Virtual Roundtable

Sustainable Biomass Availability Estimates

The webinar will begin shortly.

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

On Today's Agenda:

1. Welcome & introduction

   Torben Nørgaard
   MMMCZCS

2. Sustainability perspectives for biofuels

   Ann O'Connor
   MMMCZCS

3. Global bioenergy availability

   Evan Coleman, Katie Daehn, Florian Allroggen
   MIT Climate & Sustainability Consortium (MCSC)

4. Panel discussion & audience Q&A:

   Moderated by Gerard Ostheimer, CEM Biofuture Campaign.

   Jeremy Moorhouse, International Energy Agency (IEA)

   Olivier Dubois, Independent Expert, Former UN Food and Agriculture Organization

   Hugo Liabeuf, Associate at SYSTEMIQ

   Mark Elless, Technology Manager - Bioenergy Technologies Office at the US Department of Energy

5. Closing

Welcome & Introduction

Join at

slido.com

#biomass

Sustainability perspectives for biofuels

LCA Functional Overview

Work Stream	Mission / Scope
Lifecycle Perspectives for Policy	• Develop an LCA methodology that supports the shipping industry in their energy transition. • Provide LCA Leadership through meaningful partnerships and engagement. • LCA knowledge sharing and influence.
Projects	• Lead and develop projects that address environmental and climate impact • Support project managers in scoping and delivering LCA aspects on projects. • Support the Center with carbon accounting requirements when needed.
NavigaTE Development	• Support the NavigaTE team with scoping and defining the emissions module of NavigaTE • Interface with relevant stakeholders to collect, validate and compile input data. • Support the NavigaTE team with updates.

Our working definition of sustainable biomass

"Biomass that has been cultivated and/or sourced from a system of agricultural practices aimed at maintaining the relevant ecological, economic, and social functions of the land used to cultivate the biomass now and, in the future,".

The Center and Sustainability of Fuels

Participation in IMO Correspondence Group on the development of a fuel lifecycle guideline.

… this guideline includes the development of sustainability criteria for alternative marine fuels. The debate rests on whether these criteria should be qualitative or quantitative.

Establishing the use of materiality assessment as a means of identifying key relevant sustainability aspects pertaining to biomethane production.

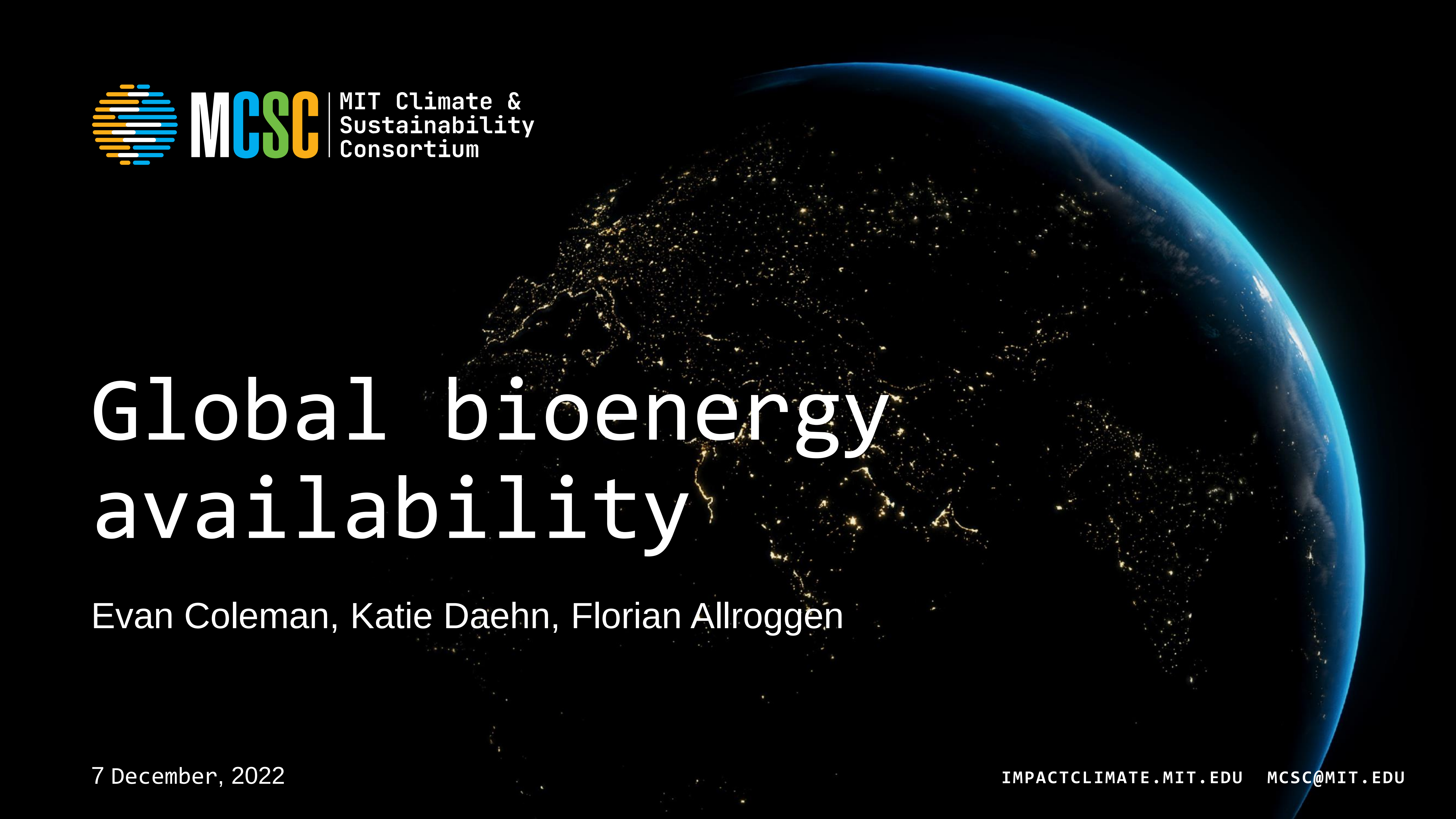
…. Finding ways of working with sustainability criteria in support of our biofuel's portfolio. Based on sustainability criteria developed by the SSI.

Scoping a project with Center partners on implementation and quantification of sustainability criteria.

…together with Center partners we are aiming towards further exploring the possibility of bringing sustainability closer towards quantification.

MIT Climate & Sustainability Consortium.

Global bioenergy availability



MIT Climate & Sustainability Consortium

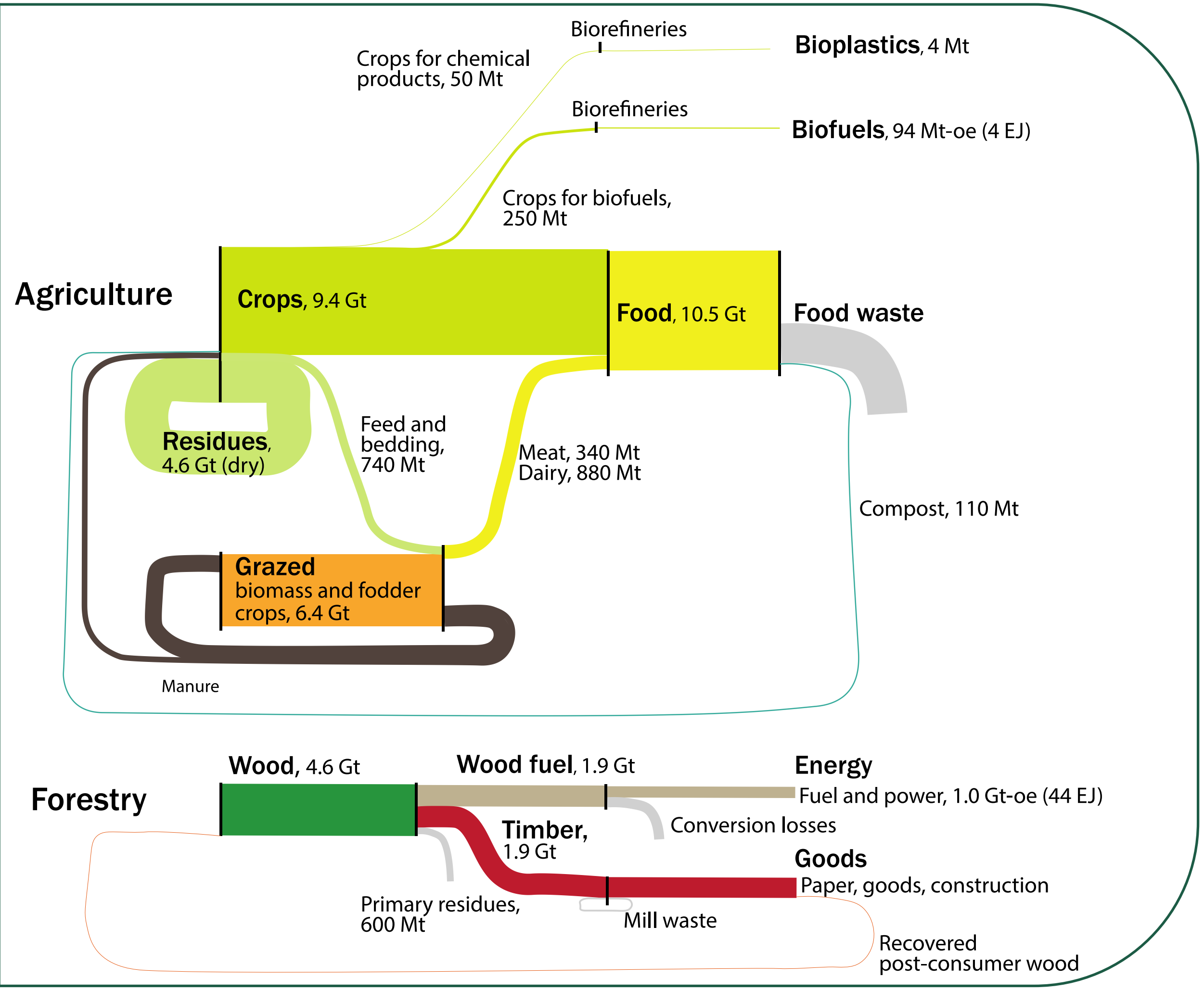
Global bioenergy availability

Evan Coleman, Katie Daehn, Florian Allroggen

7 December, 2022

Bioenergy is often considered an important **building block to meet ambitious decarbonization goals**.

Additional production needs meet the existing biomass system.



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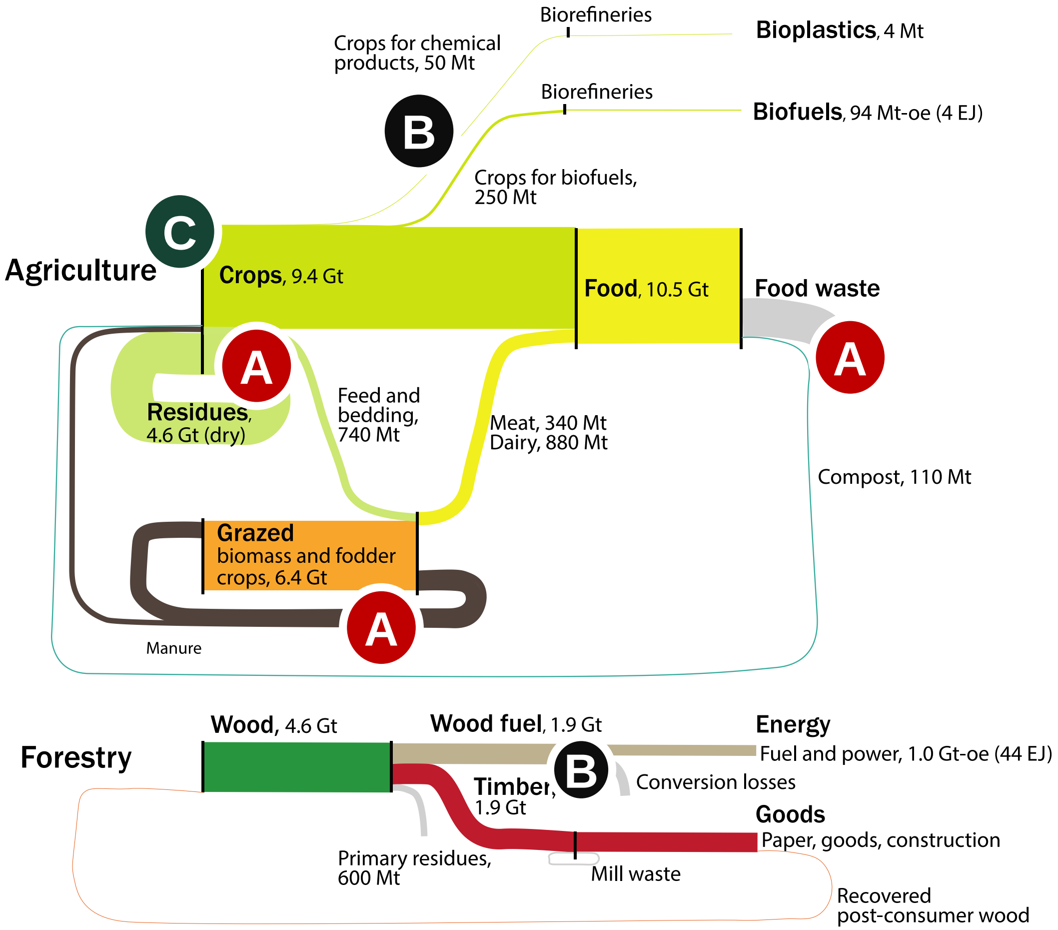
Opportunities for increasing bioenergy availability



What are the opportunities to increase bioenergy potential in this system?

A ***Use of residues:*** Leverage 'inefficiencies' in the system

B ***Improve conversion efficiency*** from crop to biofuel.

C ***Purpose-grown energy crops:*** Increase biomass supply for energy production

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Guiding question

How much bioenergy could be made available globally to support the energy transition to a decarbonized world?

Approach

Not a bottom-up study; understand existing level of agreement in literature and sensitivities to key assumptions.

Results to be presented by types of biomass:

1. Residues (agricultural, others)
2. (Purpose-grown) Energy crops

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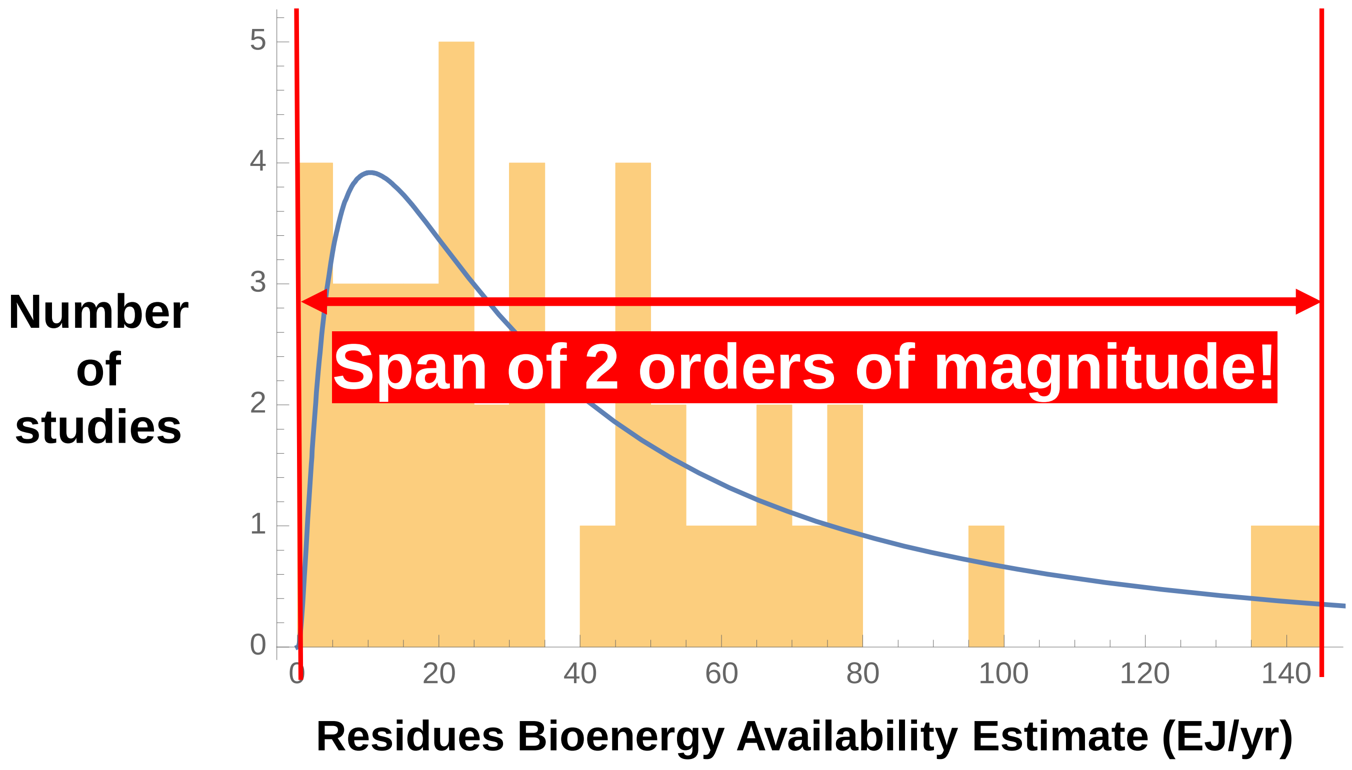
Agricultural residue availability

Bioenergy from agricultural crop residuals: variation in recent studies pointing to barriers to consensus



What is being estimated?

