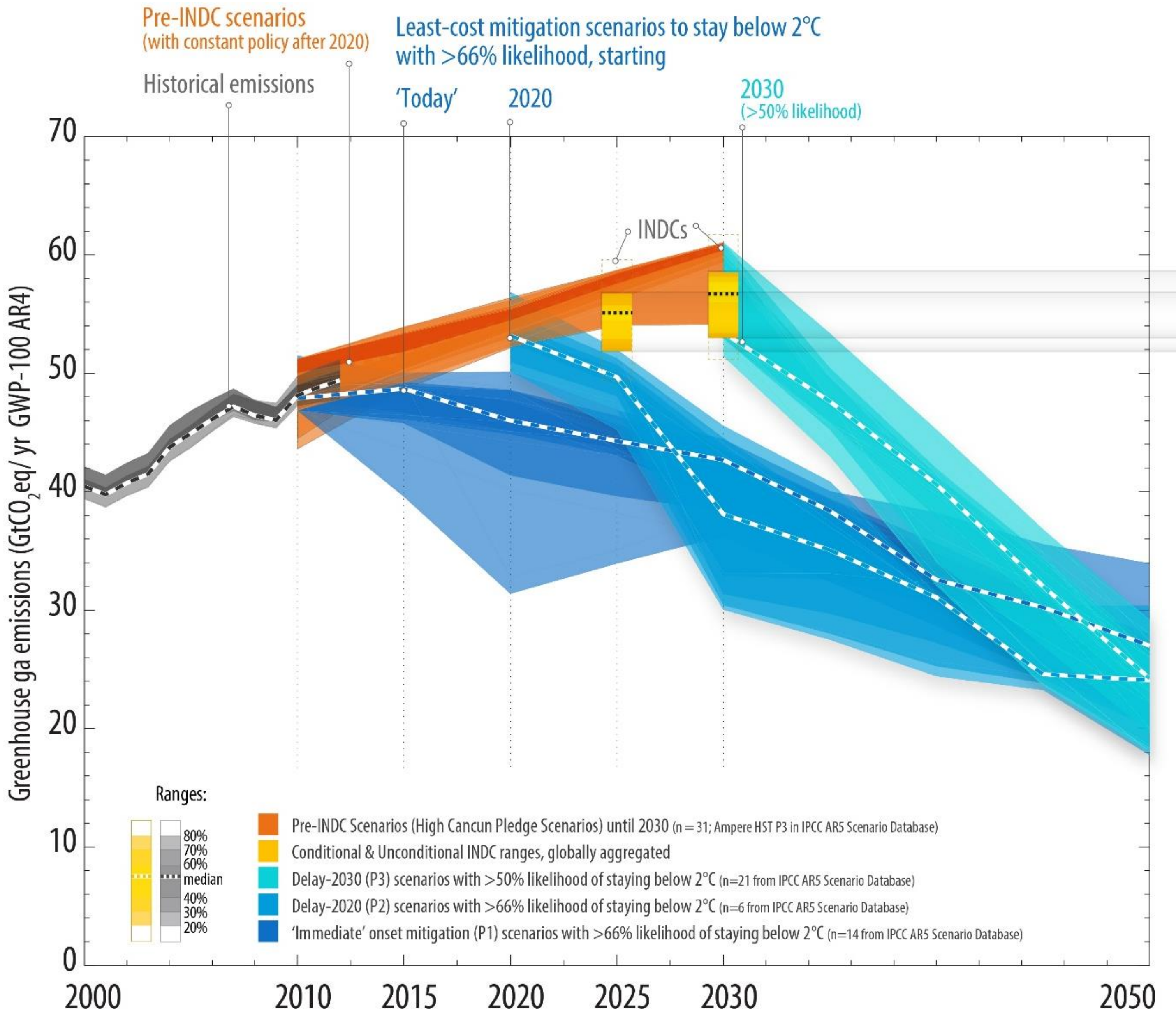
Building a sustainable economy that can maintain prosperity and address global challenges - it's all about carbon!

Failure is not an option.

Carbon Budget



Emissions reductions are targets – are projections



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Something about those CO_2 mitigation goals

All CO_2 mitigation scenarios rely on a technology that is untested and contrived from the modeled scenarios themselves: significant carbon negative assumptions; bioenergy with carbon capture and sequestration (BECCS)

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EXPLAINERS POLITICS & POLICY WORLD CULTURE MOR

It's time to start talking about "negative" carbon dioxide emissions

We have to bury gigatons of carbon to slow climate change. We're not even close to ready.

By David Roberts | @drvox | david@vox.com | Aug 18, 2017, 1:50pm EDT

ABBY RABINOWITZ AND AMANDA SIMSON SCIENCE 12.10.17 07:00 AM

THE DIRTY SECRET OF THE WORLD'S PLAN TO AVERT CLIMATE DISASTER

The Washington Post

Democracy Dies in Darkness

Energy and Environment

It's the big new idea for stopping climate change – but it has huge environmental problems of its own