The order of magnitude of the energy availability is being estimated!

What are barriers to consensus?

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Investigating variation in base assumptions

Calculating crop residue availability (simplified):

Bioenergy potential from crop residues = *crop production* (arable land × yield)

× *residue to product ratio*

× *removal and collection rate*

× (1 - *fraction for other uses*)

× *energy/mass ratio*

→ ***How are estimates affected by reasonable variations?***

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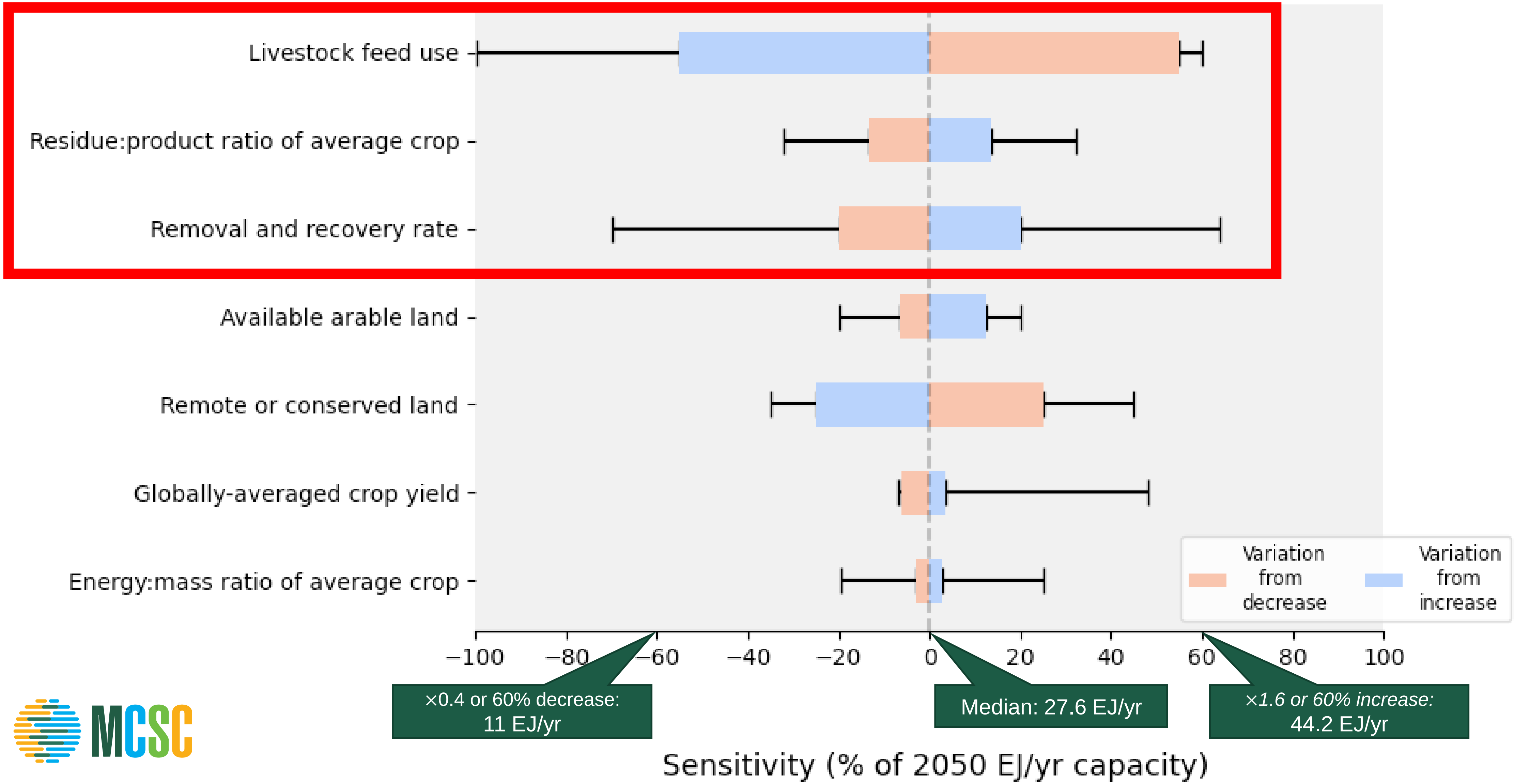
Sensitivity (OAT) of residue bioenergy potential to global factors



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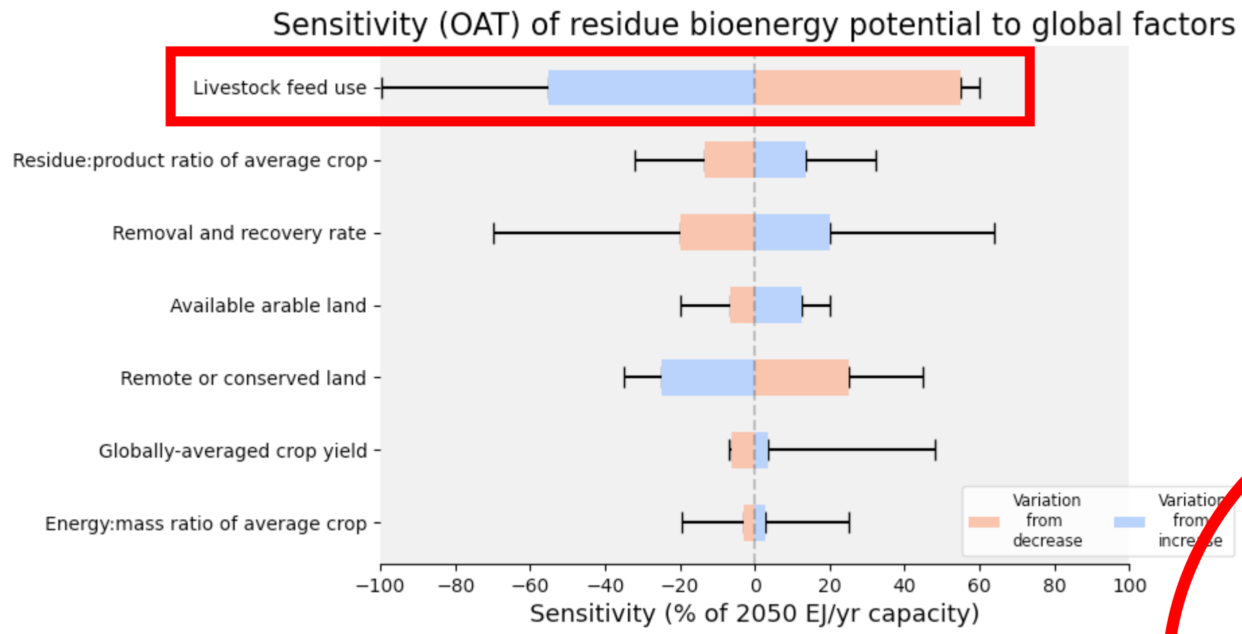
Animal residue needs are uncertain due to inconsistent definitions, few competing uses

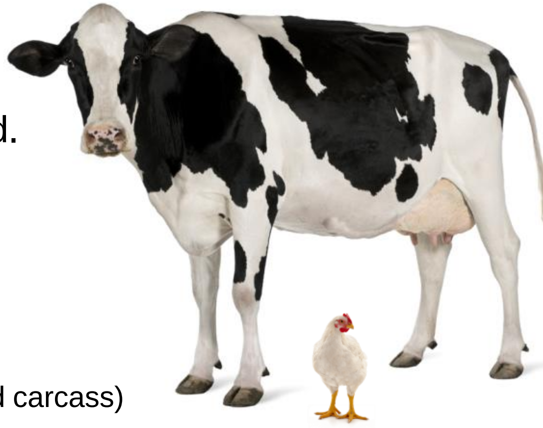


Uncertainty in the current use of residues for livestock feed.

Range of livestock feed use is 3.9-8.9 EJ/yr!

Main competing use of residues is in animal husbandry: used for bedding, feed.

Needs vary by animal (chicken vs. beef).



Net fodder feed residues for a given animal

= (FCR: kg fodder / kg live weight)
x (recovery rate i.e. kg live weight / kg dressed carcass)
x (kcal fodder / kg residue)
x (kg dressed consumed per year of a given animal)
x (% of animal feed from residues, kg residue / kg fodder)

Biggest opportunity comes from opening up grazing and fodder crop land (6.3Gt/yr biomass) to cultivation of crops for energy.

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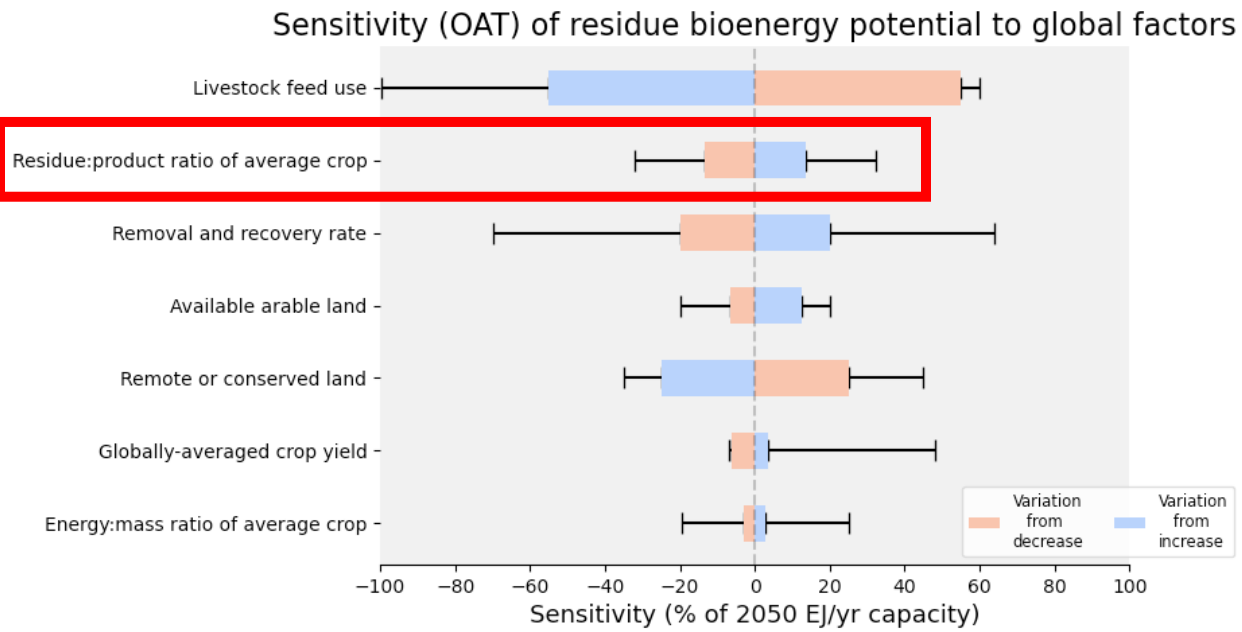
Future residue-to-product mass ratios unknown due to variance in crop cultivation forecasts

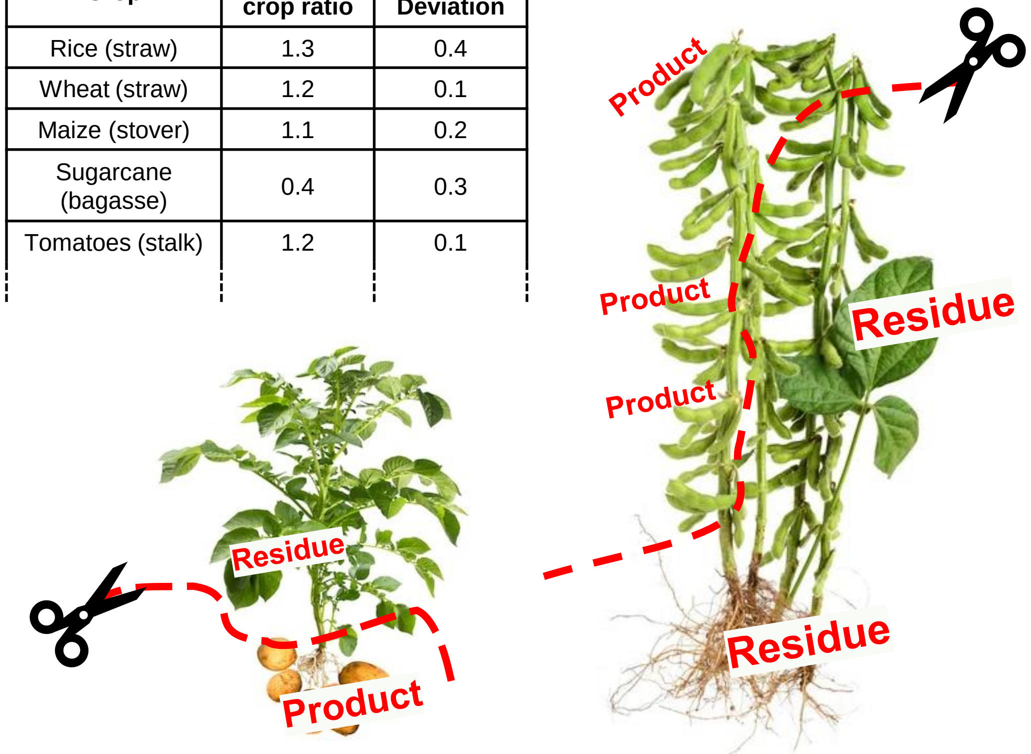
Variation between RPR estimates within crop types



Exact mix of plants to be grown remains uncertain.

Different crops have a range of residue-to-crop ratios

Crop	Residue to crop ratio	Standard Deviation
Rice (straw)	1.3	0.4
Wheat (straw)	1.2	0.1
Maize (stover)	1.1	0.2
Sugarcane (bagasse)	0.4	0.3
Tomatoes (stalk)	1.2	0.1



Potatoes: 0.3 ± 0.3 **Soy:** 3.0 ± 0.7

Sources:
Pandiyan et al., *Technological interventions for utilization of crop residues and weedy biomass for second generation bio-ethanol production* (2018)

Searle et al., *A reassessment of global bioenergy potential in 2050* (2015).

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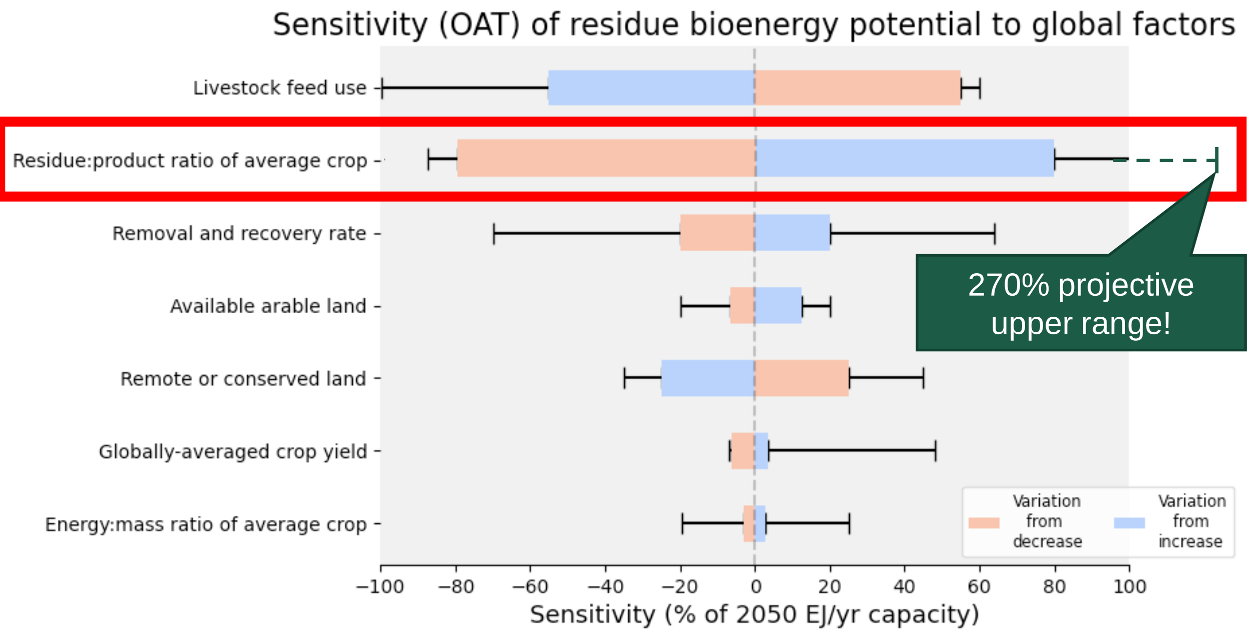

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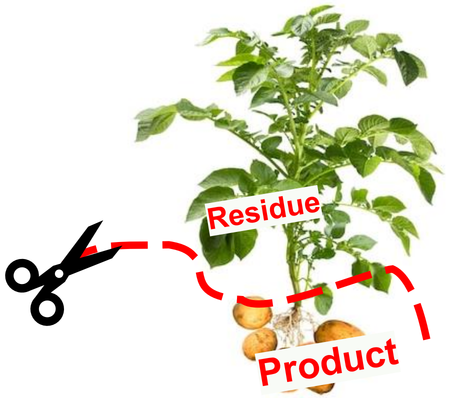

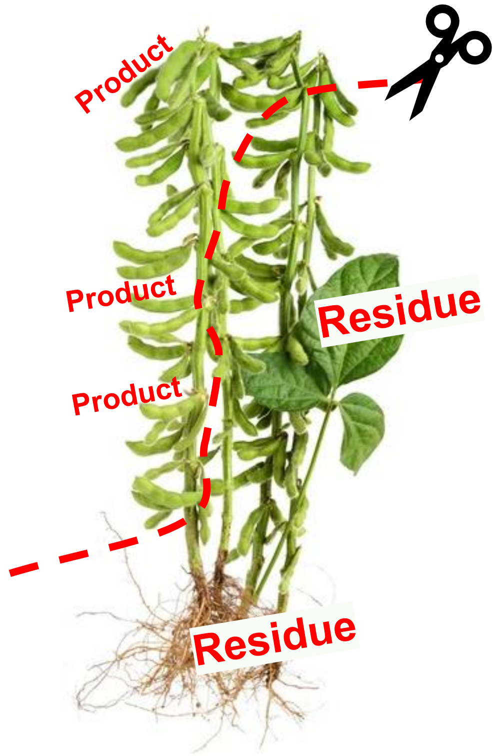

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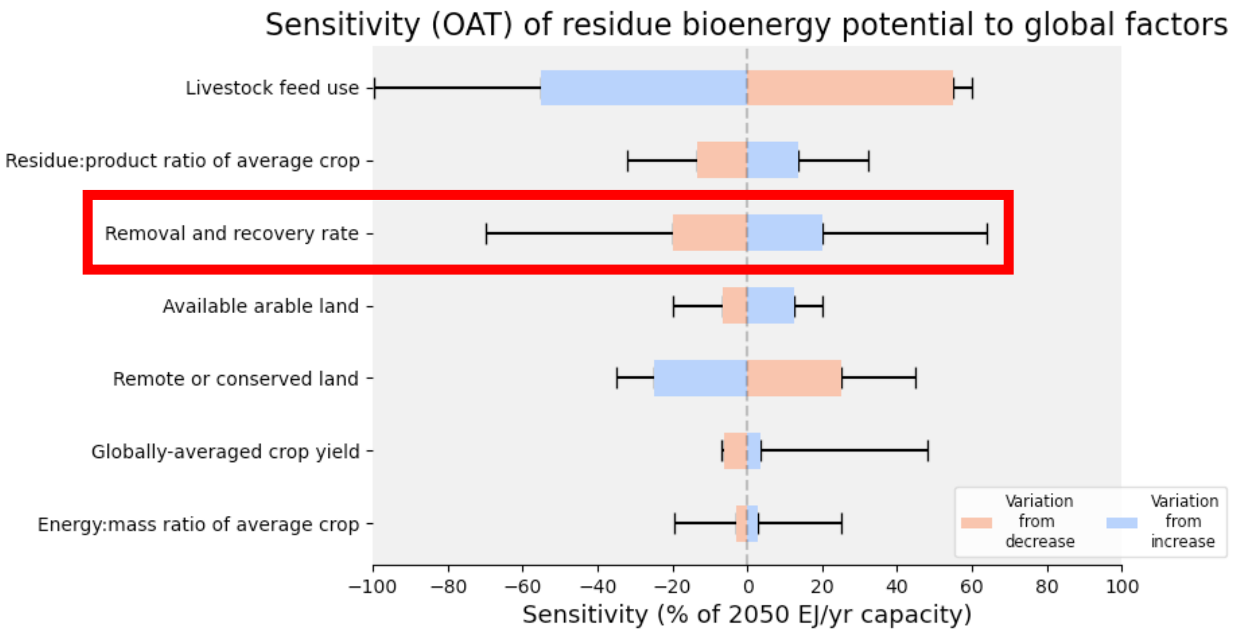
Sustainable farming practices compete with efficient removal of residues

‘Literature presents… recovery rates… between everything and nothing.’ [Bentsen et al. (2014)]



3 concepts in conservation agriculture:

- No-till
- Protect soil with left-over residues
- Crop rotation

Greater adoption likely decreases residue availability, but may provide a range of environmental and agronomic benefits.

Downstream effects on yield, on-farm emissions, and soil health are currently understudied.

Within conservation agriculture, best practices and relationships to soil (in)organic carbon under local conditions must be better understood.

Source: Powlson et al., *Limited potential of no-till agriculture for climate change mitigation* (2014)

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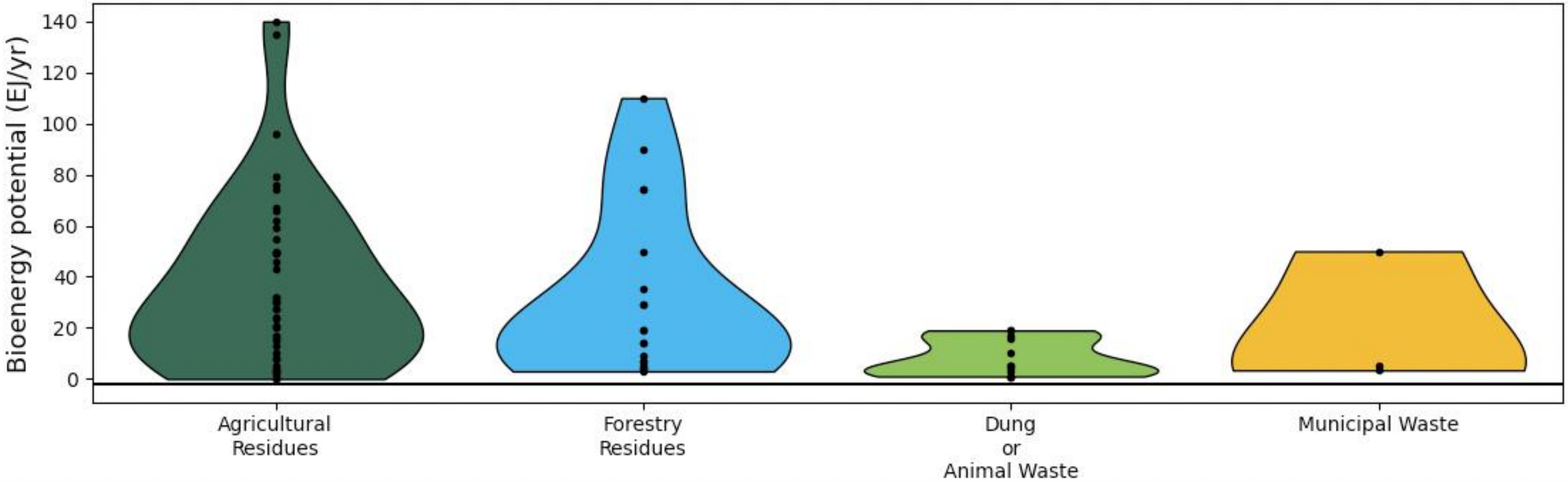
Other residues

Potential from other waste and residue sources



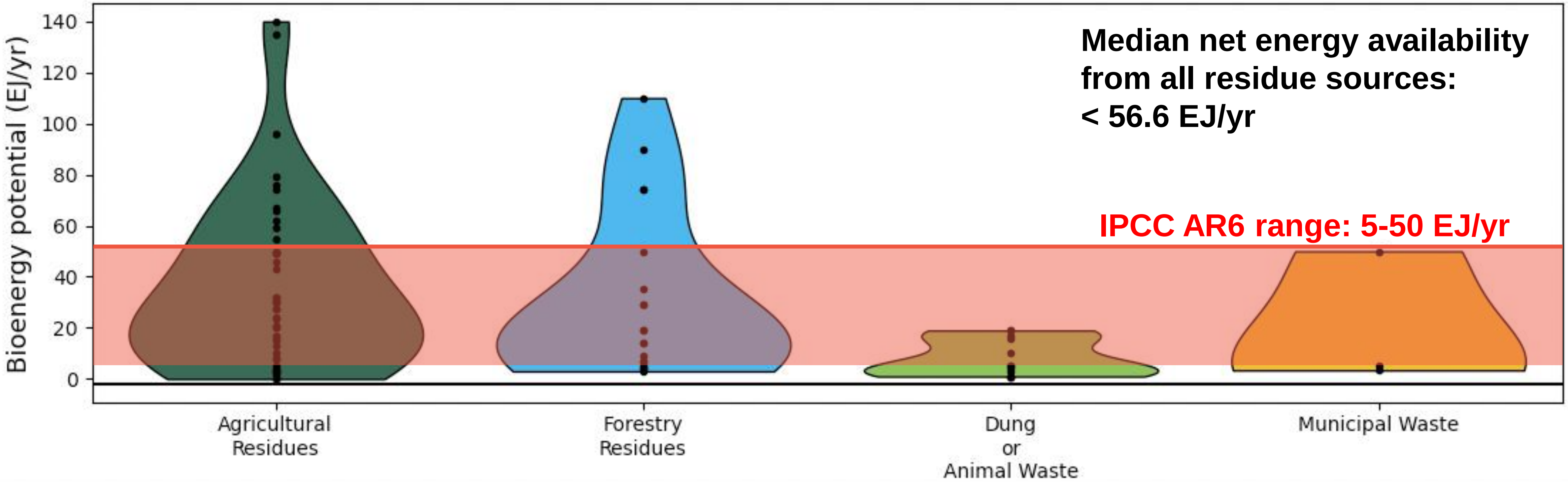
Drivers:

Removal and collection of dead wood and logging residues: feasibility and biodiversity limitations.

Field vs. stable collection. Field manure used as fertilizer and only sometimes feasible to collect.

Global variability in collection infrastructure and costs for diverting stream for bioenergy.

Total bioenergy potential from wastes and residues



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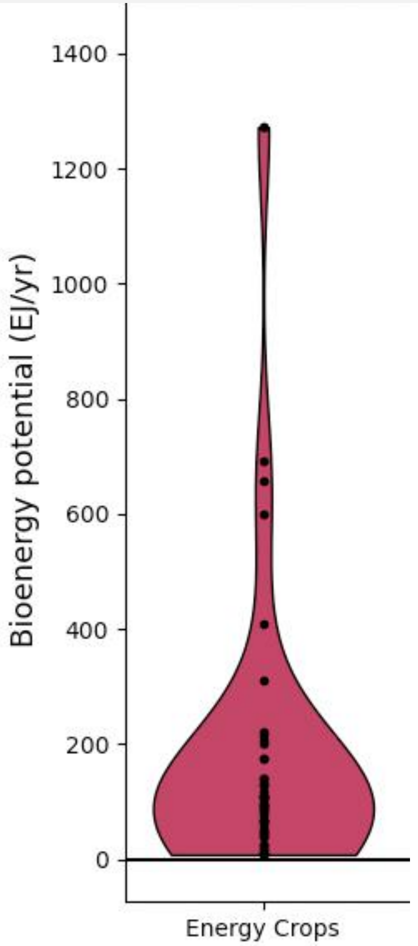
Energy crops

Purpose-grown energy crops: 90% of estimates in last 10 years are below 250 EJ/yr

Overview of estimates



Estimates by study

Range of Bioenergy Potential (EJ) Values for <u>Energy Crops</u>, by publication

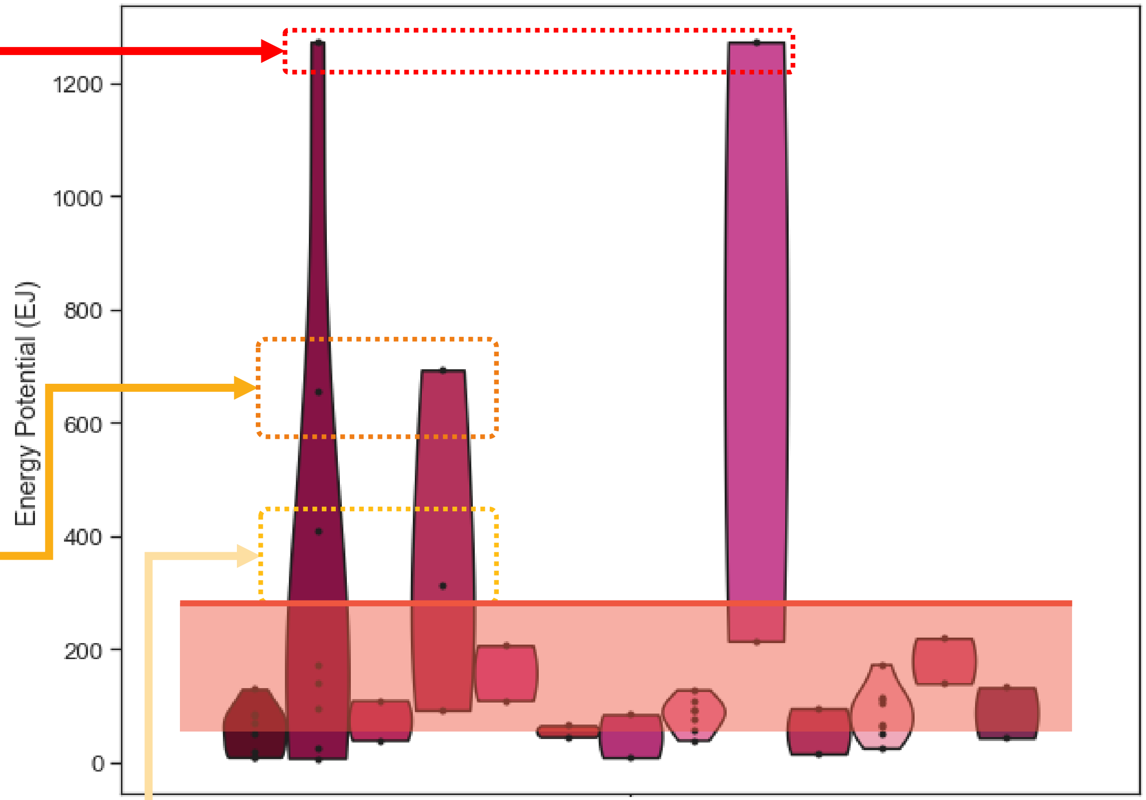
Hypothetical scenario where all parameters are maximized.