The Chemical Engineer

Policy 19th February 2018

Paris Agreement targets can't be reached with negative emission technologies

Vox

EXPLAINERS POLITICS & POLICY WORLD CULTURE MORE

The awful truth about climate change no one wants to admit

David Roberts | @drvox | david@vox.com | May 15, 2015, 12:50pm EDT

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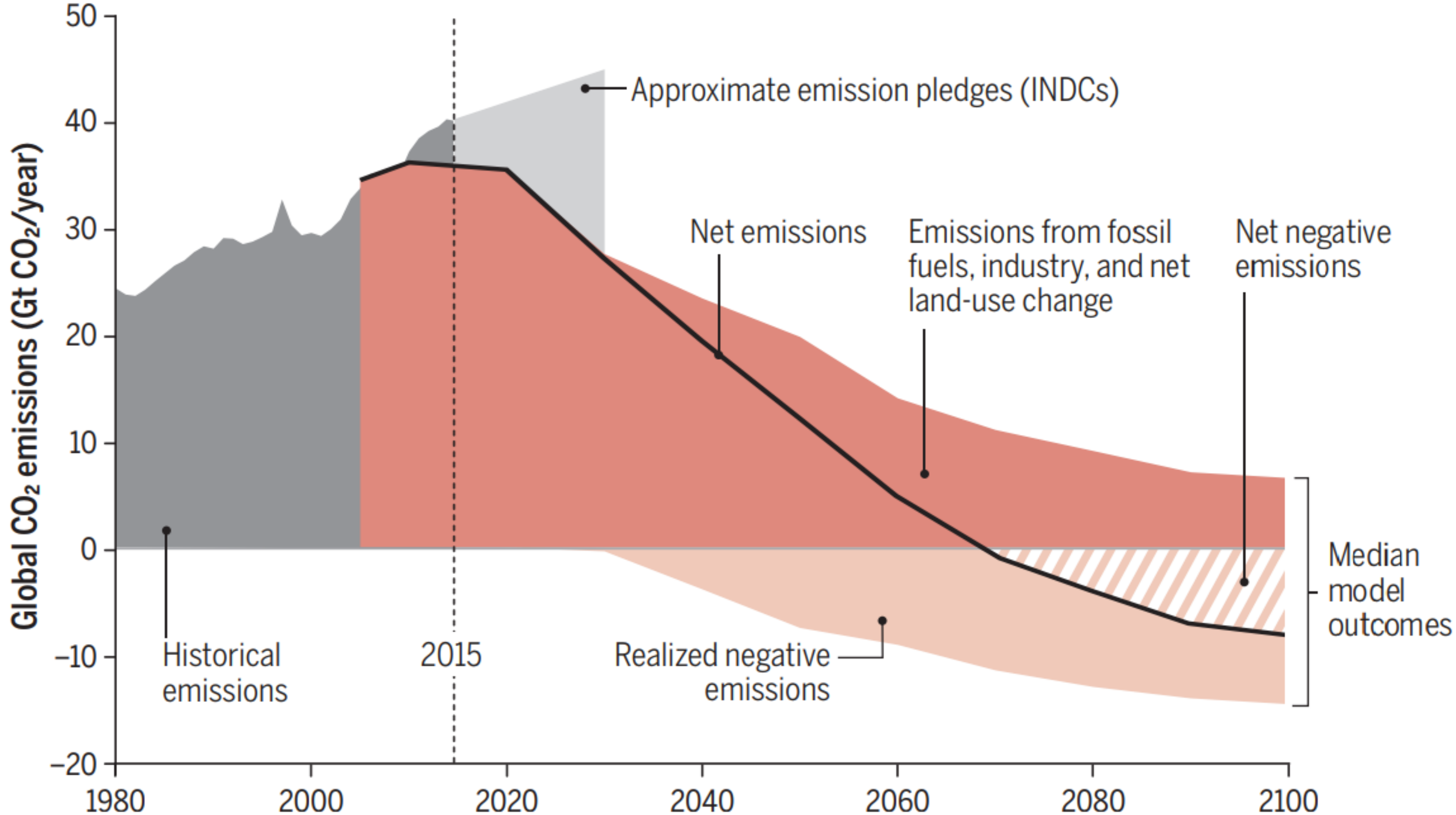
Commitments have a large reliance on negative emissions



Integrated Assessment Models for hitting the IPCC target call for an incredible increase in carbon negative pathways

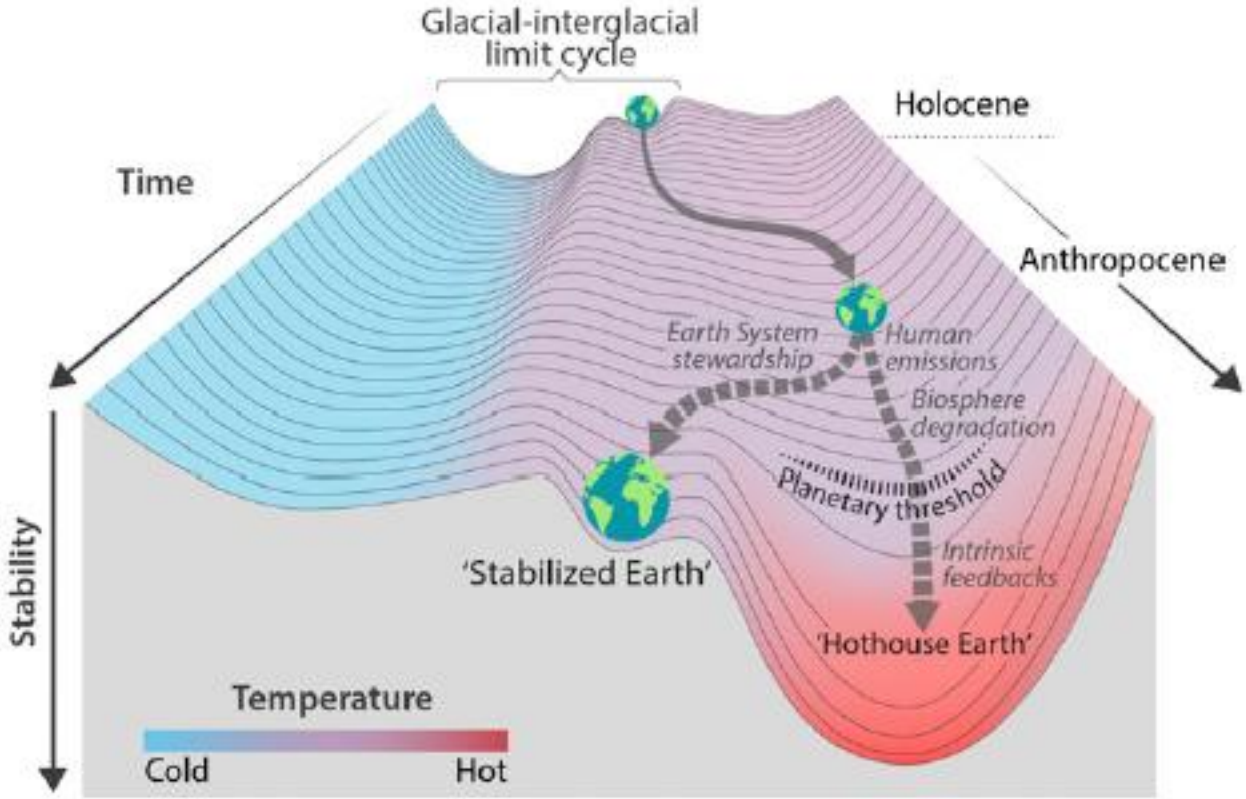
Hothouse Earth

PNAS

Trajectories of the Earth System in the Anthropocene

Will Steffen[a,b,1], Johan Rockström[a], Katherine Richardson[c], Timothy M. Lenton[d], Carl Folke[a,e], Diana Liverman[f], Colin P. Summerhayes[g], Anthony D. Barnosky[h], Sarah E. Cornell[a], Michel Crucifix[i,j], Jonathan F. Donges[a,k], Ingo Fetzer[a], Steven J. Lade[a,b], Marten Scheffer[l], Ricarda Winkelmann[k,m], and Hans Joachim Schellnhuber[a,k,m,1]

Edited by William C. Clark, Harvard University, Cambridge, MA, and approved July 6, 2018 (received for review June 19, 2018)



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The challenge is enormous!

Economy-wide transformations are needed to achieve the level of carbon mitigation and management needed.