- High intensity farming with "landless" animal production.
- Crop yields increased by 4.6x by 2050.
- Food consumption per capita is 1.2x 1998 value

Ambitious diet and crop yield assumptions.

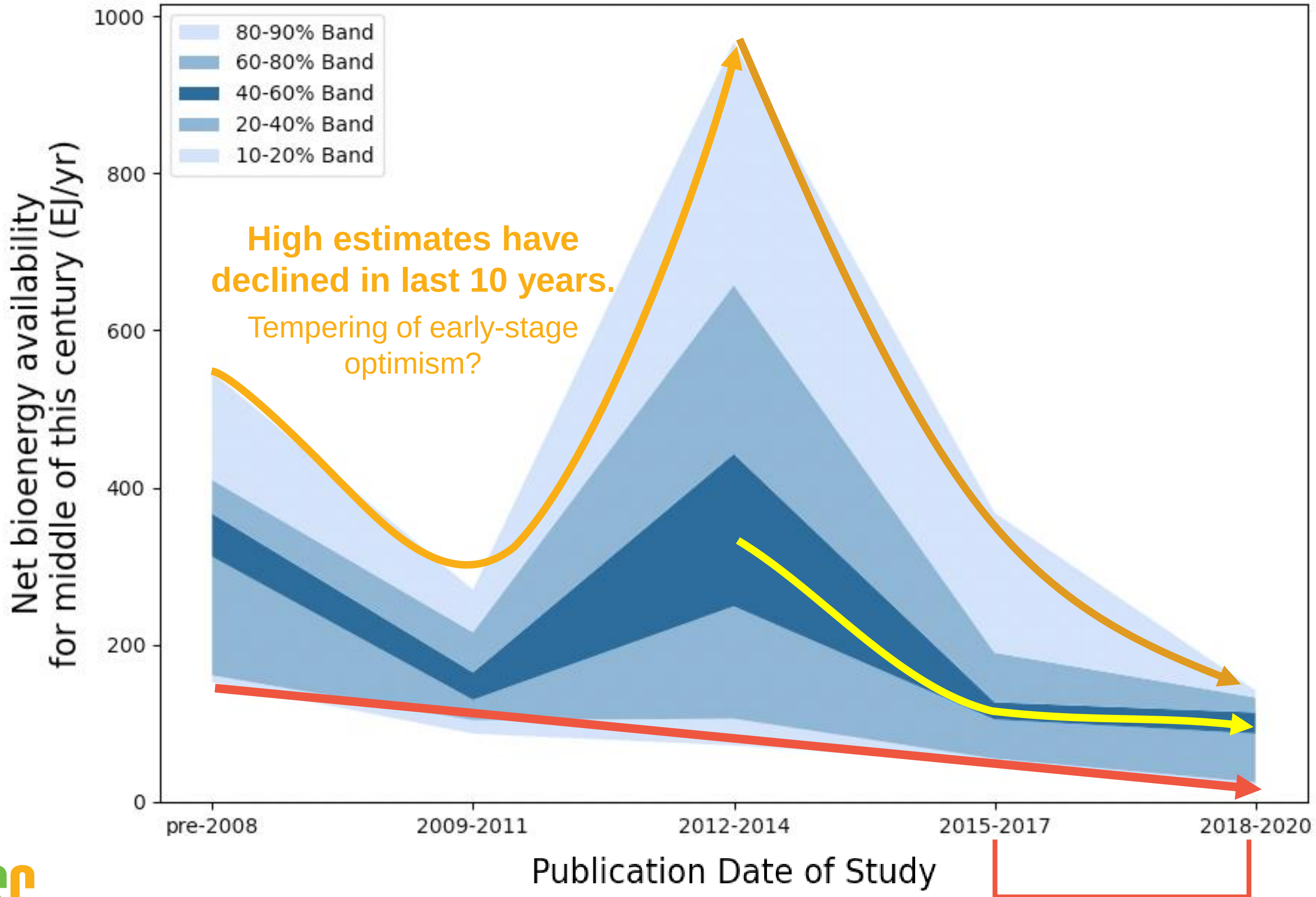
- High fertilizer use
- Largely vegetarian diets and high grazing intensification
- Deforestation for energy crops

Moderate-High Yields with High production grazing and Forest Use



IPCC AR6 range: 50-250 EJ/yr

Energy crop estimates have decreased

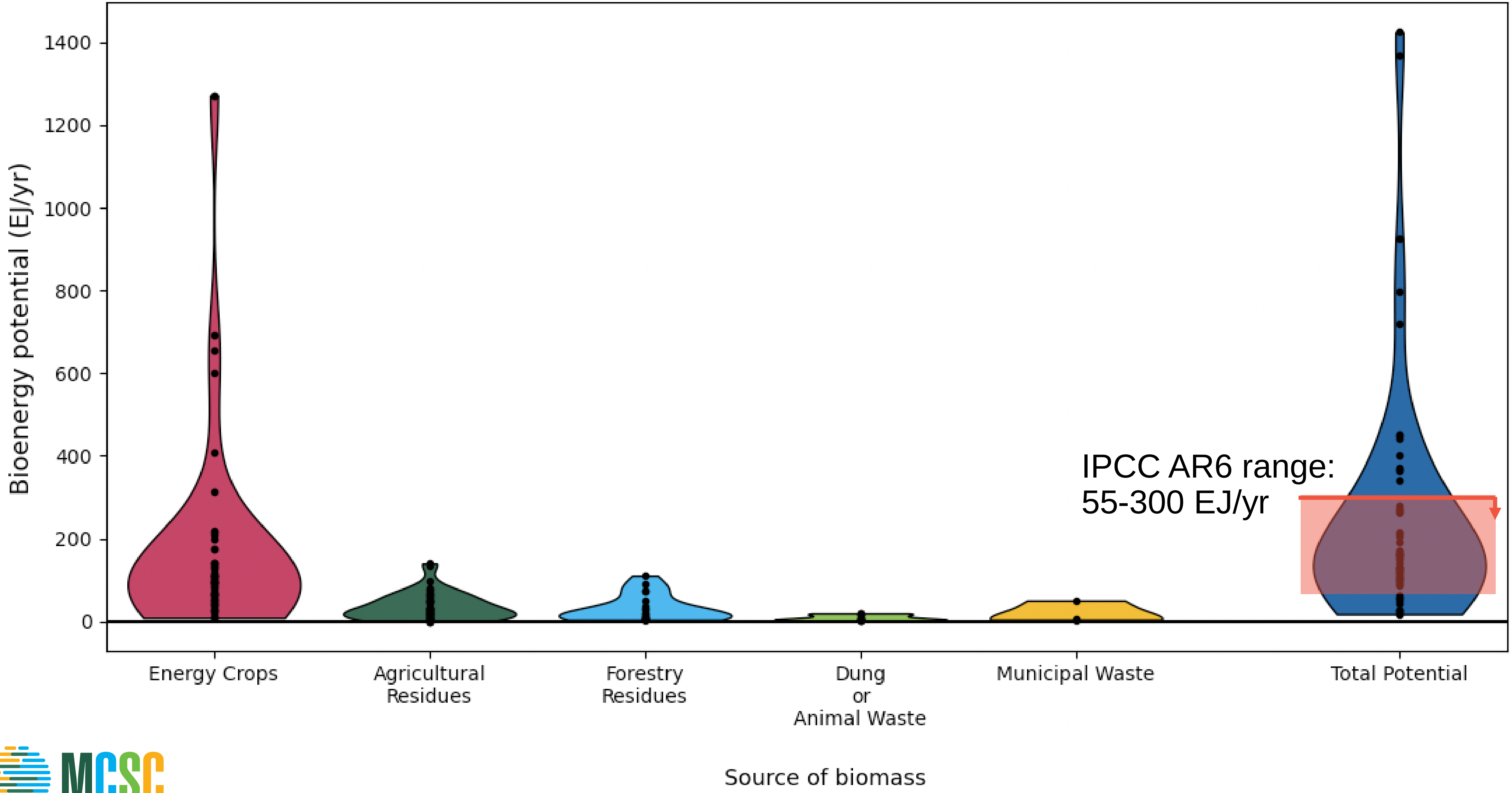


Conservative potential estimates have decreased over time.

Likely due to stricter conservation and sustainability constraints.

In the past 5 years, medians have concentrated below 200 EJ

Summary: potential from all sources



Summary of key findings

Overall primary bioenergy availability likely within the range of the IPCC report: 55 – 300EJ/yr in 2050

Residues only: economic and sustainability reasons constrain the potential of residues as a source of bioenergy to 5-50 EJ/yr in 2050.

*Significant **uncertainty** in estimates remain, mostly due to overall crop and residue production, alternative uses, and sustainable and economic removal rates*

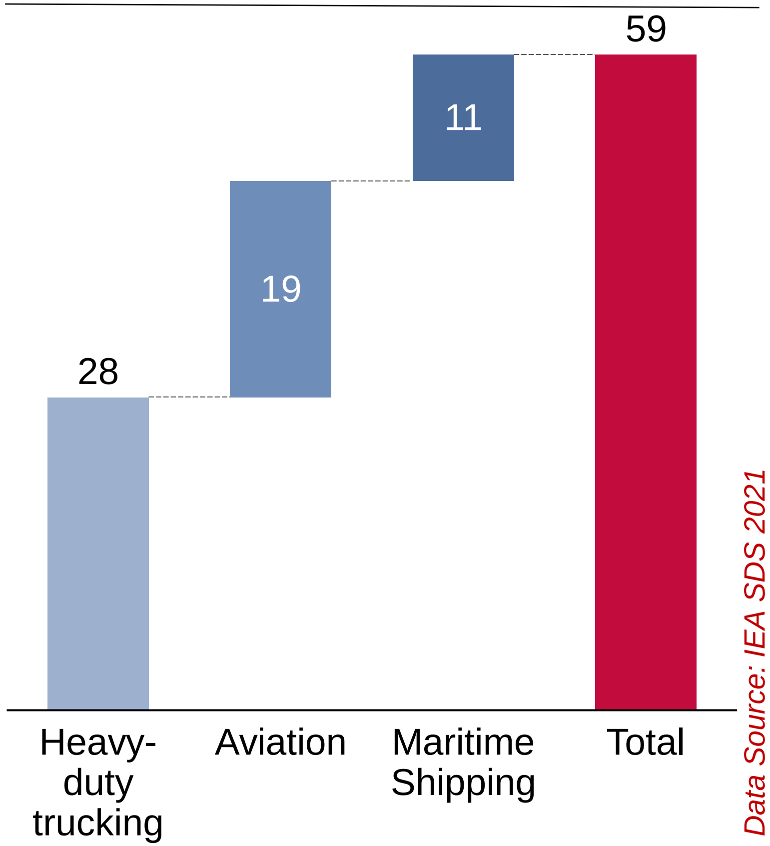
Energy crop potentials are are limited to 55-250 EJ/yr

Significant uncertainty in availability given future diets, yield assumptions and sustainable land availability.

Significant impact of current policy decisions on practical availability of bioenergy from energy crops.

For reference:

2050 energy demand of T2DT sectors, *EJ by mode*



Data Source: IEA SDS 2021

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Thank you

Katie Daehn daehn@mit.edu

Evan Coleman ecol@mit.edu

Florian Allroggen fallrogg@mit.edu

Join at

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Panel Discussion

Participants:

Gerard Ostheimer -
Moderator
Managing Director, Clean Energy Ministerial (CEM) Biofuture Campaign

Jeremy Moorhouse
Bioenergy Analyst at the International Energy Agency (IEA)

Olivier Dubois
Independent Expert, Former UN Food and Agriculture Organization

Hugo Liabeuf
Senior Energy Insights Analyst SYSTEMIQ

Mark Elless
Technology Manager - Bioenergy Technologies Office at the US Department of Energy