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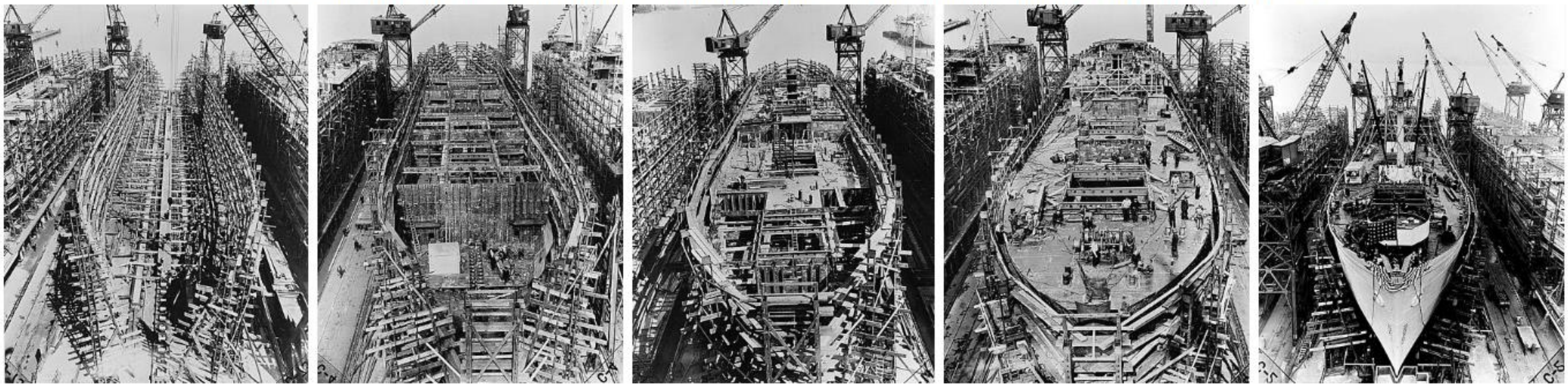
Pop Quiz – Name this ship

Pop Quiz – Name this ship

Mass-produced on an unprecedented scale, the Liberty ship came to symbolize U.S. wartime industrial output.

The construction of a Liberty ship at the Bethlehem-Fairfield Shipyards, Baltimore, Maryland, in March/April 1943



Day 2 : Laying of the keel plates

Day 6 : Bulkheads and girders below the second deck are in place

Day 10 : Lower deck being completed and the upper deck amidship erected

Day 14 : Upper deck erected and mast houses and the after-deck house in place

Day 24 : Ship ready for launching

Eighteen American shipyards built 2,710 Liberty ships between 1941 and 1945.

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Circular Carbon Economy Summit July 24-25, Golden, CO

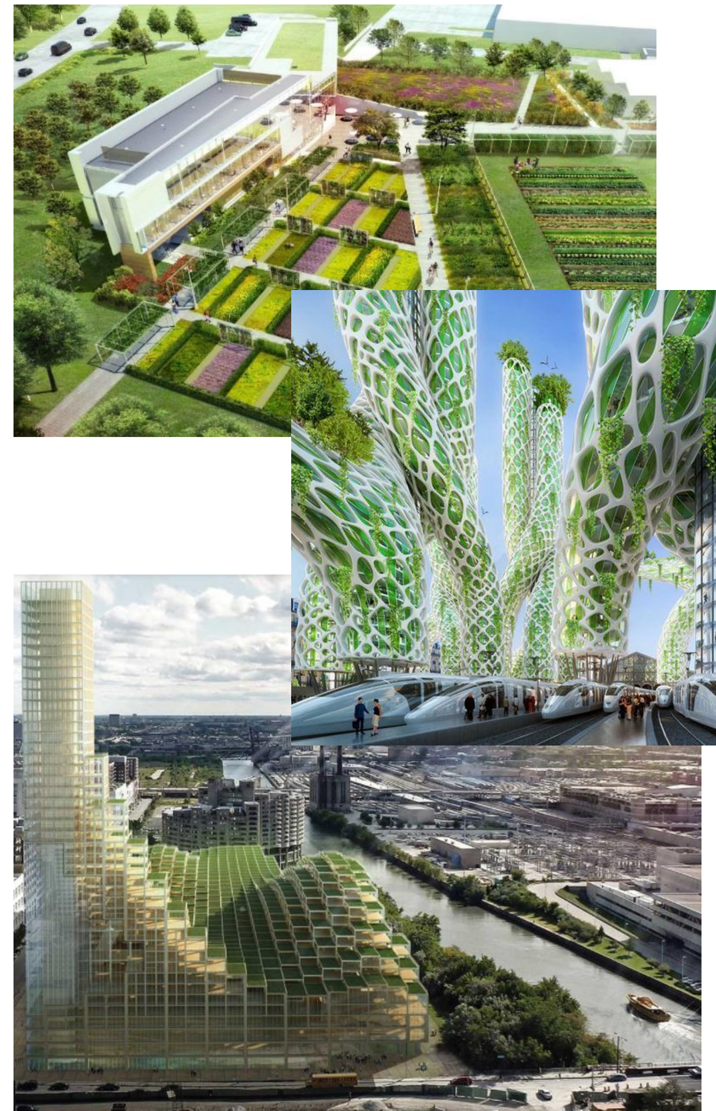
New paradigm for discussion: Focus on overall carbon implications of the natural and engineered systems considered to elucidate new ideas for R&D directions

Leveraging Natural and Managed Systems for Carbon Management

- Plant breeding and innovation
- Agroecology and landscape design
- Carbon mitigation and land sparing strategies using algae
- Quantifying and valuing ecosystem services
- The future of food: Changing what we eat and how we produce it

Leveraging Engineered Systems for Carbon Management

- Merging biology and chemistry for better CO_2 utilization
- Designing plastics for the circular carbon economy
- LCAs for carbon negative pathways
- Direct air capture and CCS at the biorefinery scale
- Leveraging the bioeconomy for large-scale carbon management
    - Opportunities for bioenergy with carbon capture and storage (BECCS)
    - Opportunities for building carbon negative pathways
- Engineering plastic recycling for the circular economy



Leveraging Natural and Managed Systems to Manage Carbon

Agroecology, Landscape Design, and Precision Agriculture

Engineering strategies to enhance productivity, carbon management and system sustainability

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Plant Breeding and Engineering

- Climate change resiliency and adaptation
- Photosynthetic efficiency
- Carbon and nutrient optimization
- Biomass quality and functionality

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Engineering Living Fertilizers

- Microbial consortia for soil amendments
- Leveraging algae in agriculture systems
- Engineering intertwined microbes for new crop microbiomes