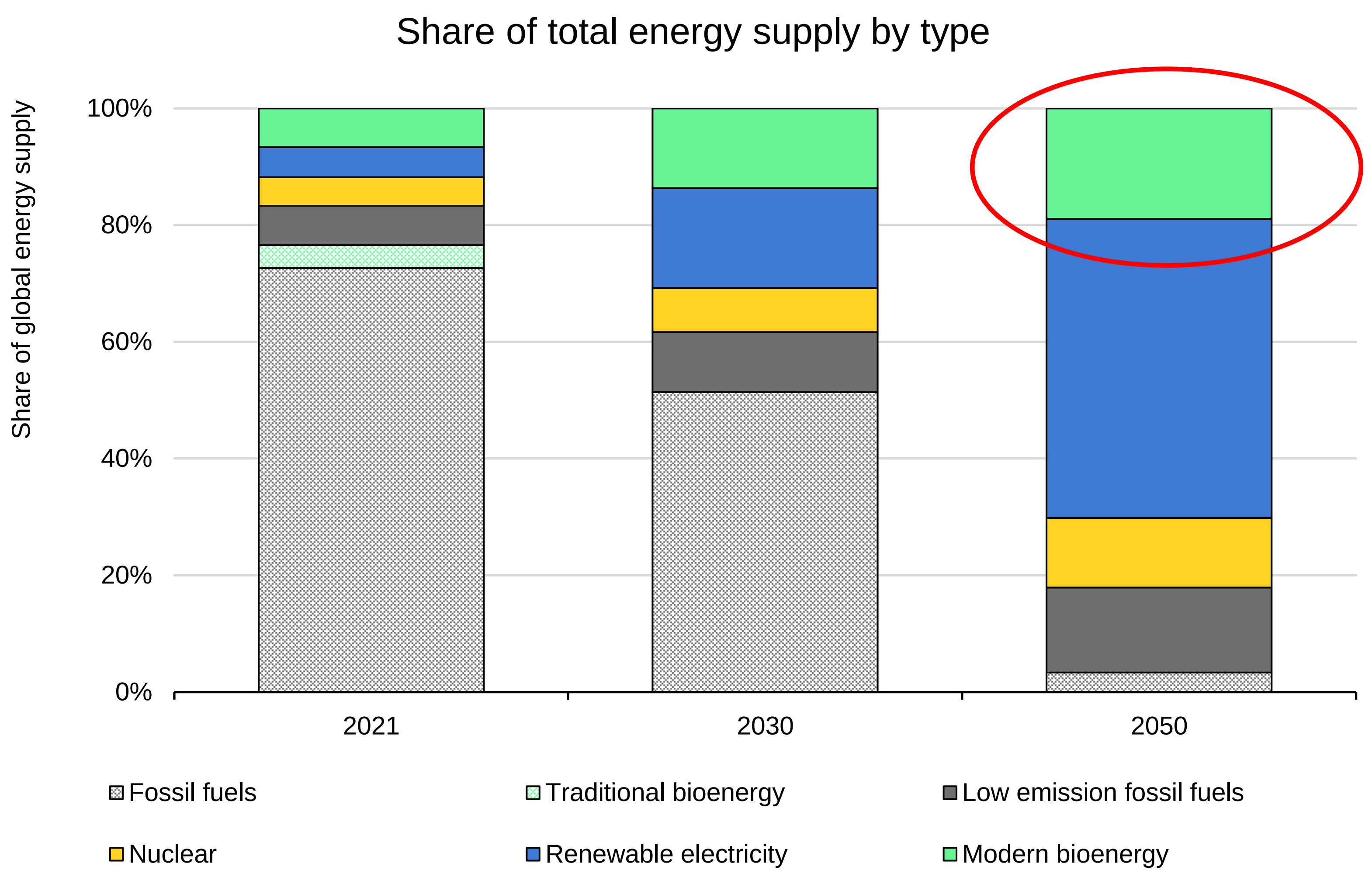
International Energy Agency

Raw materials for biofuel production

Jeremy Moorhouse

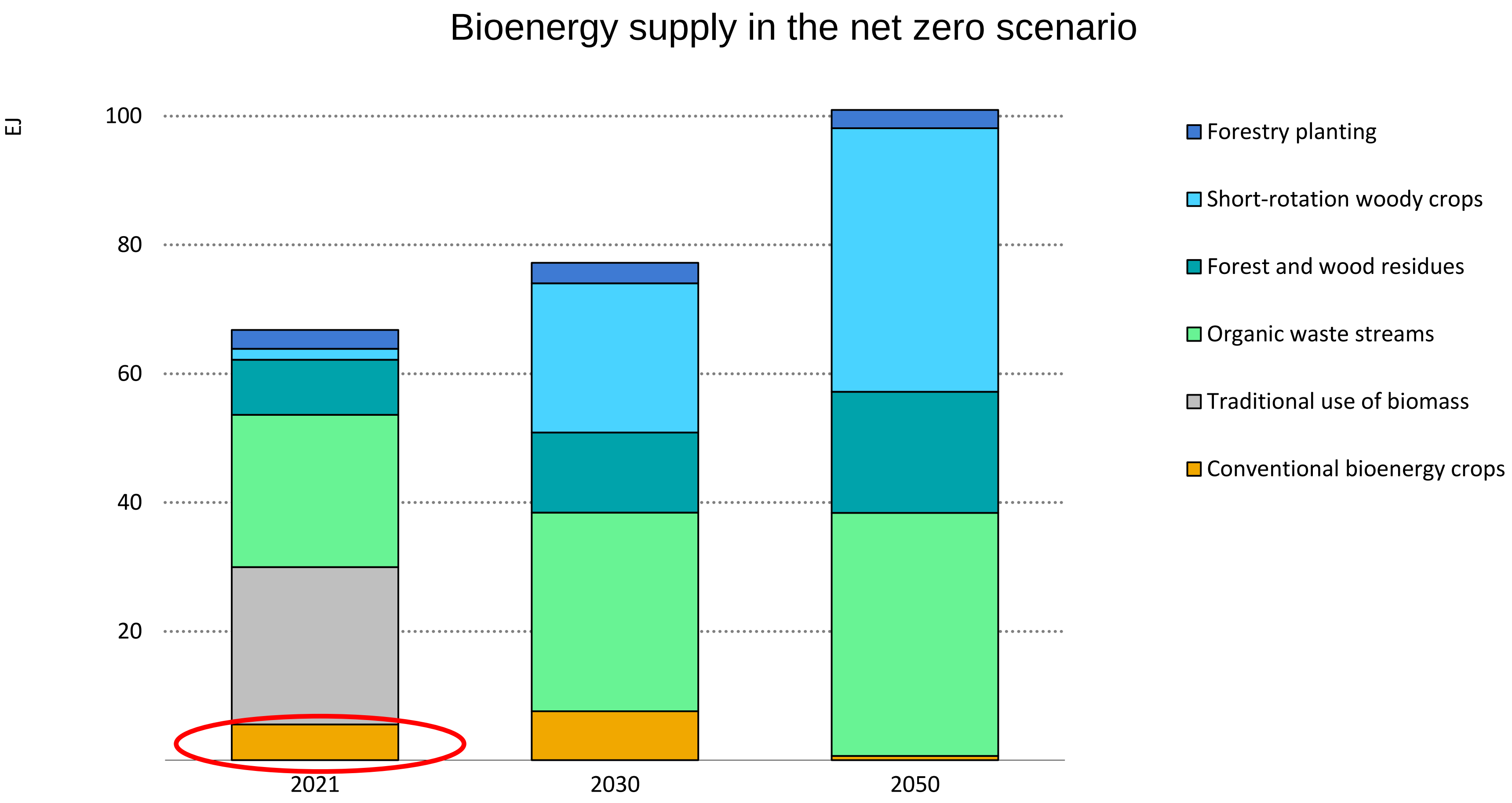
7 December, 2022 – Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

Modern, sustainable bioenergy is a key pillar on a net zero pathway…



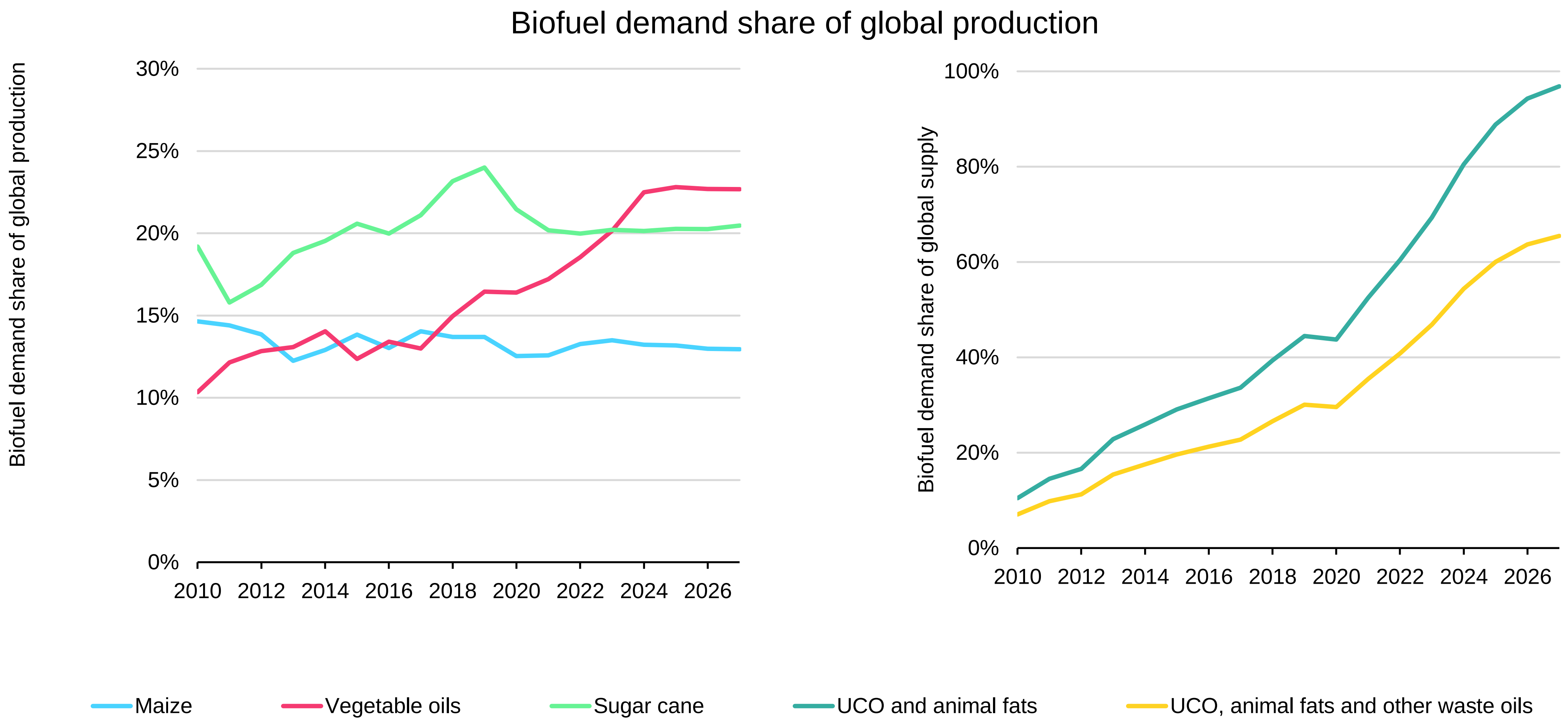
Modern, sustainable bioenergy accounts for near 20% of total energy supply in 2050 on a net zero pathway.

… and there are enough raw materials to support this growth,



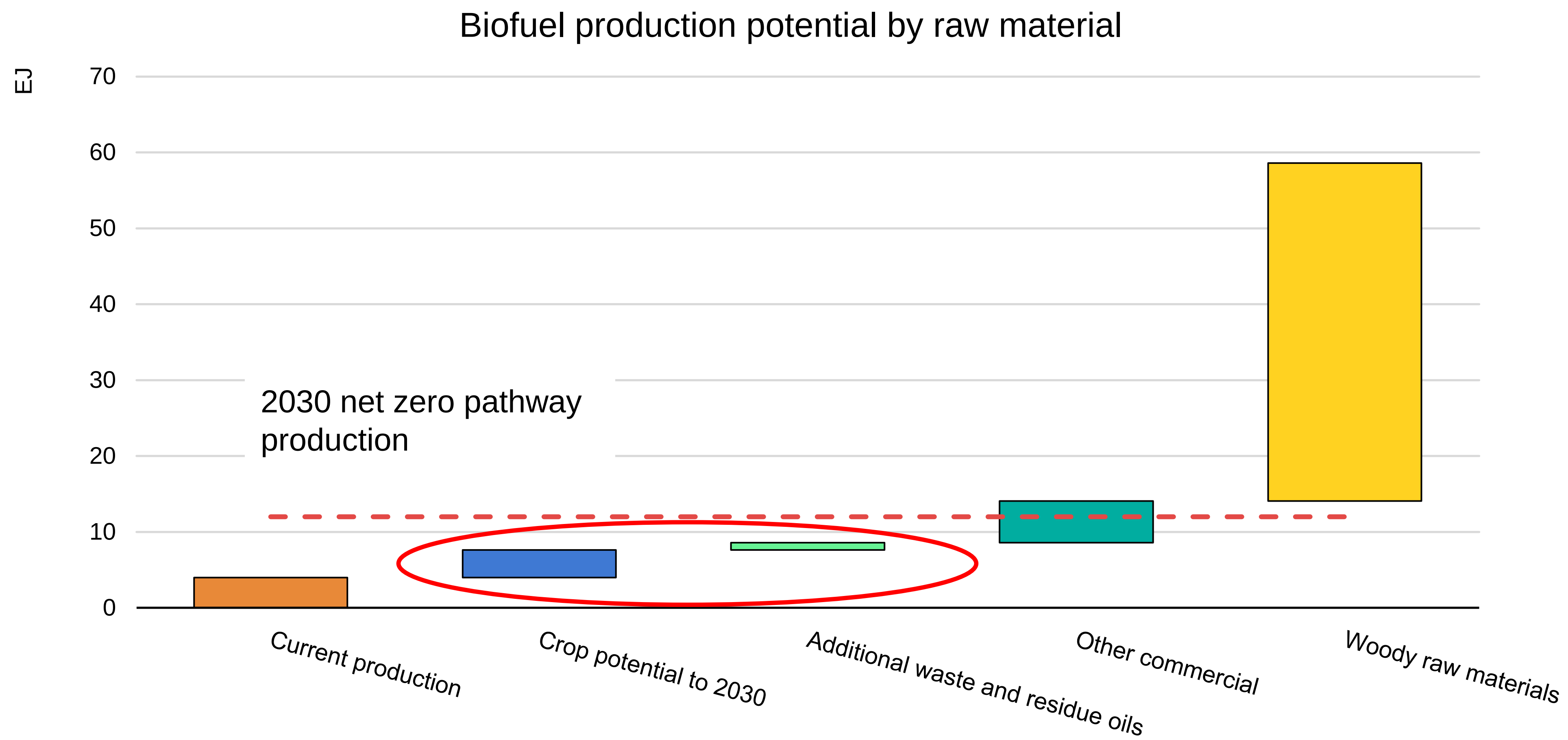
There is no increase in cropland use for bioenergy in the net zero scenario and no bioenergy crops are developed on existing forested land.

but there is a looming supply crunch for bio-based oils



Production of biofuels necessary for the energy transition may slow as demand for vegetable oil and waste and residue oils reaches supply limits by 2027. Bio-based diesels and biojet fuels are most at risk.

New supply chains and technologies will be needed.



Expanding liquid biofuels along a net zero trajectory will require commercializing new technologies and developing new supply chains.

Assessing Biomass Availability and Sustainability: Beyond Myths Towards Reality

Olivier Dubois, Senior Independent Biomass Expert

Virtual Roundtable: Sustainable Biomass Estimates , 07 December 2022

Need to Debunk three Myths on Biomass Production vs Food Security

- Food-based feedstocks always bad for food security
- Non-food feedstocks never bad for food security
- ILUC risk does not concern non-food feedstocks
- Debunking these myths is needed because too often they strongly influence biomass estimates and how to produce biomass

Myth #1: Food-based Feedstock Always Bad for Food

Not necessarily the case - Flex crops (that produce both food and other bioproducts) do not compete with food if bioproducts added to food – Possible but challenging through:

- Sustainable yield increase (e.g. sugarcane in Brazil, cassava in Zambia)
- Bioproducts replace export crops (e.g. cassava in Tanzania)
- Integrated food-energy systems (IFES)
- Outgrower schemes , so no land use change

Myth #2: Non-food Feedstock Never Bad for Food

- Less DIRECT competition with food security

BUT

- Possible negative environment effects (e.g. large scale monocropping plantations for advanced biofuels or wood-based products)
- Possible INDIRECT competition with food security
  - Regarding land use
  - Regarding the use of agricultural residues (soil, feed, energy)
- No flexibility between food and energy markets
- 2G biofuels not yet ready on large scale and for some more time

Myth #3: ILUC risk is NEW, and is ALWAYS Low or DOES NOT EXIST with non-food feedstocks

- ILUC risk is not new – It concerns all biomass production for food and non food purposes that can entail land use change – Hence concerns ALL TYPES OF LAND-BASED BIOMASS
- We know Low- ILUC Risk Practices
- And while ILUC risk certainly exist, so far not much evidence of ILUC actually happening

Example #1: Transforming an Oil Refinery into a Biofuel Refinery in Croatia

- Possibility to start with excess beetroot feedstock, a crop local farmers know well, **refused as no-go area** by the financing institution simply because food-based feedstock
- **2G solution** - based on wheat straw and Miscanthus **– much more complicated** and **risky** because of:

  Logistics (collect wheat straw from many farms)

  Farmers lack experience on new crop (Miscanthus); and

  Sensitivity of financial feasibility to small changes in energy costs

Example #2: Proposal on sustainable smallholder palm oil intensification for food and/or biodiesel + biogas from residues

- Concerned **thousands of smallholders** in Indonesia, Ghana and Cote d' Ivoire
- **No ILUC risk** because no land use change – these would concern yield in crease of existing plantations
- **Funding refused simply because** the project was about **palm oil**

Example #3: Sustainable Biofuel from Cassava in Zambia

- Step 1: Assess total production based on realistic yield increase
- Step 2: Assess what is needed for food and feed
- Step 3: Difference is amount available for bioproducts without compromising food security
- So no rocket science to estimate availability of food-based feedstocks that does not compromise food security

Key Messages:

- Sustainable biomass production is complex
- One should embrace this complexity rather than oversimplifying things by relying only on modeling and global studies
- The good news is that there is enough knowledge and tools to move from

  - “food versus fuel” to “food and fuel”

  - model-based ILUC policies and actions to low ILUC risk practices and policy support

What is needed :

- Move Away from Myths and Sweeping Statements
- Embrace the complexities of sustainable biomass production
- Be constructive and rigourous by using available tools to get things right through an integrated, contextualized and evidence-based approach

Let’s Be Constructive and Promote Proven Good Biomass Production Practices

- Agro-ecological zoning
- Outgrower schemes
- Integrated food energy systems
  - Optimizing land use efficiency by mixing energy and food crops (e.g. rotations, agroforestry systems)
  - Optimizing biomass use through cascading uses (e.g. biogas from livestock manure)

We need **policies to promote proven good biomass production practices** rather than relying only on scenario results of modelling and global studies to develop policies

Maybe get some Inspiration from FAO's Key Messages on Sustainable Bioenergy

- The sustainability of bioenergy is context specific. Therefore its assessment must be based on local reality not models and global studies
- Tools and knowledge are now available to reduce risks and enhance opportunities of bioenergy
- Per se bioenergy is not good or bad; it depends on how it's managed
- Bioenergy should be be seen as another opportunity for esponsible investments in sustainable agriculture, rural development and bioeconomy

Thank you for your attention!

Contacts: olivierdubois1957@gmail.com

Energy Transitions Commission

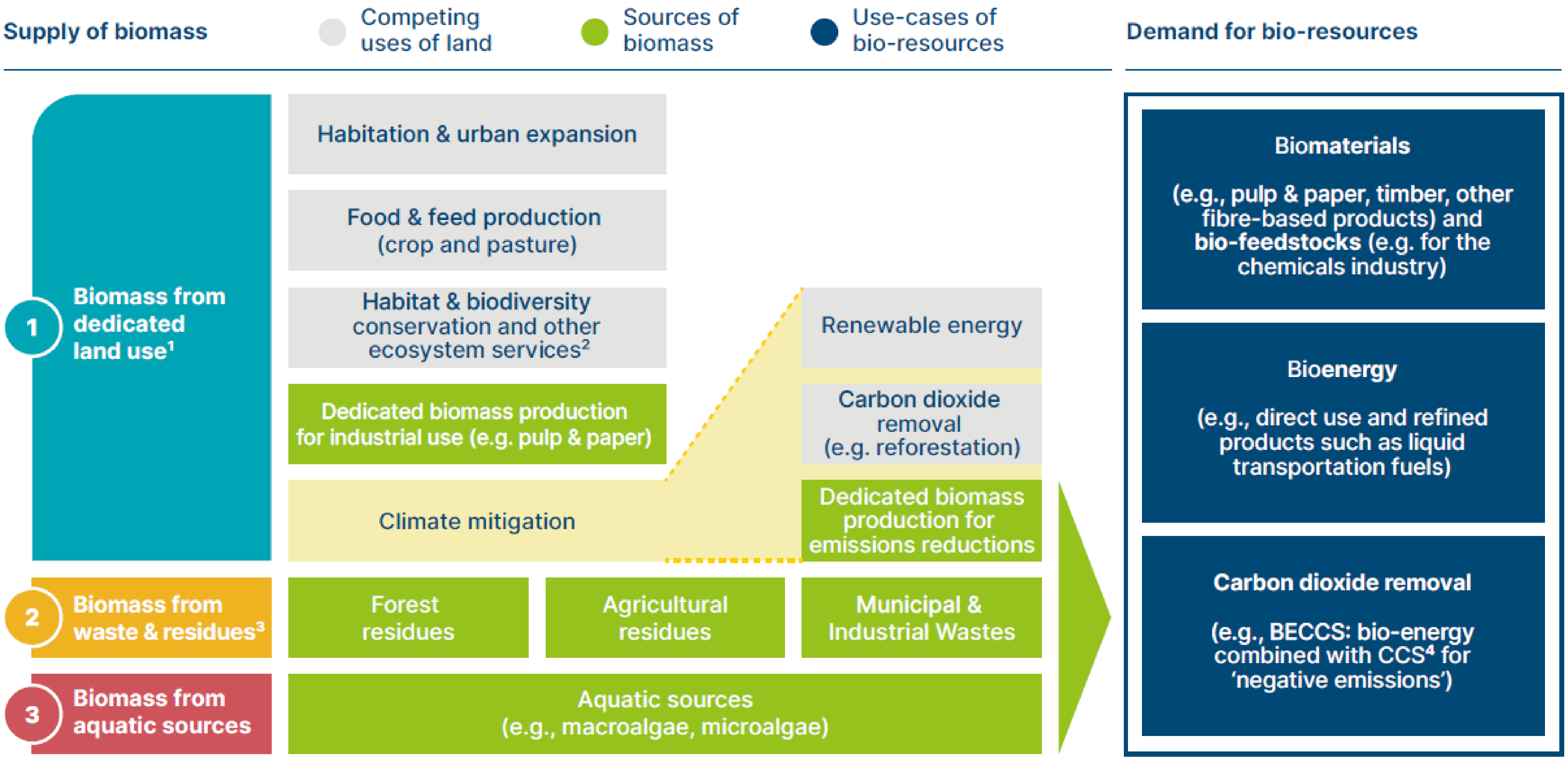
The **Making Mission Possible** Series

Bioresources within a net-zero emissions economy

Maersk McKinney Møller & CEM Biofuture workshop

December 7th 2022

Bioresources are in high demand, but supply of sustainable, low lifecycle emissions biomass is constrained by competing uses of land



Notes: (1) Parallel uses of land (e.g., double-cropping and forest/landscape management) can reduce competition between uses of land by combining biomass production with agriculture or ecosystem services. (2) Includes ecosystem services such as nutrient cycling, soil quality maintenance, water regulation, erosion mitigation, water and air purification, recreation, etc. (3) Biomass from waste and residues are generated as a by-product of using land for other primary purposes listed in category 1 (e.g., agriculture, human habitation, managed forestry). (4) BECCS: bioenergy with carbon capture & storage (CCS).

Bio-based decarbonisation can only be a small share of the decarbonisation technology mix

			Use of biomass	2020 primary biomass demand, EJ/Year if all energy demand is replaced by biobased uses
Materials uses		Timber[1]	As raw timber or woody products	6
		Pulp & paper[1]	Transformed into pulp	10
		Plastic feedstocks	As a new platform chemical	20
Energy uses	Industry	Steel	Biochar combustion in furnaces	45
		Cement	Biomass combustion in furnaces	13
		Aluminium	Biomass combustion in furnaces	7
	Transport	Light duty	Biodiesel created via gasification and F-T	120
		Heavy duty	Biodiesel created via gasification and F-T	59
		Shipping	Bio-diesel drop-in fuel, 100% substitution	19
		Aviation	Biofuel SAF (gasification and F-T synthesis)	24
	Power & heating	Space & water heating	Biogas/pellets used in boilers and CHP-plants	77
		Power	Bioenergy (wood pellets)	239

60 EJ (high range of the ETC prudent supply case)²

~650 EJ

potential biomass demand if all sectors convert current energy and material demand to biomass

40-60 EJ

biomass in ETC supply prudent case in 2050²

Notes: F-T: Fischer-Tropsch. (1) Wood resource balances show a ~13% gap between FAO sources (c.14EJ, primary and secondary resources) and uses of woody biomass. (2) Excludes c.4 EJ of recycled woody biomass. (3) Example bioresource for comparison; not exhaustive.
Sources: IEA ETP 2017 & 2020; Material Economics

Bio-based routes have higher technology readiness levels today but face carbon abatement and transition issues by mid-century

- Criteria favourable to bio
- Bio & non-bio are equivalent (generally or in specific locations / timelines)
- Criteria favourable to non-bio

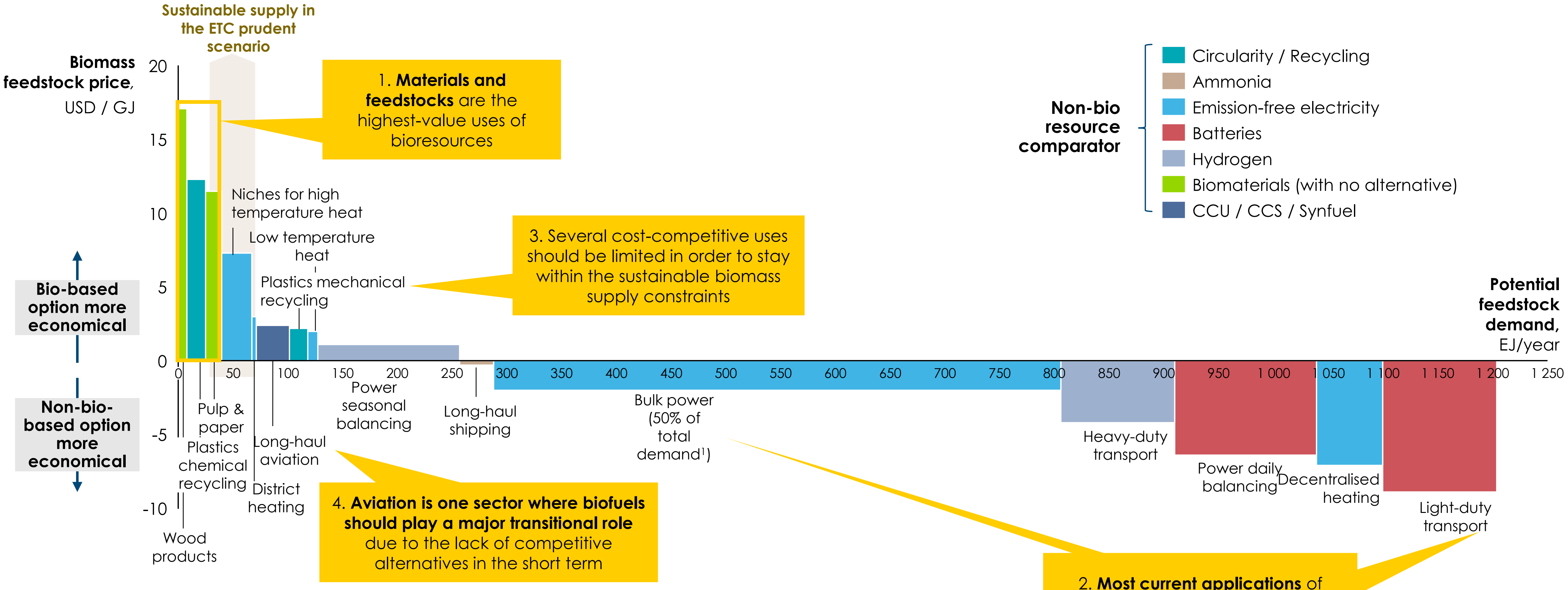
			Key decarbonization route		How does the bio-route compare with the non-bio options in terms of...	
			Bio	Non-bio	Feasibility today	Carbon abatement
Material uses		Timber	Timber	None	No non-bio alternative	
		Pulp & paper feedstock	Pulp	None		
		Plastics feedstocks	Chemical feedstock	Recycling	Mechanical recycling at commercial scale; primary routes have low TRLs	Non-bio route based on clean electrification technologies is zero carbon (even at point of use). The bio route CO_2 abatement potential: • Is highly dependent on source and supply chain of biomass • Emits carbon at point of use, except if combined with CCS (not feasible in transport sectors). This also adversely affects local air quality.
Energy uses	Industry	Steel	Biochar reduction / heat	Electrification / CCS / Hydrogen	Non-bio routes at pilot stage	
		Cement	Biomass combustion	CCS	CCS not applicable to process emissions	
		Industrial heating	Biomass boiler	Heat pump	Heat pumps not applicable to high temperatures	
	Transport	Light duty	Bioethanol	BEV	BEVs and biofuels at commercial scale	
		Heavy duty	Biodiesel	FCEV	FCEV trucks close to commercial stage	
		Shipping	Biofuels	Ammonia in ICE	Ammonia ships at pilot stage	
		Aviation	Bio jetfuels	Synfuels	Synfuels production at pilot stage	
	Power & heating	Power bulk generation	Biomass plant	RE	Renewables deployed at scale	
		Power intraday		RE + batteries	Battery storage starting its commercial deployment	
		Power interday		Hydrogen storage	Hydrogen storage at pilot stage	
		Residential heating	Biomass boiler	Electric heat pump	Heat pumps deployed at scale	

Source: ETC analyses (2021).

Materials and feedstocks are the highest priority uses of bioresources while aviation biofuels should be given priority given current lack of alternatives

Cost-parity curve – Breakeven biomass cost vs. alternative leading non-biogenic solution; global (2050 outlook)

“At what biomass feedstock price is the bio option cost effective?”



Note: Currently excludes carbon removal applications. 1. We limit the potential demand for biomass for ... ne segment in order to make the graph readable.
Source: Material Economics and ETC analysis (2021)

Plants capture carbon as they grow; co-benefits depend on how land is managed and where that carbon is stored in the long term

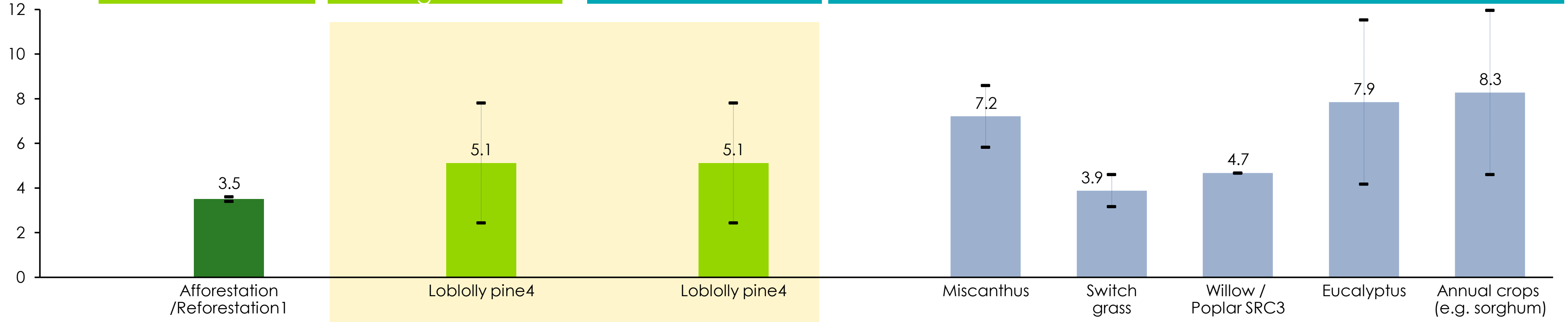
Annual net removals of carbon from the atmosphere per unit area, t Ceq./ha/yr

Natural climate solutions (NCS)

Commercial forestry Long life materials from managed forests

BECCS[2] feedstocks from **managed forest** residues

BECCS[2] feedstocks from **energy crops**



Carbon sequestration

Carbon sequestration in plants

Long-life products
Medium – long term depending on end-of life

Includes both timber & long-life products made from biomass (e.g., plastics)

Carbon sequestration underground; requires BECCS[2]

Energy/ materials/ other value streams

Ecosystem services

Co-products for materials & energy

Energy (for power or for industrial processes)

Biodiversity

Very good

Moderate to severe impact

Severe impact

(1) Afforestation/Reforestation assumes 500 tCO_2/ha = 136 tC/ha from forest regrowth over 40 years to maturity (assumes linear uptake), so mean annual accrual rate is 3.4 tC/ha/yr; WRI figure of crop/pastureland to forest of 3.6 tC/ha/yr. (2) BECCS: Bioenergy with carbon capture and storage; (3) SRC: Short rotation coppice; (4) Loblolly pine plantations in the southern US - mean annual biomass increment ranged from 5 to 16 Mg/ha/yr, depending on site quality, planting density, and cultural intensity. Assumes carbon content of ~49% wt. on dry basis. Sources: Smith et al. (2018), *Impacts on terrestrial biodiversity of moving from a 2°C to a 1.5°C target*; Smith et al. (2016), *Biophysical and economic limits to negative CO_2 emissions*; Zhao et al., (2016) *Maximum response of loblolly pine plantations to silvicultural management in the southern United States*. WRI (2018), *Carbon Benefits Index*.