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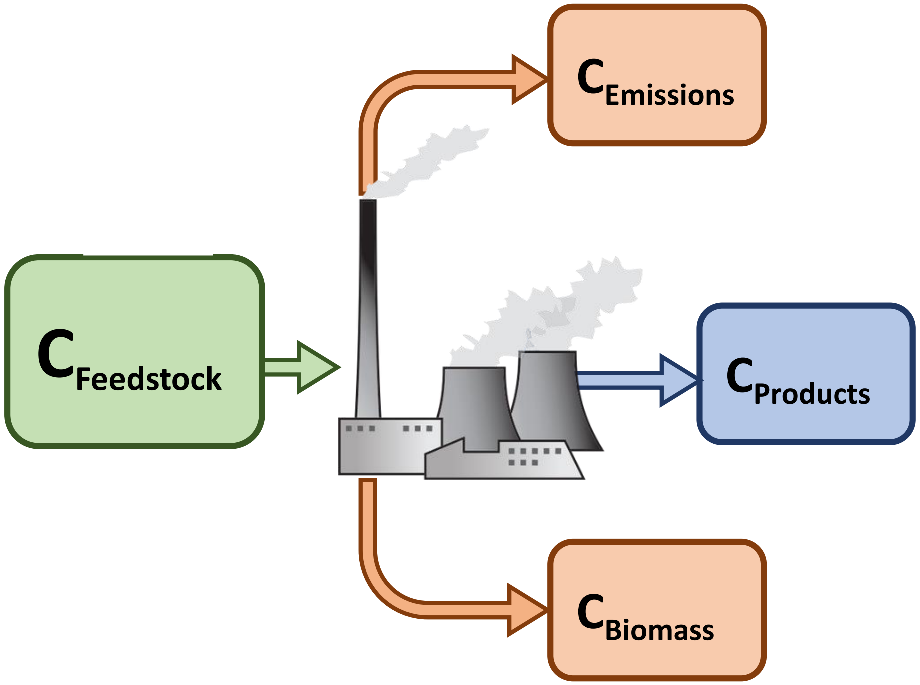
Carbon Efficiency / Biomass Efficiency

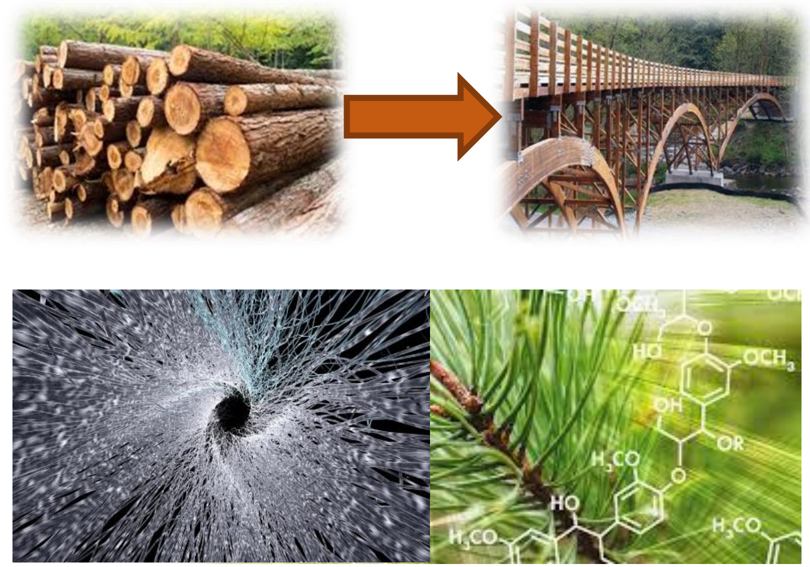
Carbon Efficiency



- Carbon efficiency considers the carbon flux through the system.

Optimizing systems for carbon will require leveraging biomass properties in product functionality – biomass efficiency

Biomass Efficiency



- Biomass efficiency considers also inherent chemical and structural components of the biomass feedstock that confer an efficient utility for the feedstock.

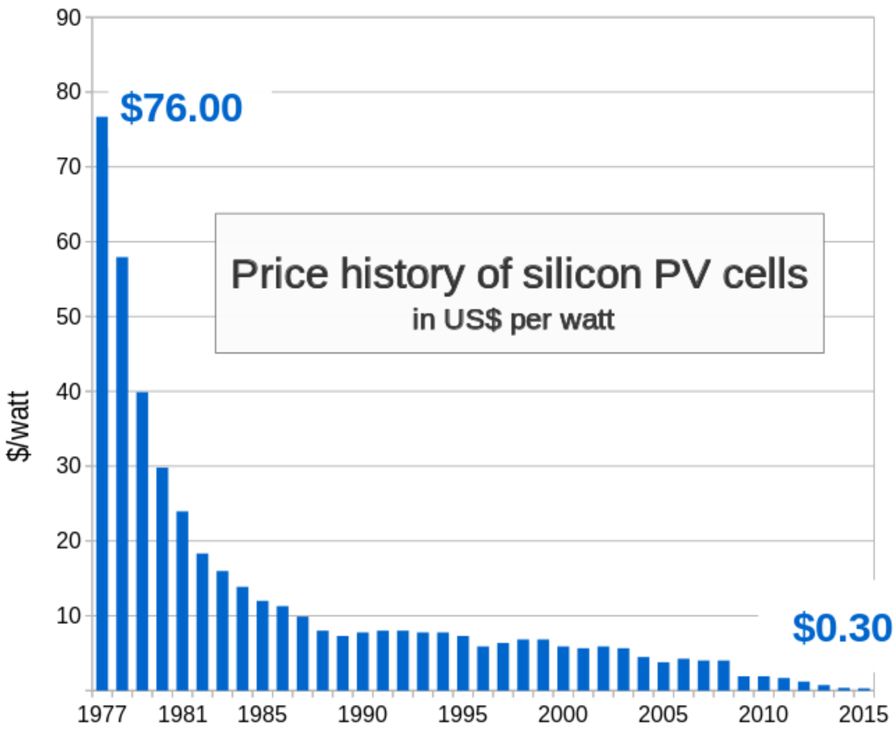
Future of Food

What we eat and how we produce it is changing and is driving new innovations in biotechnology, agriculture, sustainability, and engineering