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

US DOE’s Bioenergy Technologies Office’s Resource Assessment for Sustainable Biomass for use as a fuel feedstock in the contiguous US:

DOE Billion-ton Reports (2005, 2011, 2016, 2023)

Mark P. Elless, Ph.D.
Technology Manager, Bioenergy Technologies Office
December 7, 2022

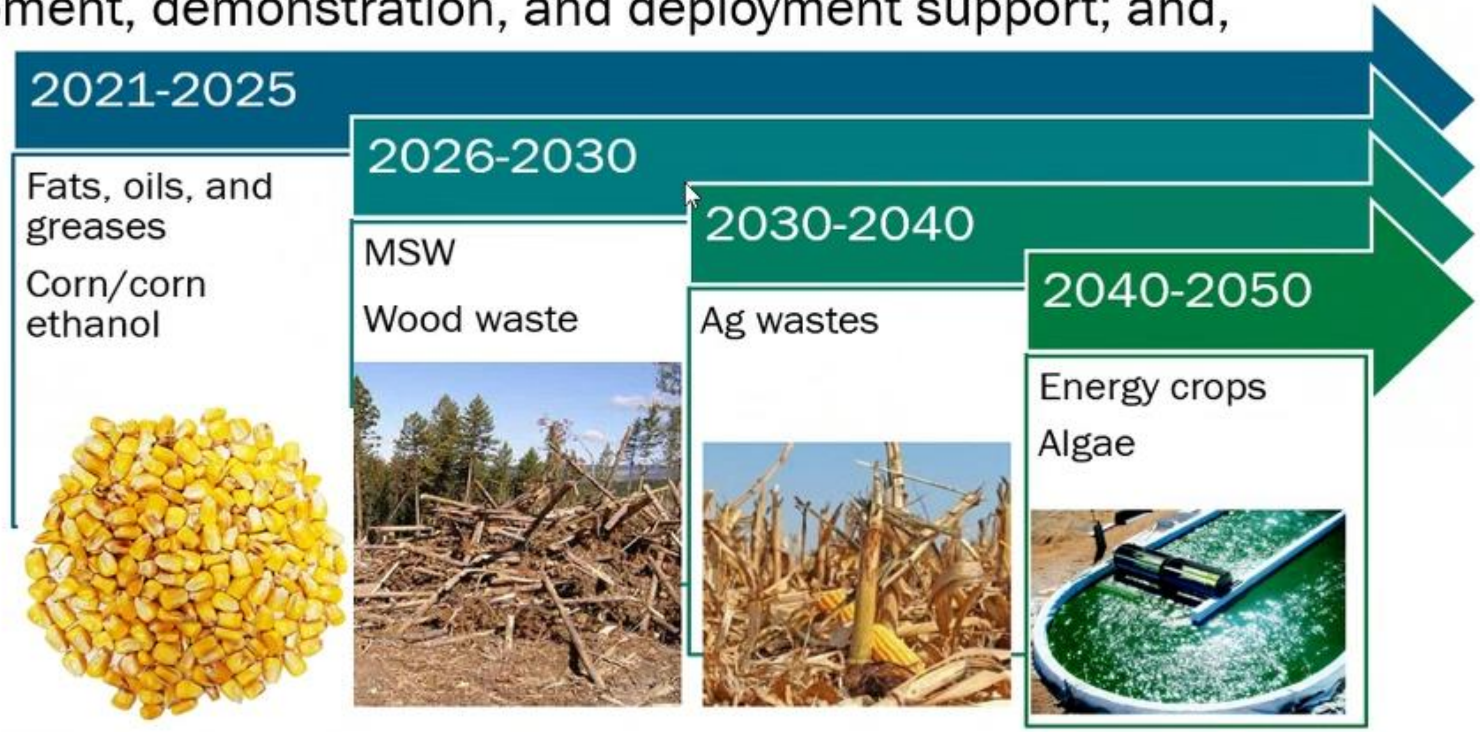
Matt Langholtz, Scott Curran
Oak Ridge National Laboratory

US SAF Grand Challenge Roadmap

Objective: Create a multi-agency plan of federal actions that will support stakeholders to build the SAF supply

Derisk technology, supply chains and markets and reduce barriers;

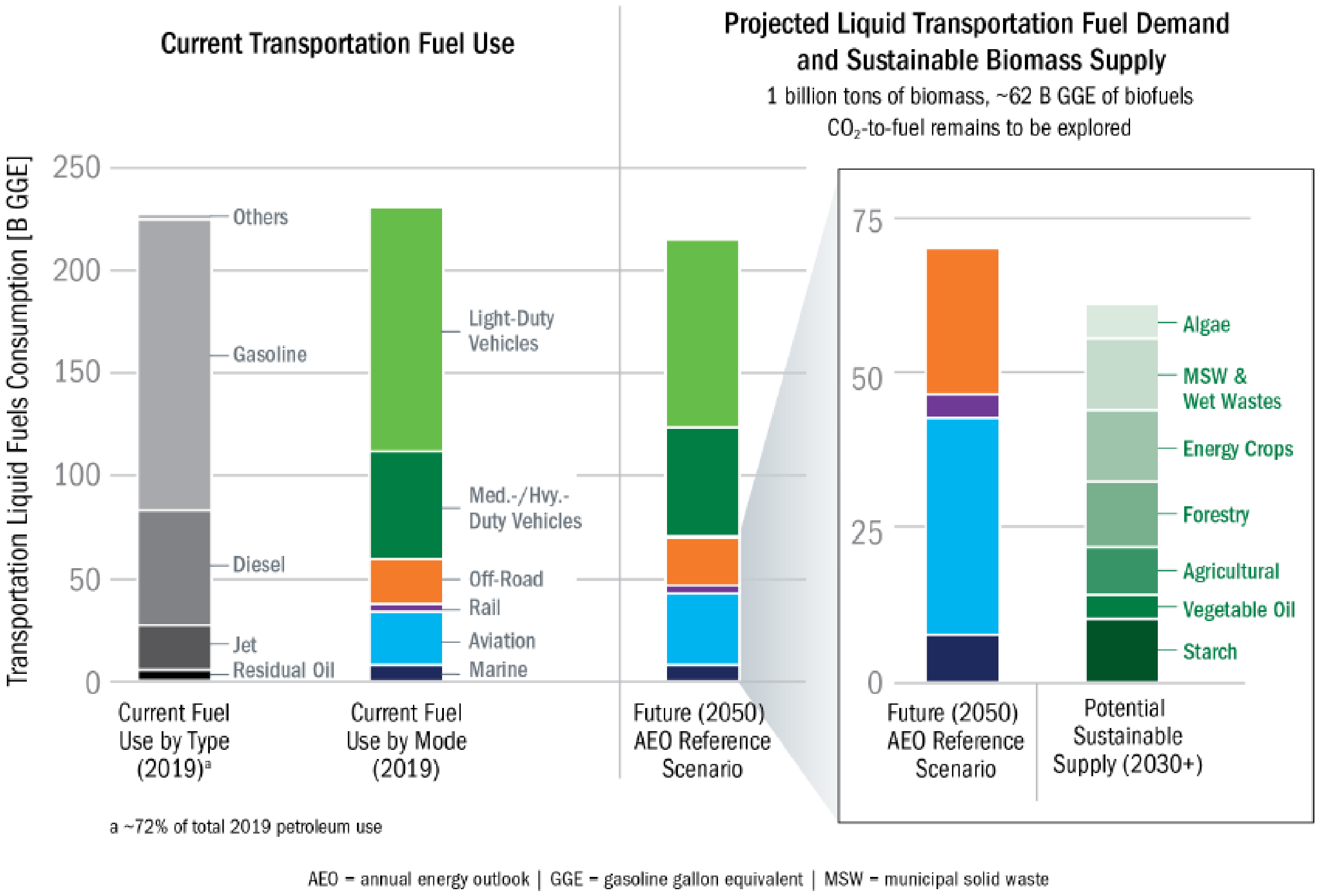
- Leverage existing government research, development, demonstration, and deployment support;
- Accelerate new research, development, demonstration, and deployment support; and,
- Implement a supporting policy framework



The Role of Biomass in Sustainable Transportation: US Perspective

- Transportation accounts for 34% of U.S. greenhouse gas (GHG) emissions.
- Biofuels are part of a sustainable transportation fuel strategy to decarbonize all modes.
- U.S. biomass can meet the needs of "hard to electrify" modes, such as aviation, marine and rail.

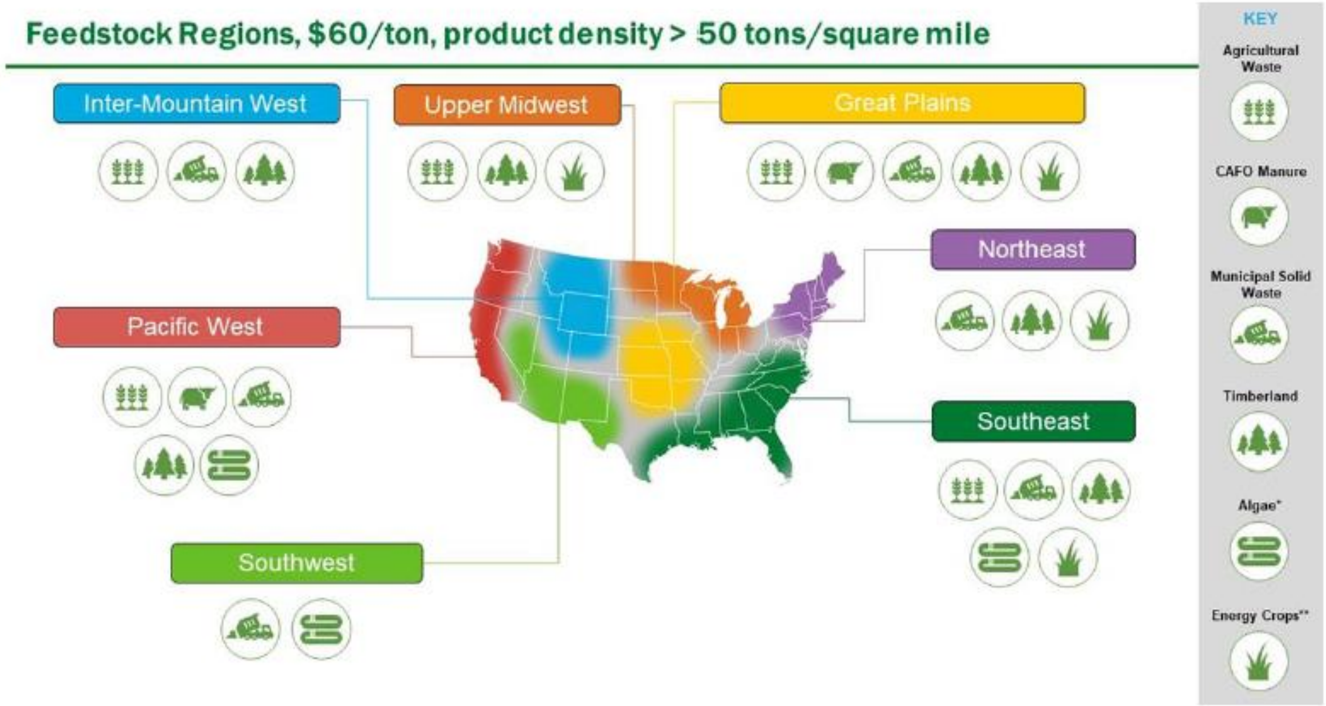
Focus areas for biofuels:
- **Ethanol for passenger cars**
- **"Drop-in" fuels that can use existing infrastructure such as renewable diesel/sustainable aviation fuels**



Slide adapted | Dr. Valerie Reed

Biomass is Widely Available in US: Potential for 1 Bill Tons Annually

- The U.S. has the potential to produce 1 billion tons of sustainable biomass annually.
- About 645 million tons of biomass is needed to make 35 billion gallons of SAF annually.
- No single resource type is sufficient on its own to meet demand.
- A diversified feedstock supply will:
  - Deliver economic and environmental benefits across the U.S.
  - Increase resilience across the supply chain.



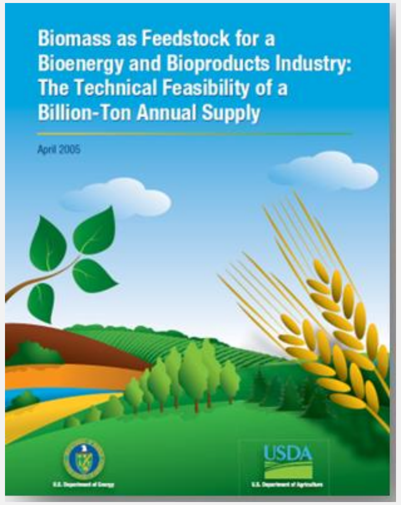
*Saline, current productivities, minimally lined saline ponds, co-location with CO_2 from coal, natural gas, and ethanol plants at prices from $755-$2,889 per dry ton ($2014)
**Energy crops derived from 2040 dataset, all other biomass from 2017 dataset

Slide adapted | Dr. Valerie Reed

History of U.S DOE BETO “Billion-Ton” Resource Assessment Reports

The 2016 Billion-Ton Report: Third report in a series of national biomass resource assessments commissioned by the U.S. DOE **to inform national bioenergy policies and research, development, and deployment strategies.**

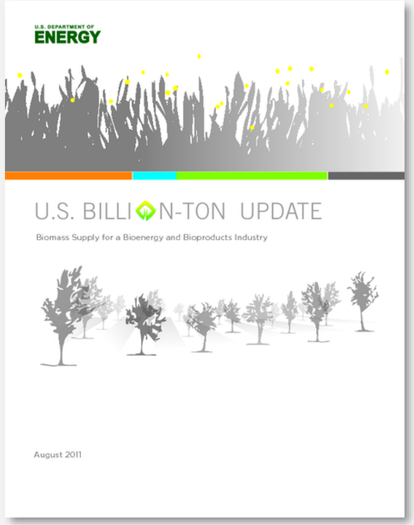
2005



Supply…

Can we displace 30% of the country’s petroleum consumption?

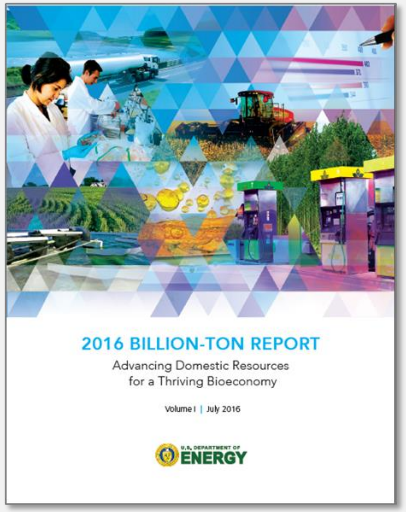
2011



…Cost…

- County-level supplies by cost.
- Economic model of ag+energy crops.

2016 (BT16)



…Sustainability.

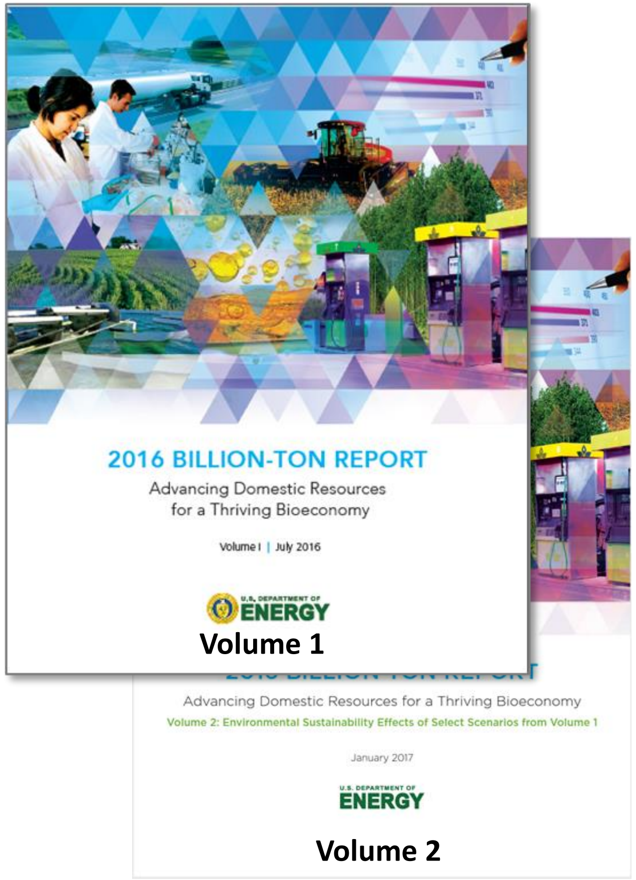
- 44 feedstocks w/ modeled crop yields
- Forest model
- Delivered costs
- 2 Volumes + visualization tools

BT16 report was product **collaborative effort** among national laboratories, government agencies, academic institutions, and industry.