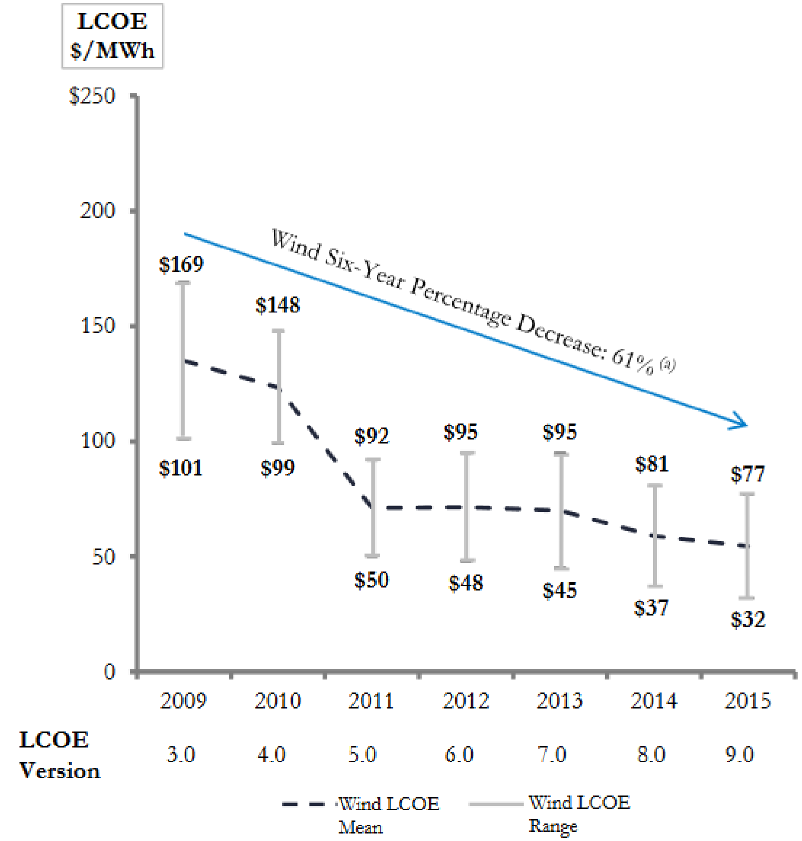



Leveraging Built and Engineered Systems to Manage Carbon

Power-up carbon-down



Source: Bloomberg New Energy Finance & pv.energytrend.com



Source: Lazard estimates.

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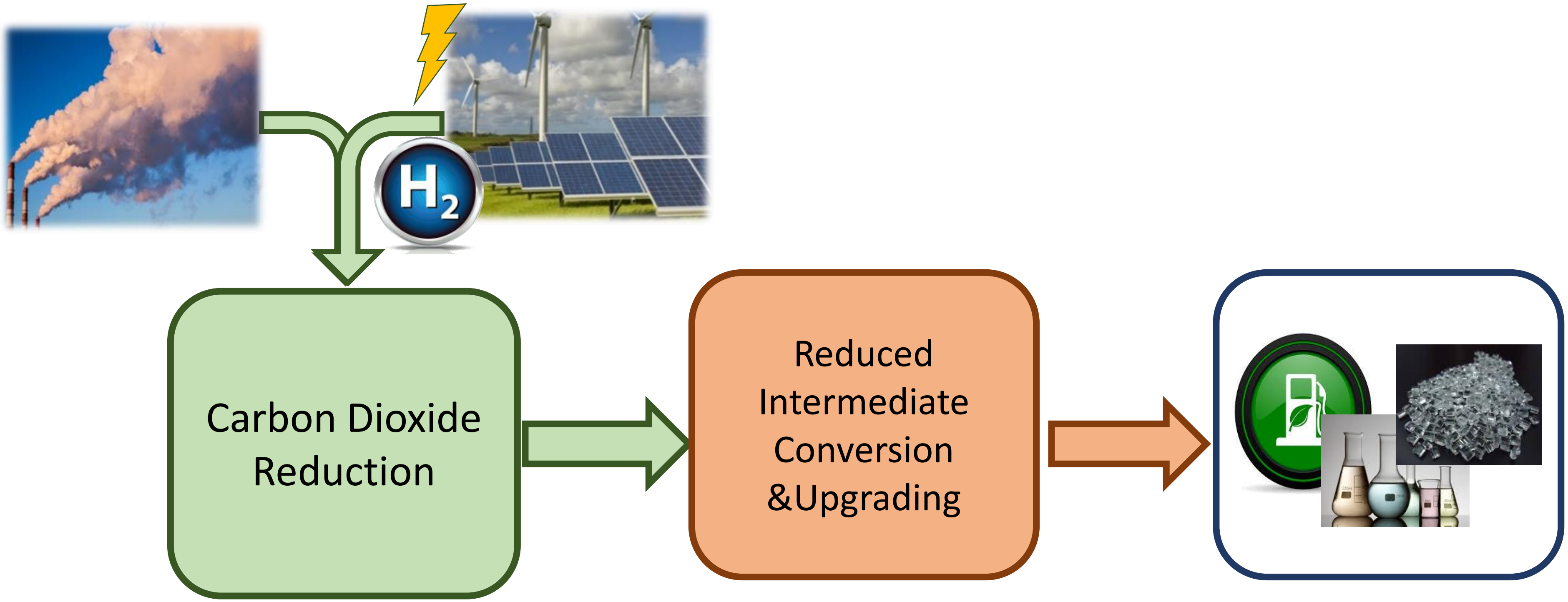
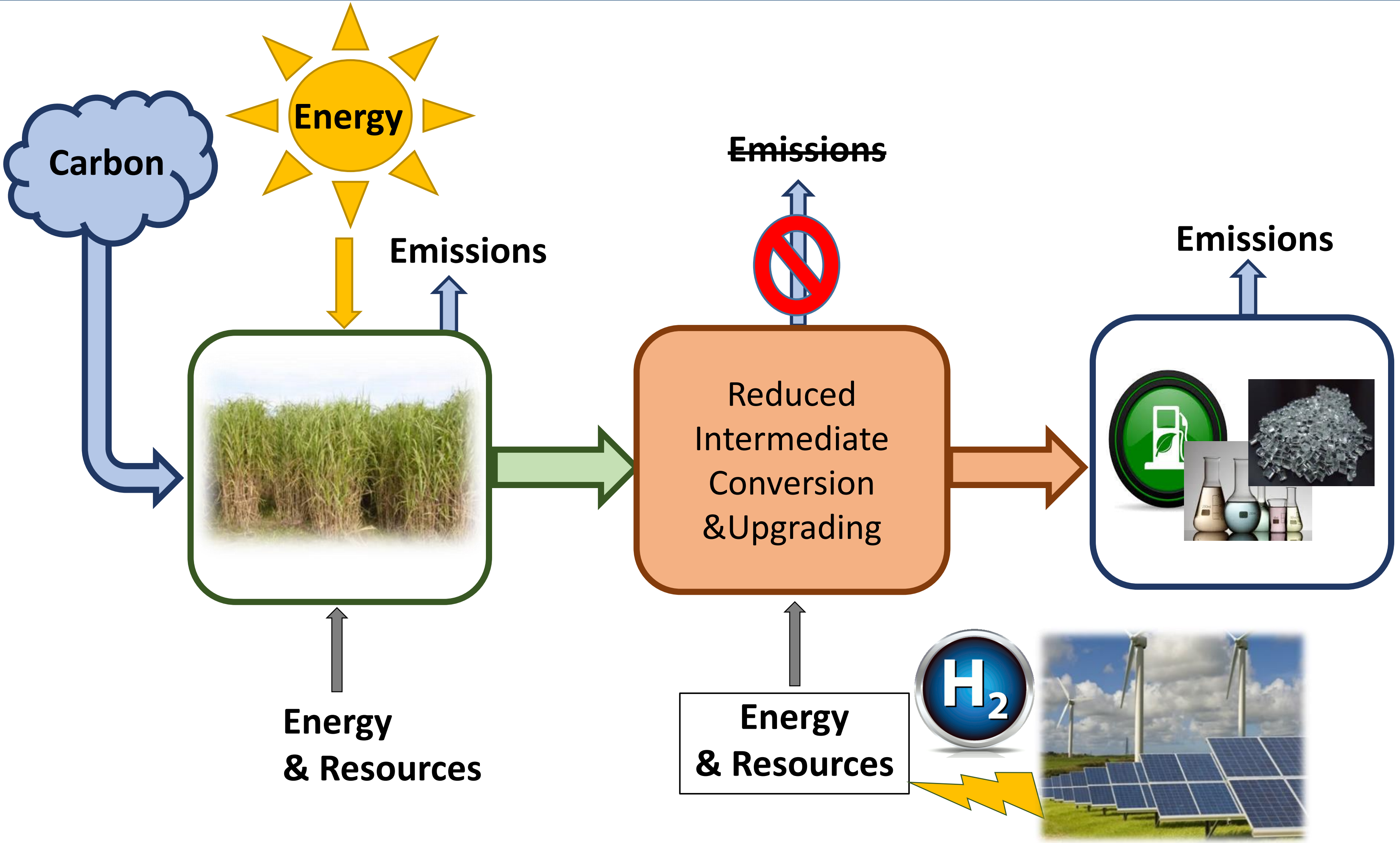
Rewiring Carbon Utilization

Building a “parallel” single-carbon platform bioeconomy



Bypassing land use requirements by leveraging low-carbon power to directly reduce CO_2 into amenable intermediates for upgrading without photosynthesis.

Rewiring Carbon Conversion



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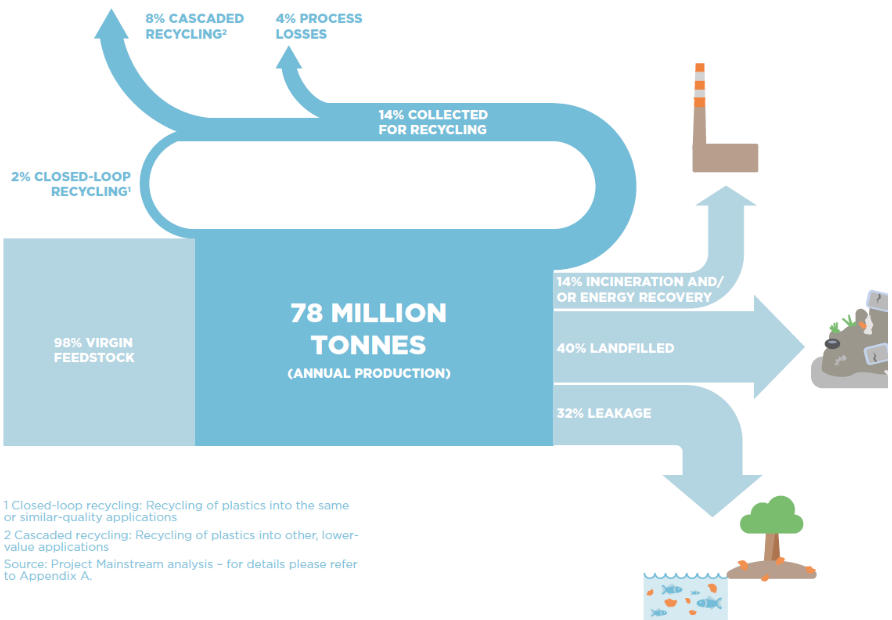
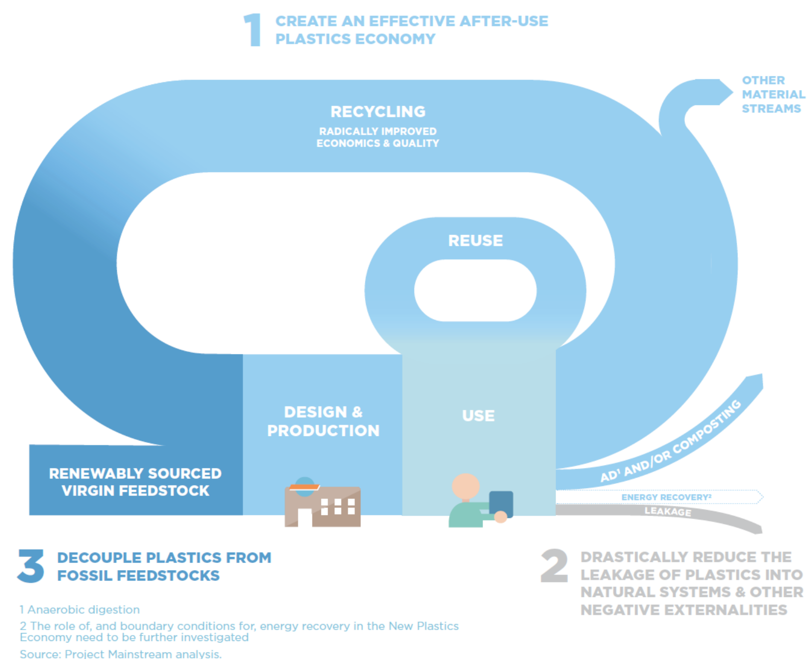
Designing plastics for the circular economy

Plastics are a hallmark of modern life and consumer use of plastics is projected to grow over the coming decades. According to the Ellen MacArthur Foundation, the projected growth in consumption would result in oceans that contain more plastics than fish (by weight) by 2050. Currently, only about 2% of plastics are recycled into the same or similar-quality applications. Modern plastics need to be designed with end-use, particularly their recyclability, in mind. Participants in this session will discuss challenges in designing plastics for a circular carbon economy.

LINEAR → CIRCULAR





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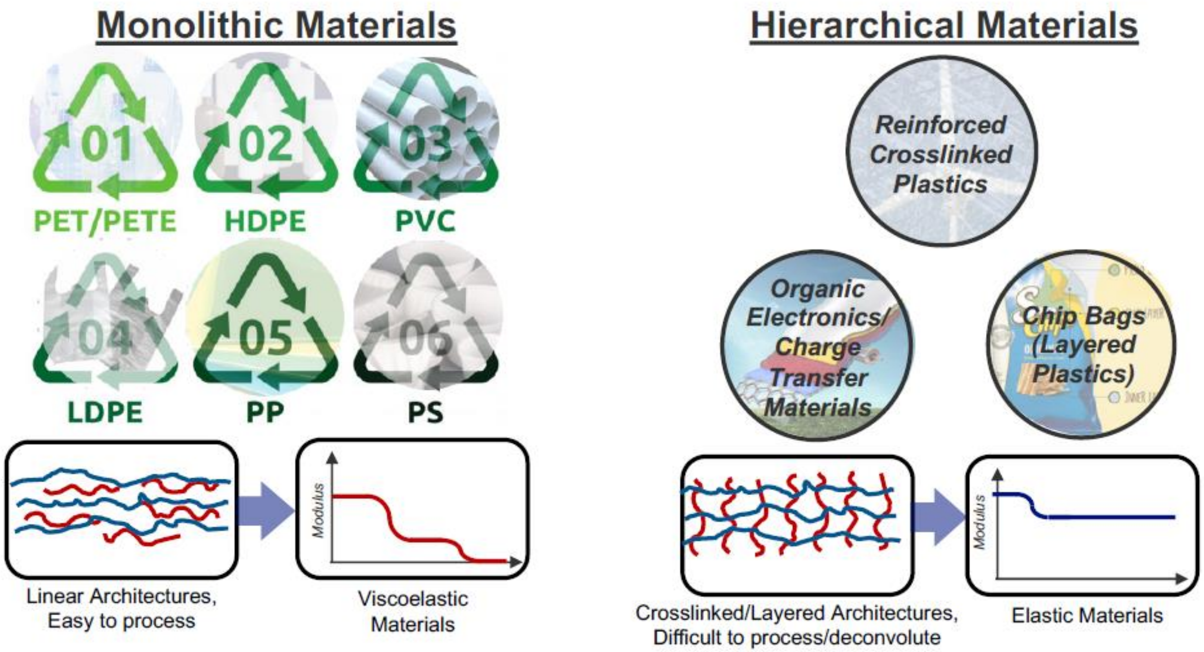
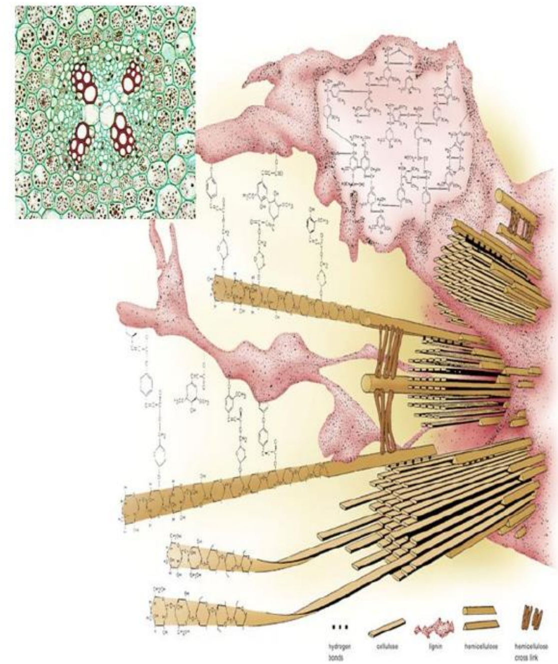
Upcycling legacy plastics

What is the fate of the plastics produced now?



An aside on biomass conversion….



Biomass recalcitrance is all about unlocking polymers in heterologous composite material, and biomass conversion techniques are applicable to plastics upcycling. – Gregg Beckham, NREL

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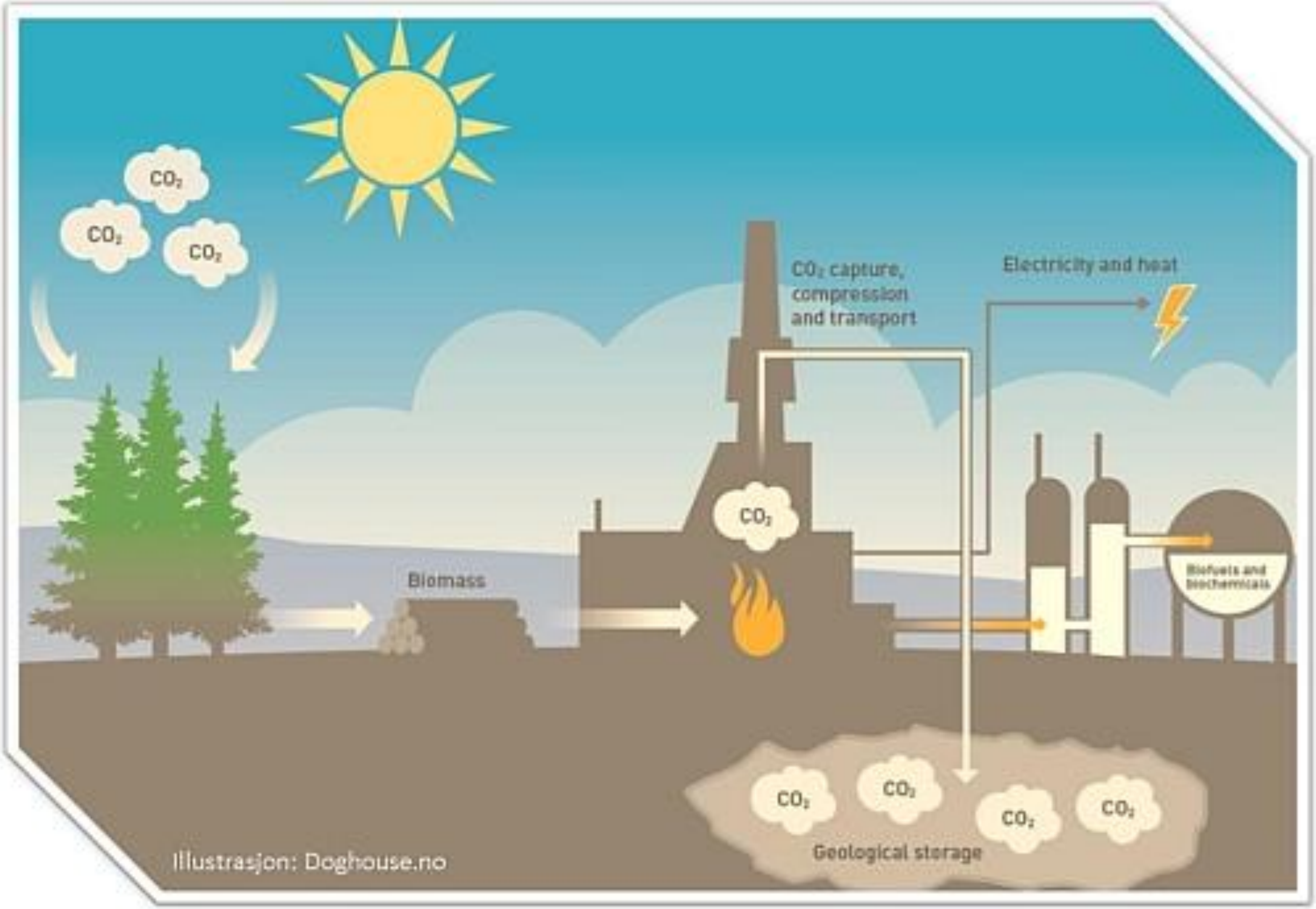
Bioenergy carbon capture and storage (BECCS)

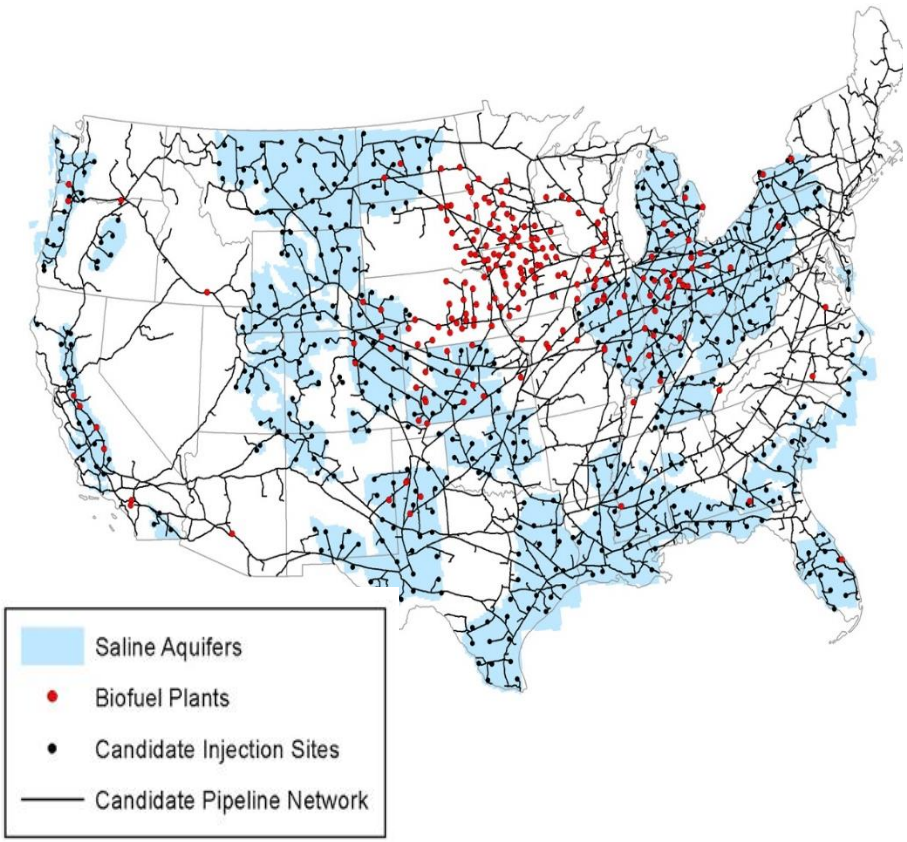


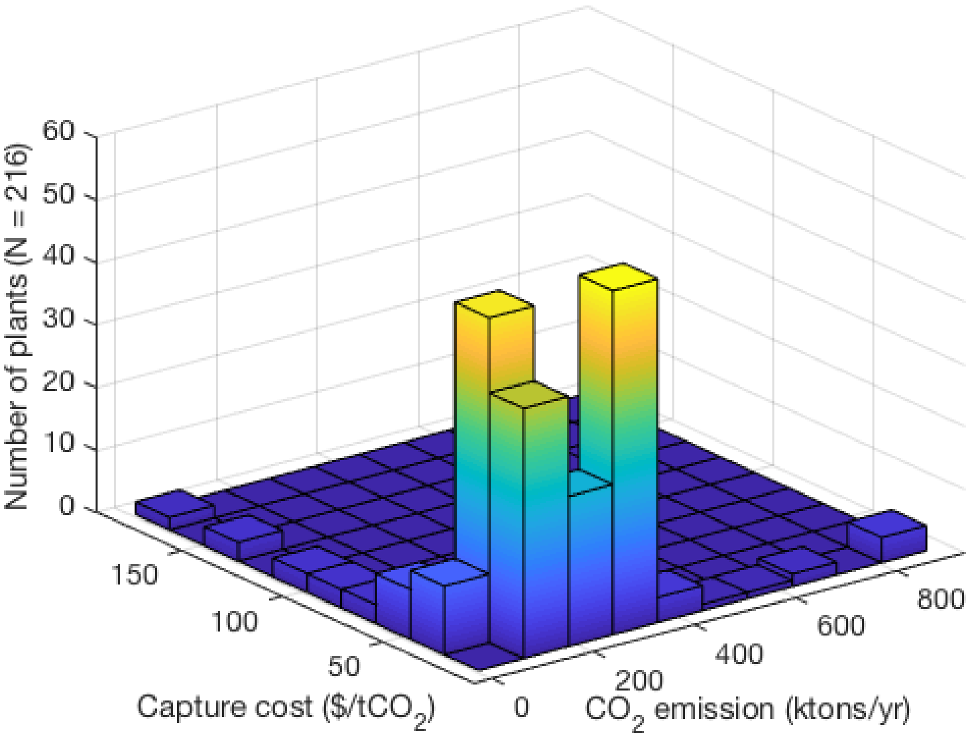
BECCS

CCUS at US biorefineries

Near-term deployment of carbon capture and sequestration from biorefineries in the United States

Daniel L. Sanchez[a,1], Nils Johnson[b], Sean T. McCoy[c,d], Peter A. Turner[a], and Katharine J. Mach[e]





Sanchez et al. *PNAS* (2018).

Direct Air Capture

- CO_2 is not too dilute
  - CO_2 vs kinetic energy
  - $20,000 vs $300
- Direct air capture is real
  - Several start-ups have prototypes
- But this needs to be big
  - 100 million units needed to balance current emissions

Estimates made by Dr. Klaus Lackner, Arizona State University

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Carbon Storage in Products and Buildings

3D Printed biomass

Engineered wood to displace steel and concrete

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Vertical Agriculture & Engineered Ecosystems

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Summary

- Addressing global challenges including population growth, resource and land limitations, and climate change will require concerted large-scale and economy wide action
- The bioeconomy is an example of a circular economy system that can be expanded to provide renewable and sustainable fuels, products, and materials
- Beyond renewable products, the bioeconomy can be leveraged to manage carbon on an industrial scale, which will provide new opportunities for a distributed, horizontally integrated future economy
- New technologies being conceived of and developed through the collaborative research of the Biomass R&D Board are serving and will serve to enhance the overall economy's resource efficiency, which will provide both economic and environmental benefits to our society

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USDA and DOE Expert Engagement

USDA-DOE Events this year

- *Innovations in Vertical Agriculture and Sustainable Urban Ecosystem Engineering,* June 26-27, USDA, Washington, DC

- *Third Annual DOE/USDA Joint Summit on Bioenergy and the Bioeconomy: Fostering Collaboration in Bioeconomy Research*, July 17-18, Madison, WI

- *Realizing the Circular Carbon Economy: Innovations in Energy and Agriculture*, July 25-26, NREL, Golden, CO

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