(History details in BT16 Table 1.1)

BT16- Models and Assumptions

- **BT16** was developed to support the U.S. Department of Energy's efforts towards **national goals of energy security and associated environmental and economic benefits**.
  - Potential of **future market scenarios** not projections or predictions
  - Include **multiple sustainability criteria**, including forest and residue removal limits and biodiversity protections
  - **Expert external review** of report completed in 2015
- **Uses two primary models** for analysis of potential sustainable biomass resources
  - Ag Model: Policy Analysis System (**POLYSYS**)
  - Forest Model: Forest Sustainability and Economic Assessment Model (**ForSEAM**)
- Waste resources: multiple surveys inc. EPA, USDA and others
- **Assumptions** detailed in appendices (BT16 V1: pages 335- 384)
  - Appendix A – Biomass Consumed in the Current Bioeconomy
  - Appendix B – Forest Resources
  - Appendix C – Agricultural Residues and Biomass Energy Crops
  - Appendix D - Microalgae



2016 BILLION-TON REPORT
INTERACTIVE VERSION

BIOENERGY KNOWLEDGE DISCOVERY FRAMEWORK
KDF U.S. DEPARTMENT OF ENERGY

Volume 1: https://www.energy.gov/eere/bioenergy/downloads/2016-billion-ton-report-advancing-domestic-resources-thriving-bioeconomy

Volume 2: https://www.energy.gov/eere/bioenergy/downloads/2016-billion-ton-report-volume-2-environmental-sustainability-effects

https://bioenergykdf.net/billionton2016/overview

Examples of Sustainability Constraints/ Assumptions on BT16 Report

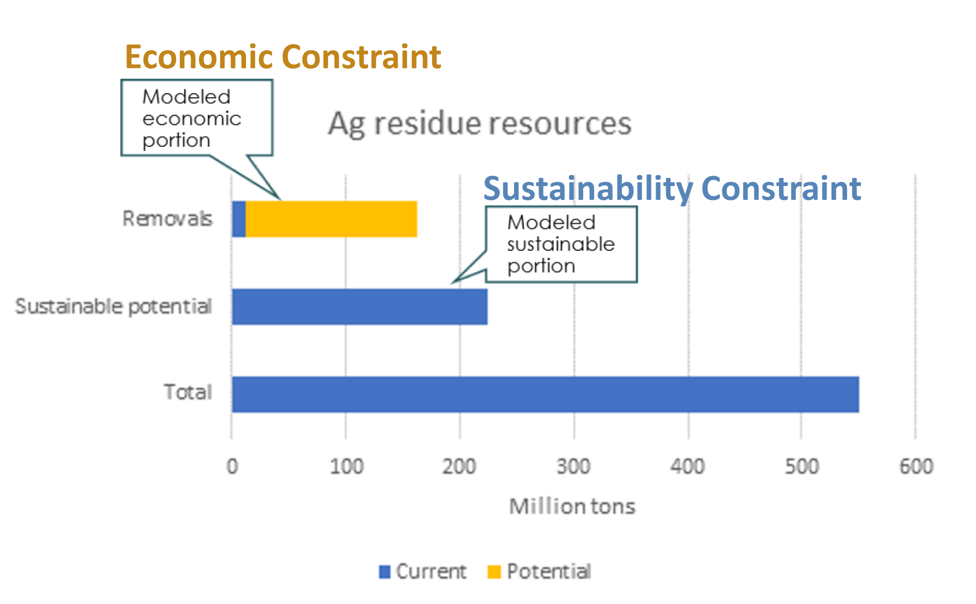
Constraints

Sustainability Constraints in BT16 - Agriculture

Sustainability assumption or constraint	Sustain. category	Implementation
Trend toward reduced till and no till for corn, wheat	Soil quality, water quality	Management assumptions
High fraction of crop acres no-till		Management assumptions
Residue removal prohibited on conventionally tilled acres		Management assumptions
Crop residue removal based on wind and water erosion estimates and soil carbon loss		Residue removal tool used to estimate retention coefficients
No residue removal for soy		Management assumption
Acceptable residue removal different for reduced and no till		Residue removal tool to estimate retention coefficients
Multi-county NRCS crop management zones (e.g., tillage assumptions)		Spatially explicit rotation and management assumptions
Annual energy crops on land with low erosion potential and assumed part of multicrop rotation		Excluded land area
Irrigated cropland or pasture excluded	Water quantity	Excluded land area
No supplemental irrigation of energy crops		Management assumptions
No use of pastureland in counties west of 100th meridian		Excluded land area
No transition of non-agricultural lands to energy crops	Greenhouse gas emissions	Excluded land area

24

Impact of a Selected Constraints



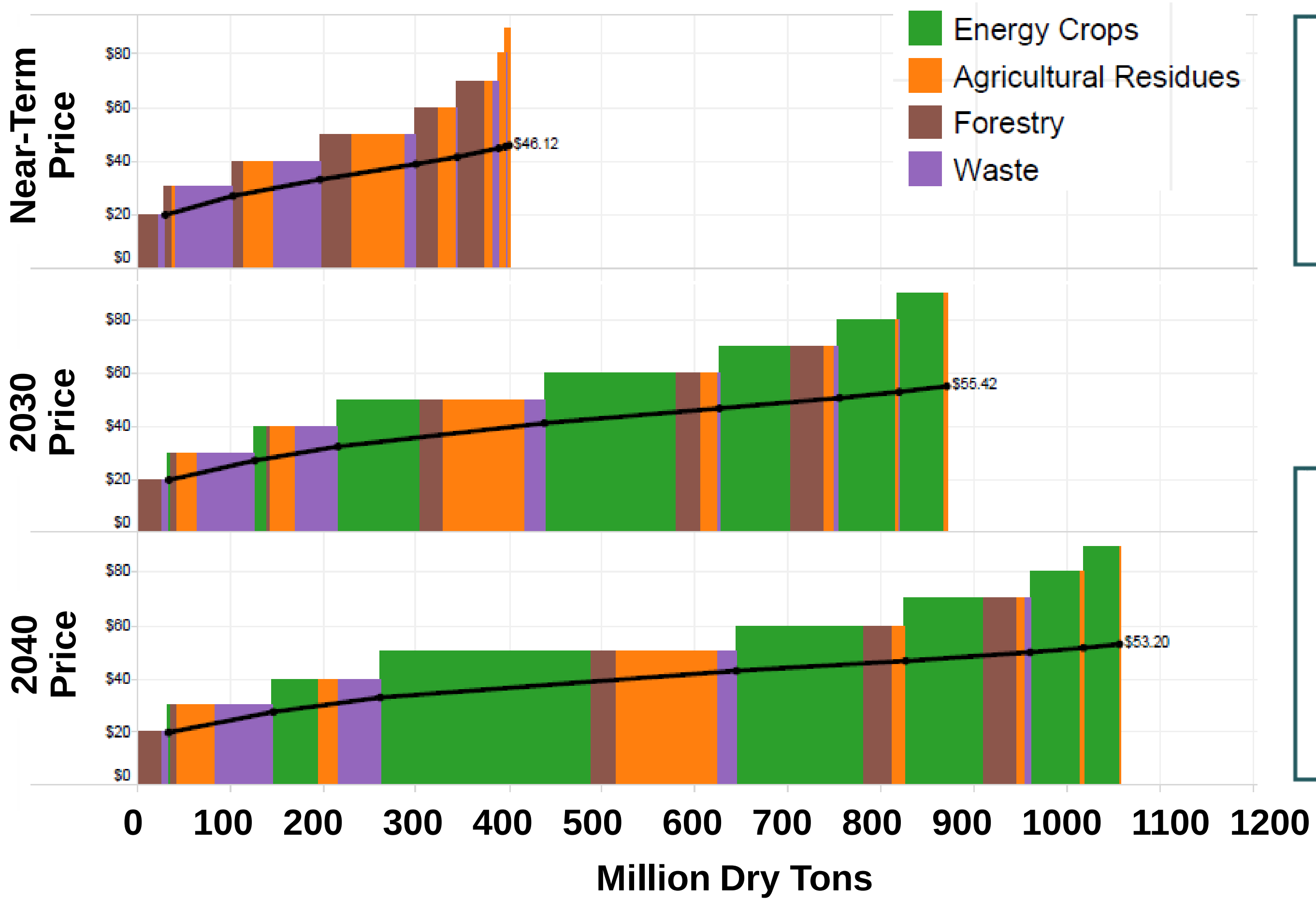
Ag Example: BT16 report captures **only about 1/3 of the total ag residue** as available under the given sustainability and economic constraints

Details in BT16 V1 Chapter 4

Forestry example in backup slides

Full Assumptions for BT16 detailed in appendices (BT16 V1: pages 335- 384)

BT16 - Available Biomass Depends on Price and Time



Near-term potential resources include **~400 M tons** of wastes, forest lands and ag residue resources

Mature market potential adds more than >400 M tons of biomass **energy crops**

Growth in supplies being dependent on market pull

https://bioenergykdf.net/billionton2016/1/9/tableau
BT16, Executive Summary Fig.6

The next “Billion–Ton” study (BT23) in Progress

Billion-ton 2023

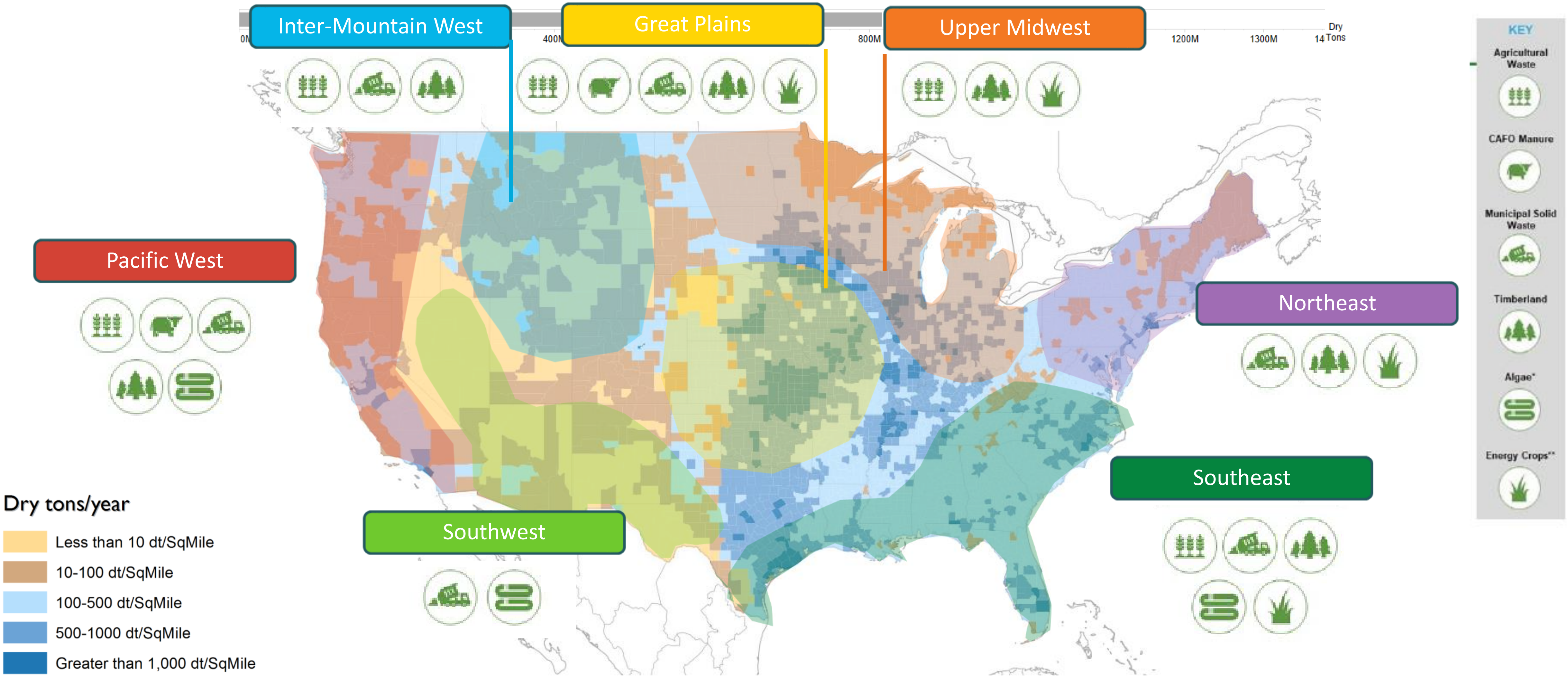
Release date:
~ Sept. 2023

- **Objective**: Assemble most recent biomass resource assessment information in single document with focus on decarbonization *with improved messaging*
- Add new feedstocks
- Update waste and algae resource assessment
- Refine forest resources
  - Consider markets in Southeast (not covered in BT16)
  - Evaluate resources available through fire reduction thinnings

	BT23
Resources	Adding oilseeds, cover crops, macroalgae, and CO_2
Cost analysis	Same as BT16
Spatial scale	Same as BT16
Time horizon	Near-term and mature-market
USDA projections	2023 USDA Baseline projections; 2021 FIA inventory
Crop residue modeling	Same as BT16
Environmental constraints and impacts	Same as BT16
Data reporting format	Same as BT16

Stakeholder engagement is ongoing!

Additional BETO analysis efforts are leveraging "Billion-ton" report's spatial density maps of biomass availability based on economics



*Base-case scenario, $60 offered price, combined resources, year 2040

Thank You!

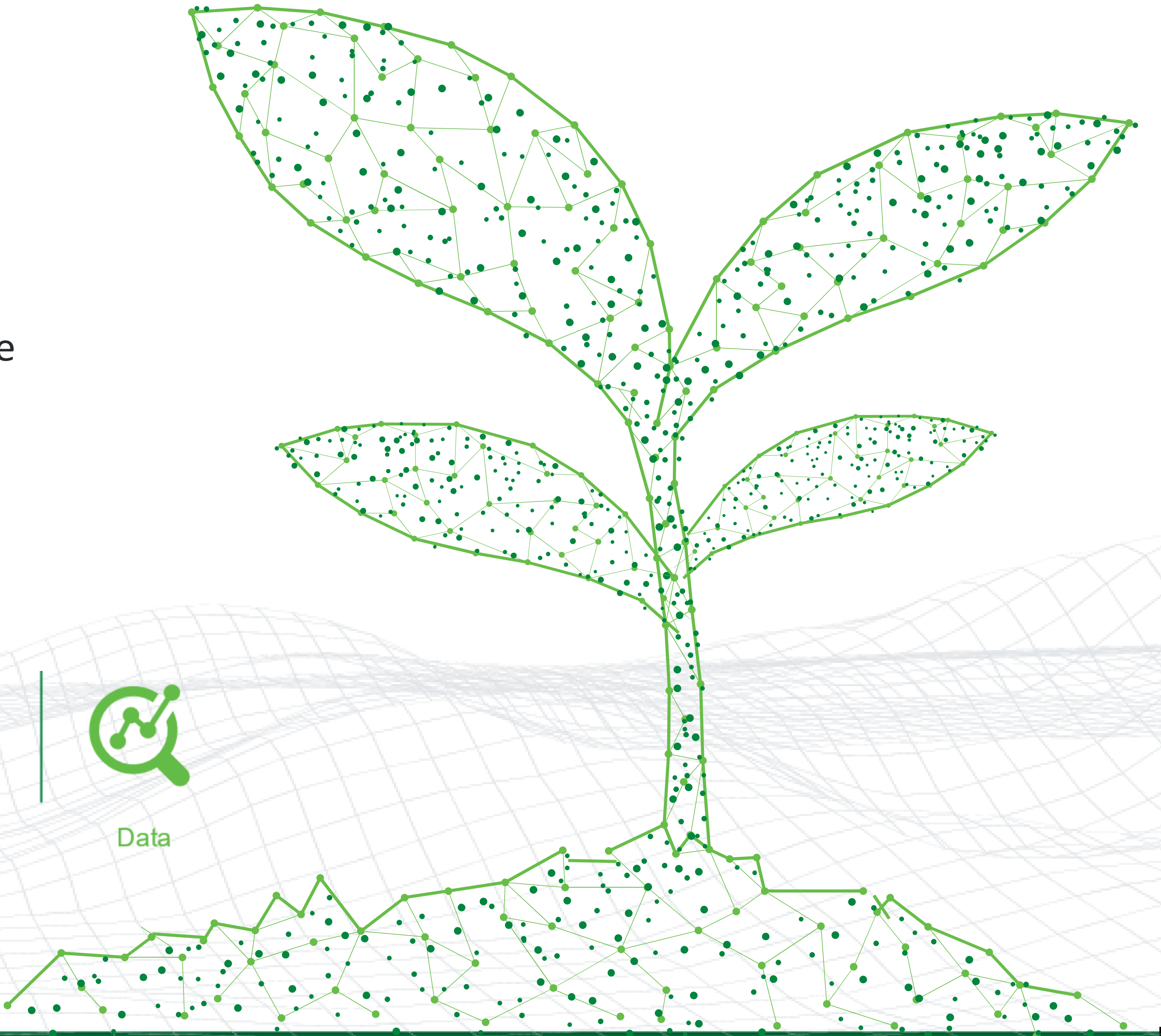
Dr. Mark Elless

Technology Manager

US DOE Bioenergy Technologies Office

Email: Mark.Elless@ee.doe.gov

Feedstock | Algae | Conversion | Systems | Data



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Thank you for joining!

The recording & presentation will be shared with all participants shortly.

Let's stay in touch

Visit our website www.zerocarbonshipping.com and make sure to follow us on LinkedIn to stay up to date with the latest news and events.

Upcoming Projects

→ Maritime Decarbonization Strategy Report – Published tomorrow.

→ Maritime Decarbonization Strategy Launch Webinar on Friday, December 9th - 9-10:30 am CET. Register today.

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping