Biomass for bioenergy: Resources today and in the future

Advanced School on the Present and Future of Bioenergy
10 October, 2014

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http://www.ornl.gov/sci/ees/cbes/

Special thanks to FAPESP for support
Photo credits to authors, Ron Savage, or as noted.

U.S. DEPARTMENT OF ENERGY

Climate Change Science Institute
AT OAK RIDGE NATIONAL LABORATORY

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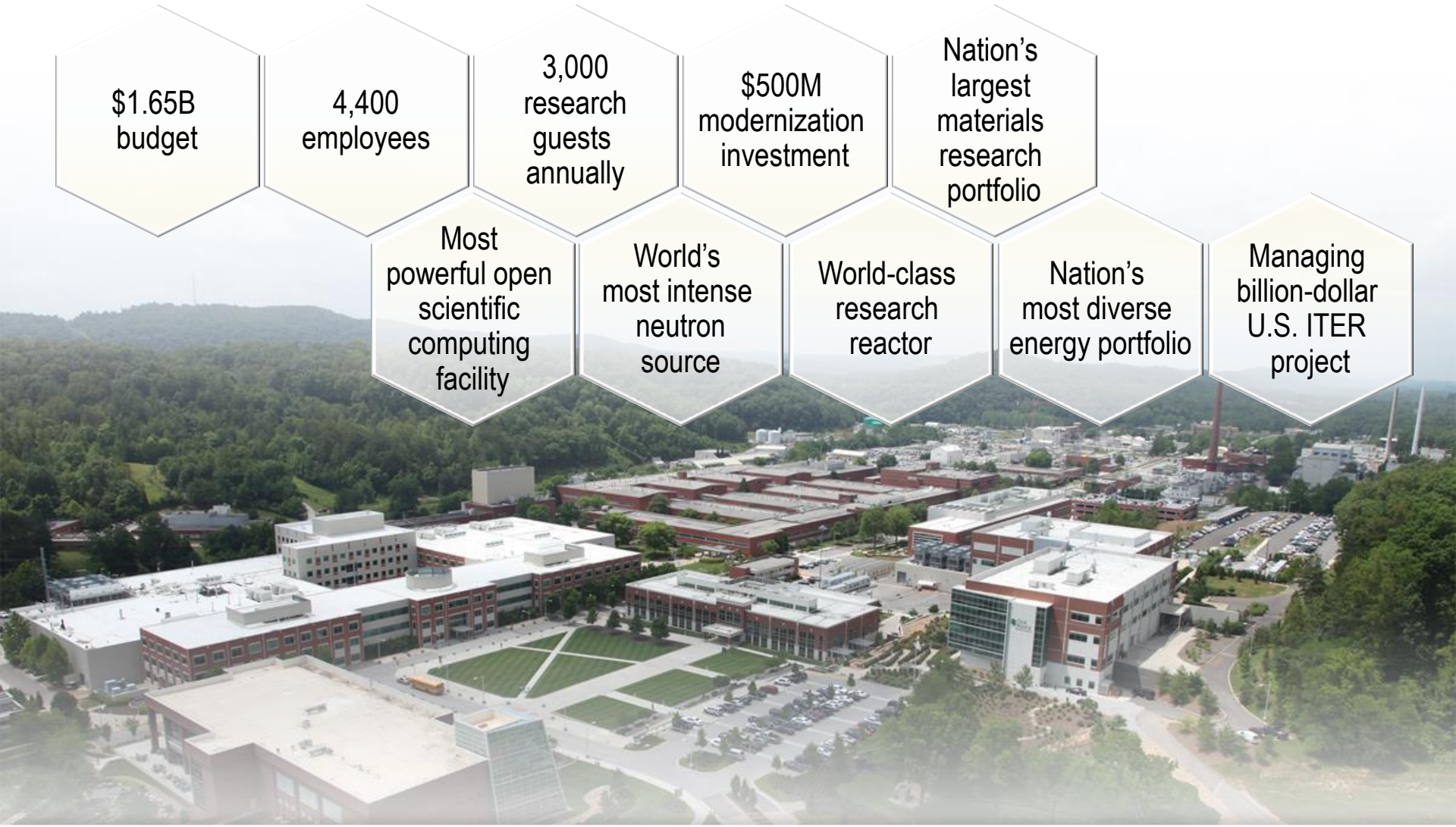
Biomass for bioenergy: Outline*

- What sources?
- Why?
- Which crops preferable?
- Current resources?
- Future resources?
- Examples
- Discussion
- Resources for more information

*Title and topics requested by ESPCA organizers

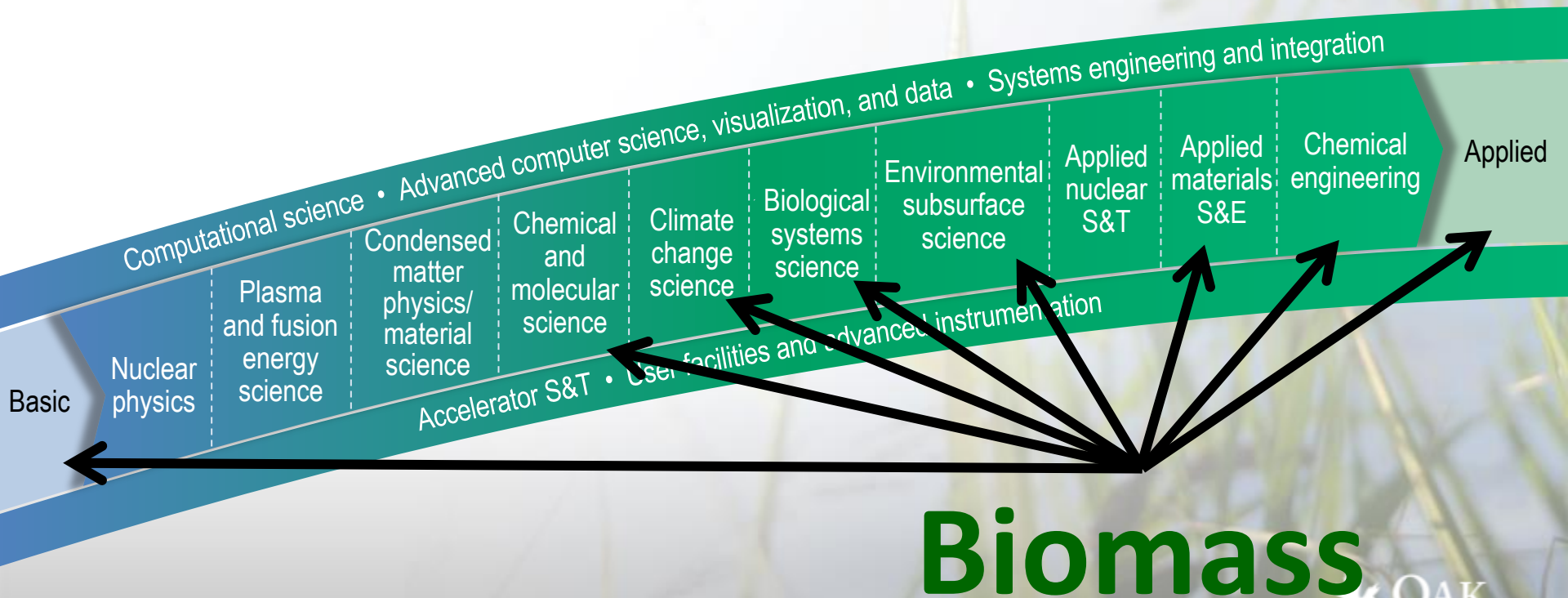
OAK RIDGE National Laboratory

What is Oak Ridge National Laboratory (ORNL)? U.S. Department of Energy's Largest Science and Energy Research Center:



ORNL's Mission

Deliver scientific discoveries that accelerate the development and deployment of solutions in clean energy and global security, and in doing so, create economic opportunities



Biomass

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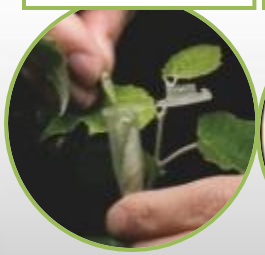
Bioenergy research at ORNL: basic sciences to applications

BESC
BioEnergy Science Center

Molecular biology, chemical and structural analysis and characterization, modeling and simulation

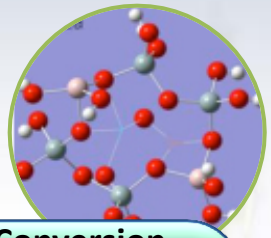
Feedstock development

Biomass deconstruction



Center for BioEnergy Sustainability
Environmental
Socio-economic indicators,
Integrated land management,
Management best practices

Feedstock Supply Analysis
Terrestrial & algal feedstocks,
Advanced logistics,
Supply & price projections

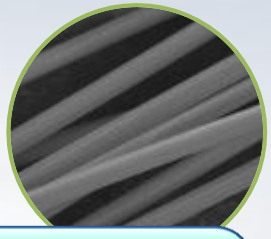


Conversion
Biochemical & thermochemical conversion,
Catalytic upgrading,
Materials of construction

Bioproducts

Biofuels

Biopower



Carbon Fiber Technology Facility
Materials S&E

Lighter weight vehicles

National Transportation Research Center
Engine evaluation
Fuel effects

Transportation biofuels

US DOE EERE Bioenergy Technologies Office

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Biomass for bioenergy: Outline

- **What biomass to use?**
- Why?
- Which crops preferable?
- Current sources
- Future sources
- Examples
- Discussion

Photo: Ken Goddard, UT Extension

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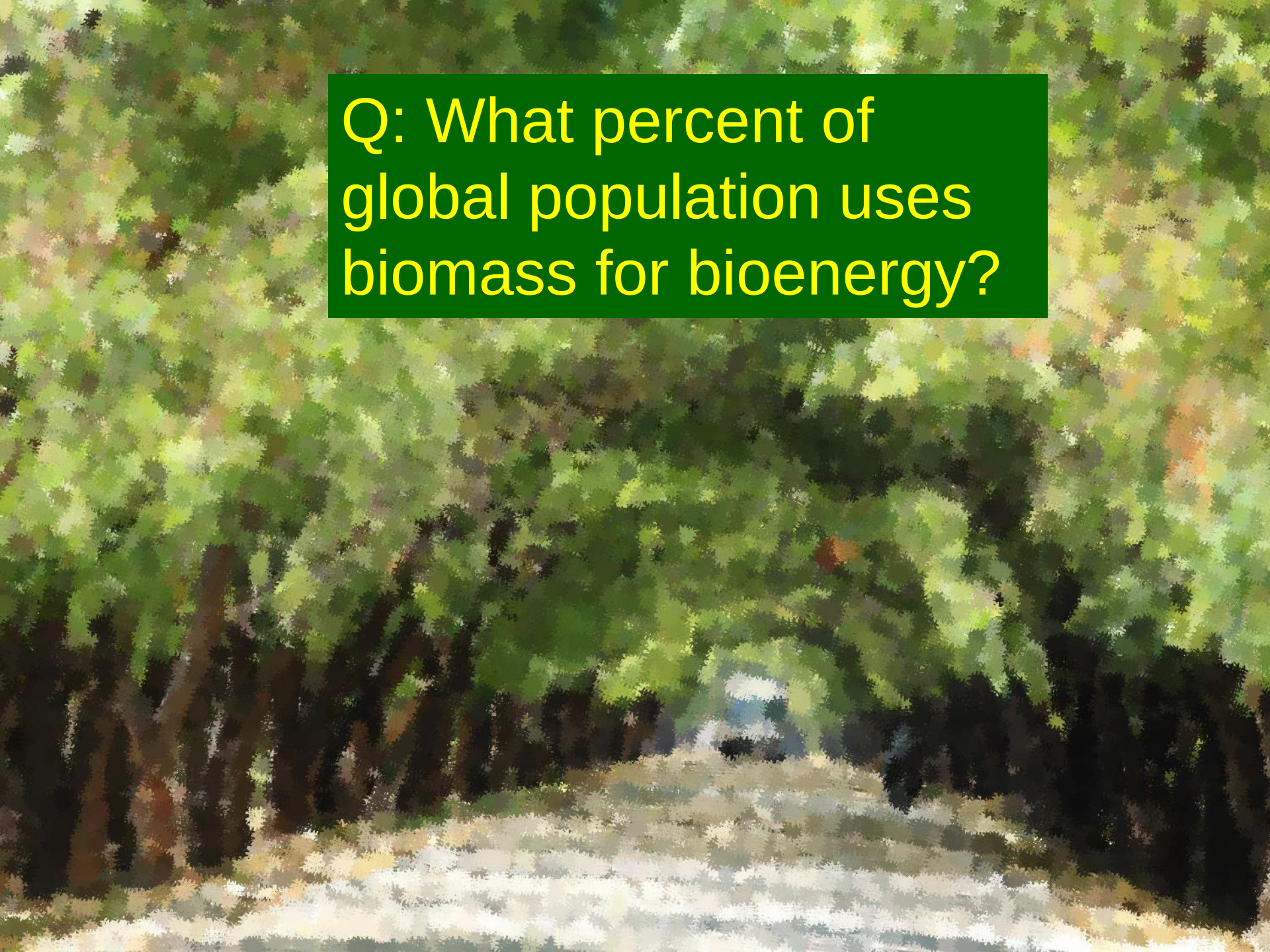
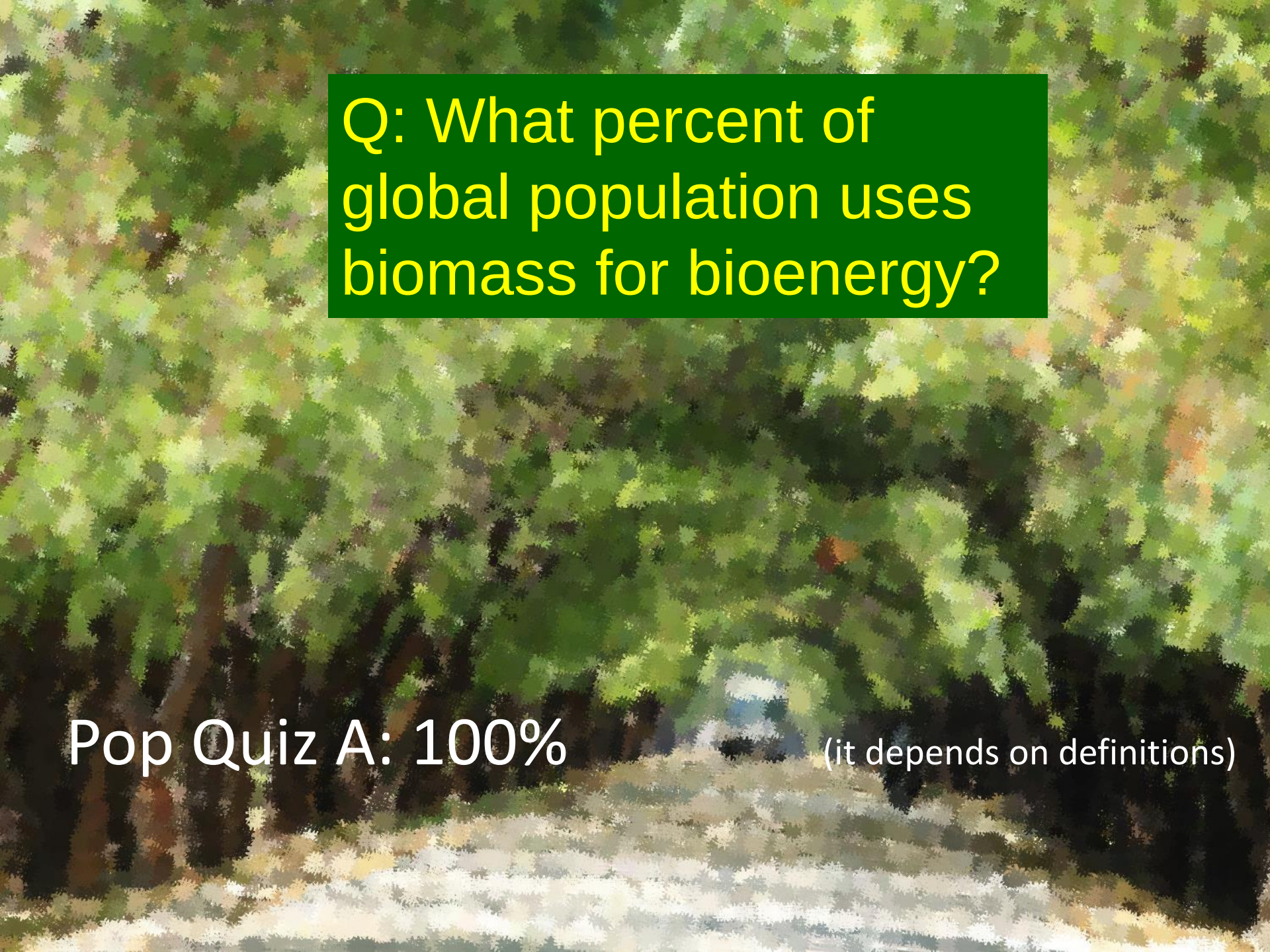
Photo credit: Ron Savage
http://sierravistaimages.zenfolio.com/


Q: What percent of global population uses biomass for bioenergy?


Q: What percent of global population uses biomass for bioenergy?
Pop Quiz A: 100%
(it depends on definitions)

Defining biomass for bioenergy

- One cannot answer questions about what, where or how much biomass for bioenergy until the terms are clearly defined.
- Definitions are often political or regulatory.
- Example from Environmental Protection Agency of USA (US EPA) for the final rule (2010), under US Energy Independence and Security Act (EISA law, December, 2007) also known as the Renewable Fuel Standard-2 (RFS2):

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Defining biomass for bioenergy

US RFS 2: "Renewable biomass means each of the following (including any incidental, de minimis contaminants that are impractical to remove and are related to customary feedstock production and transport):

1. **Planted** crops and crop residue harvested from existing agricultural land cleared or cultivated prior to December 19, 2007 and that was nonforested and either actively managed or fallow on December 19, 2007.
2. **Planted** trees and tree residue from a tree plantation located on non-federal land (including land **belonging to** an Indian tribe or an Indian individual that is held in trust by the U.S. or subject to a restriction against alienation imposed by the U.S.) that **was cleared at any time prior** to December 19, 2007 and actively managed on December 19, 2007.
3. **Animal waste** material and animal byproducts.
4. Slash and pre-commercial thinnings from **non-federal forestland** (including forestland belonging to an Indian tribe or an Indian individual, that are held in trust by the United States or subject to a restriction against alienation imposed by the United States) that is not ecologically sensitive forestland.
5. Biomass (organic matter that is available on a renewable or recurring basis) obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, in an **area at risk of wildfire**.
6. **Algae**.
7. Separated **yard waste or food waste**, including recycled cooking and trap grease, and materials described in § 80.1426(f)(5)(i). Source: http://www.epa.gov

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Defining biomass for bioenergy

- Simple definition: ***biomass, n—material originating from living or recently living (non-fossil) sources***.

Examples include parts of or whole plants, animals, algae and marine organisms.

Source: This was the shortest of several proposals to ASTM International Standard Committee, based on similar definition in use in EU (current EN Standard); September, 2014 subcommittee work group.

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Defining biomass for bioenergy

Many other definitions – even in "international standards":

- From "ASTM E48.91" SUB-COMMITTEE ON TERMINOLOGY
- Current Definitions of Biomass in E1705: [committee.sub], attribution, Terminology Standard,
- **biomass**—total weight of living matter in a given volume. When considered as an energy source, biomass is further subdivided into: (1) primary biomass, rapidly growing plant material that may be used directly or after a conversion process for the production of energy, and (2) secondary biomass, biomass residues remaining after the production of fiber, food, or other products of agriculture, or biomass by-products from animal husbandry or food preparation that are modified physically rather than chemically. Examples include waste materials from agriculture and forestry industries (manure, sewage, etc.) from which energy may be produced. The above distinction noted between primary and secondary biomass is based on economic factors; these are defined differently in ecological science. E1126
- **biomass**—any material, excluding fossil fuels, which is or was a living organism that can be used as a fuel directly or after a conversion process. Peat is not a biomass. E1126, E1218
- **biomass**, *n* – biological material including any material other than fossil fuels which is or was a living organism or component or product of a living organism. [D02.12] D5864; [D02.14] D6469, 4175

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Defining biomass for bioenergy

Key points:

- We cannot answer questions about “what, where, or how much” biomass – current and future – unless we start with a clear definition.
- Definitions vary depending on purpose.
- One consistent aspect of definitions: **when discussing bioenergy, definitions exclude fossil fuel.**

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Biomass for bioenergy: Outline

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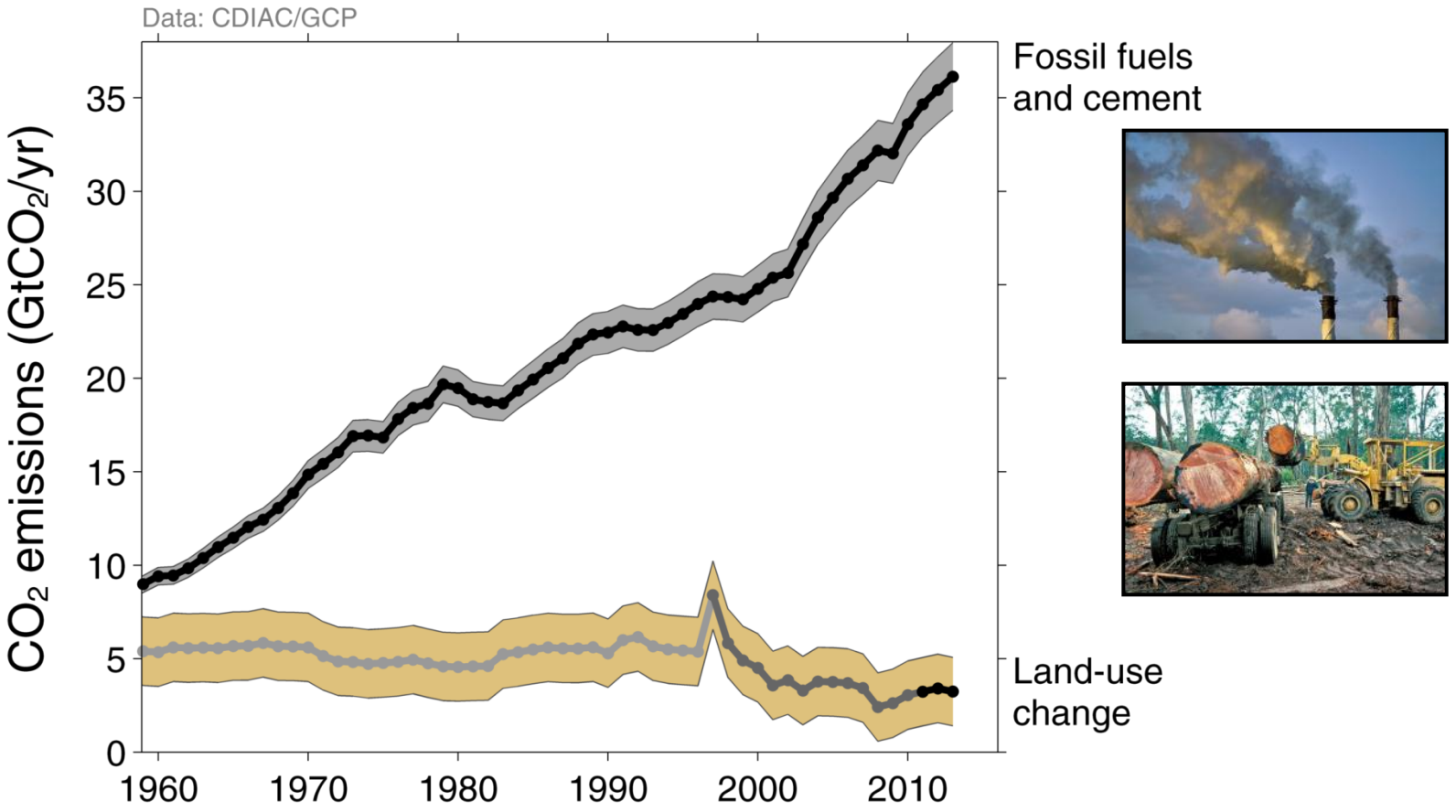
Why biomass for bioenergy: Total Global Emissions

Total global emissions: 39.4 ± 3.4 $GtCO_2$ in 2013, 42% over 1990
Percentage land-use change: 36% in 1960, 19% in 1990, 8% in 2013

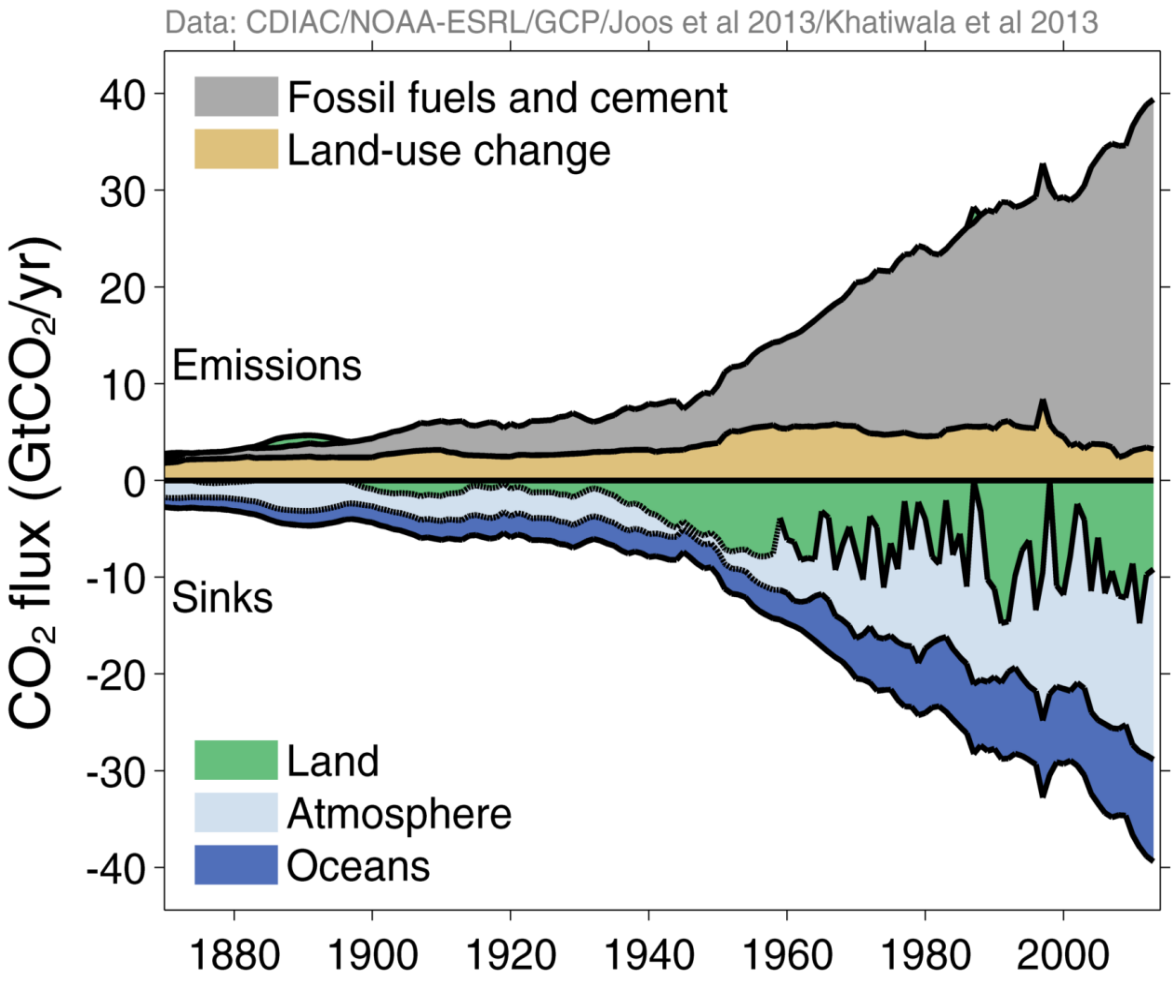


Three different methods have been used to estimate land-use change emissions, indicated here by different shades of grey

Source: CDIAC; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014

Why biomass for bioenergy: Global Carbon Budget

Emissions are partitioned between the atmosphere, land, and ocean



Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2014; Global Carbon Budget 2014

Why biomass for bioenergy?

Key points:

- Fossil fuel consumption is the problem. Impacts
  - Air quality
  - Sustainable employment
  - Equity today and for future generations and
  - Climate change
- Need effective alternatives to fossil. Bioenergy:
  - Is dispatchable for power, electricity, heat, mobility and other services
  - Can replace liquid and gaseous fossil fuels in existing systems
  - Stores chemical energy for future use and helps balance other more variable renewable resources

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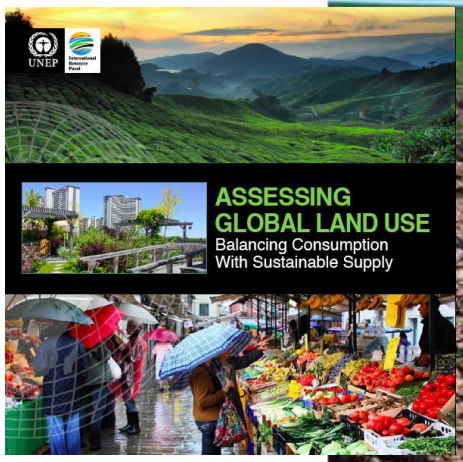
United Nations Environmental Program (UNEP): Land degradation by soil erosion

- More than a billion hectares affected worldwide
- 2 – 5 Mha cropland severely degraded every year
- Data and effects with high variability
- Way forward to meet future demands: improve local land management



Source: UNEP, Assessing Global Land Use (2013)

Why biomass for bioenergy?

Key points:

- Fossil fuels are primary climate change problem; Land management is one part of the solution.
- Current land management must improve
- Society needs effective incentives to improve land management.
- This leads to another topic requested for today…

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Biomass for bioenergy: Outline

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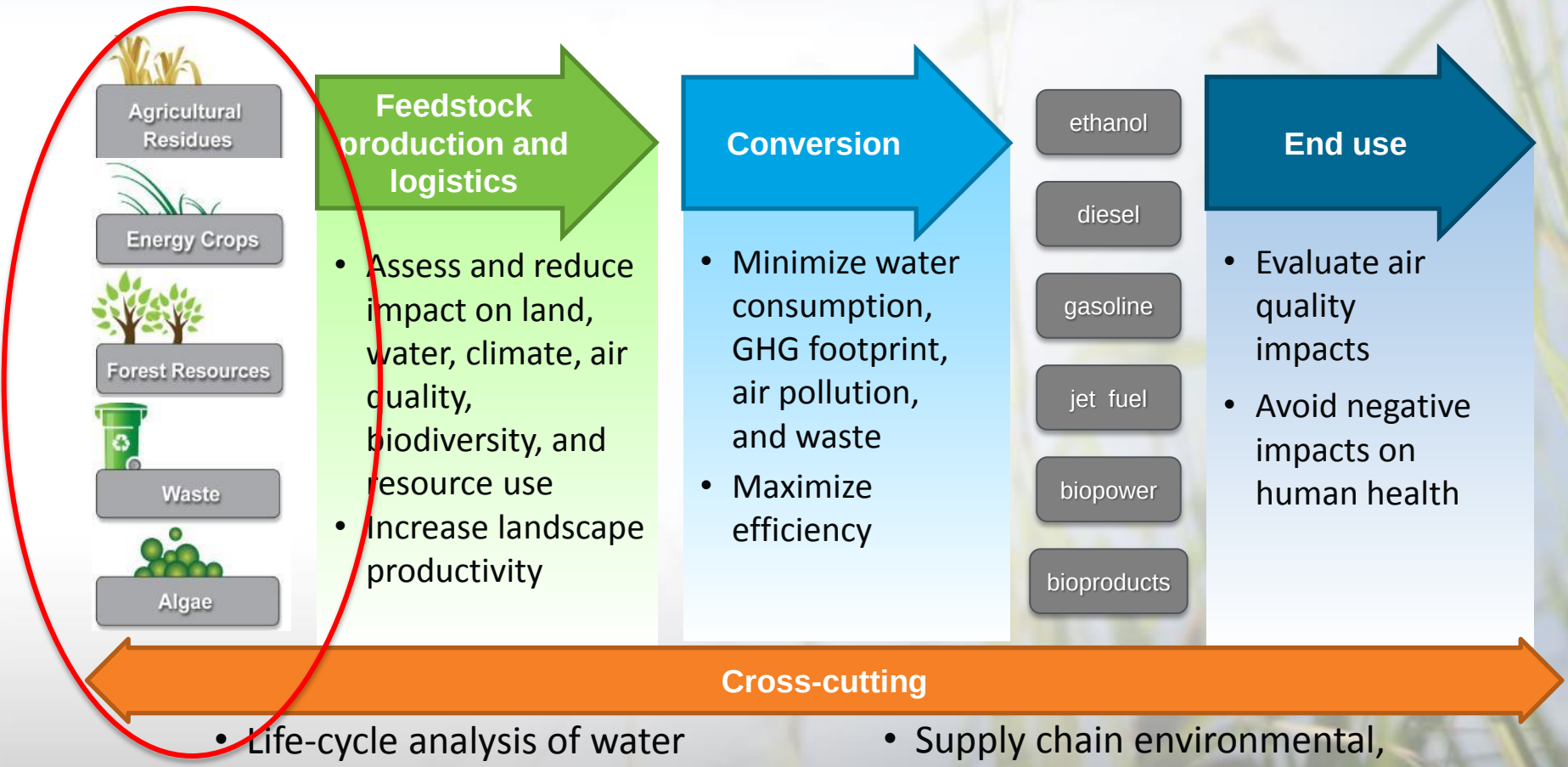
DOE Bioenergy Technology Office's Sustainability Activities

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

Identifying and addressing the challenges for sustainable bioenergy production through field trials, applied research, capacity building, modeling, and analysis.



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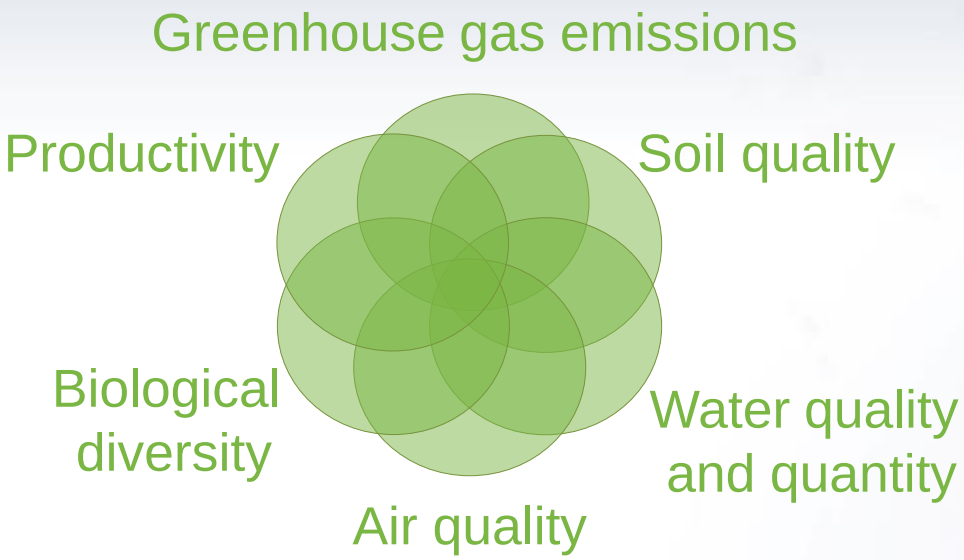
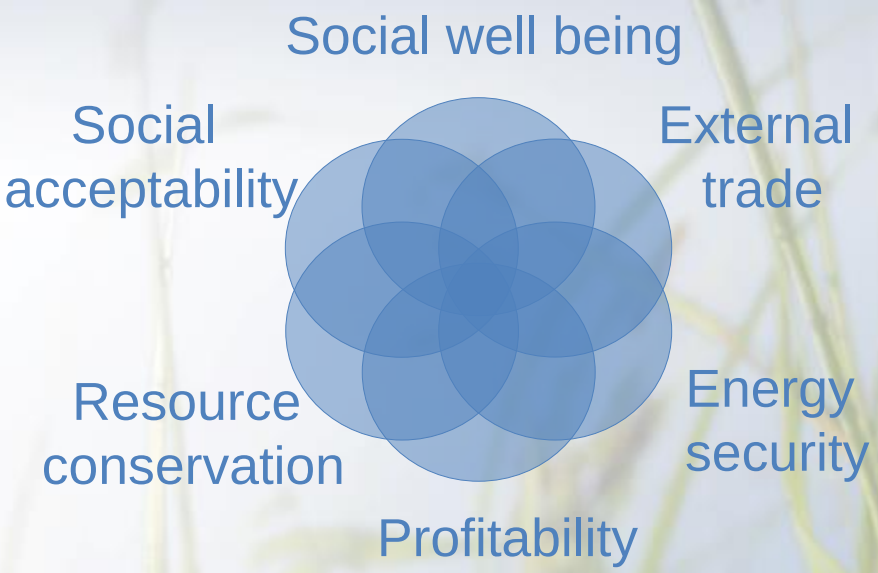
Which crops preferable? Apply criteria: Indicators of environmental and socioeconomic sustainability



McBride et al. (2011)
Ecological Indicators
11:1277-1289



Dale et al. (2013)
Ecological Indicators
26:87-102.

Recognize that measures and interpretations are <u>context</u> specific

Efroymson et al. (2013) *Environmental Management* 51:291-306.

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Looking at the biofuel supply chain in terms of sustainability indicators

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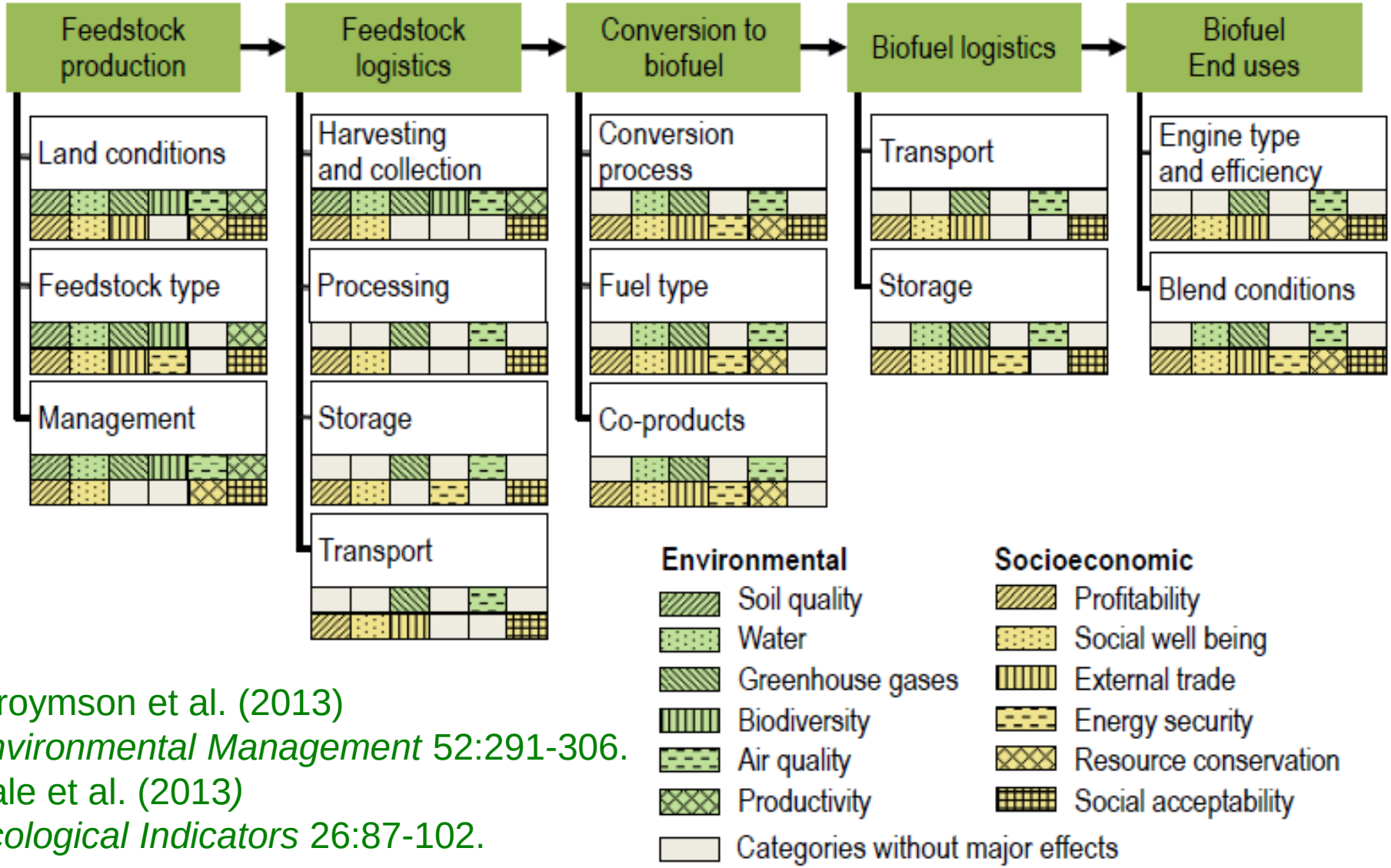

Efroymson et al. (2013)
Environmental Management 52:291-306.
Dale et al. (2013)
Ecological Indicators 26:87-102.

Which biomass crops are preferable?

Preferred biomass production systems –

- Promote improved land management
- Provide other services to society
- Increase efficiency and help minimize or eliminate:
  - fossil fuels
  - "wastes"
- Reduce "climate forcing" (different from GHG emissions – and worthy of a separate talk)
- Can compete in the local market
- Support adaptive management
- Promote continual improvement toward "sustainability"

What biomass sources are recommended?

- Those that most effectively achieve society goals

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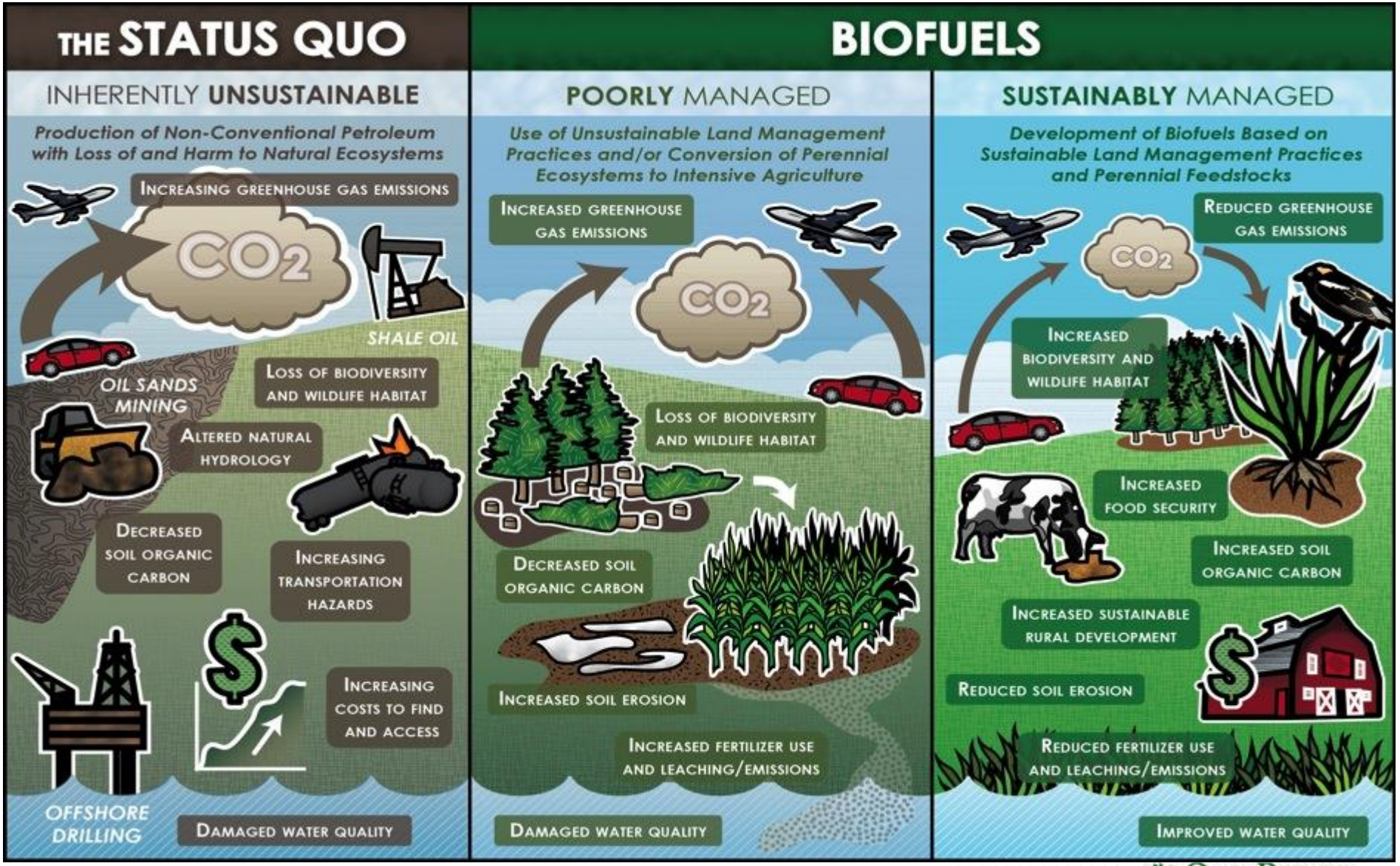
Biofuels need to be sustainably managed



Dale B et al. (2014) Take a Closer Look: Biofuels Can Support Environmental, Economic and Social Goals. Environmental Science & Technology 48(13): 7200-7203.

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Biomass for bioenergy: Outline

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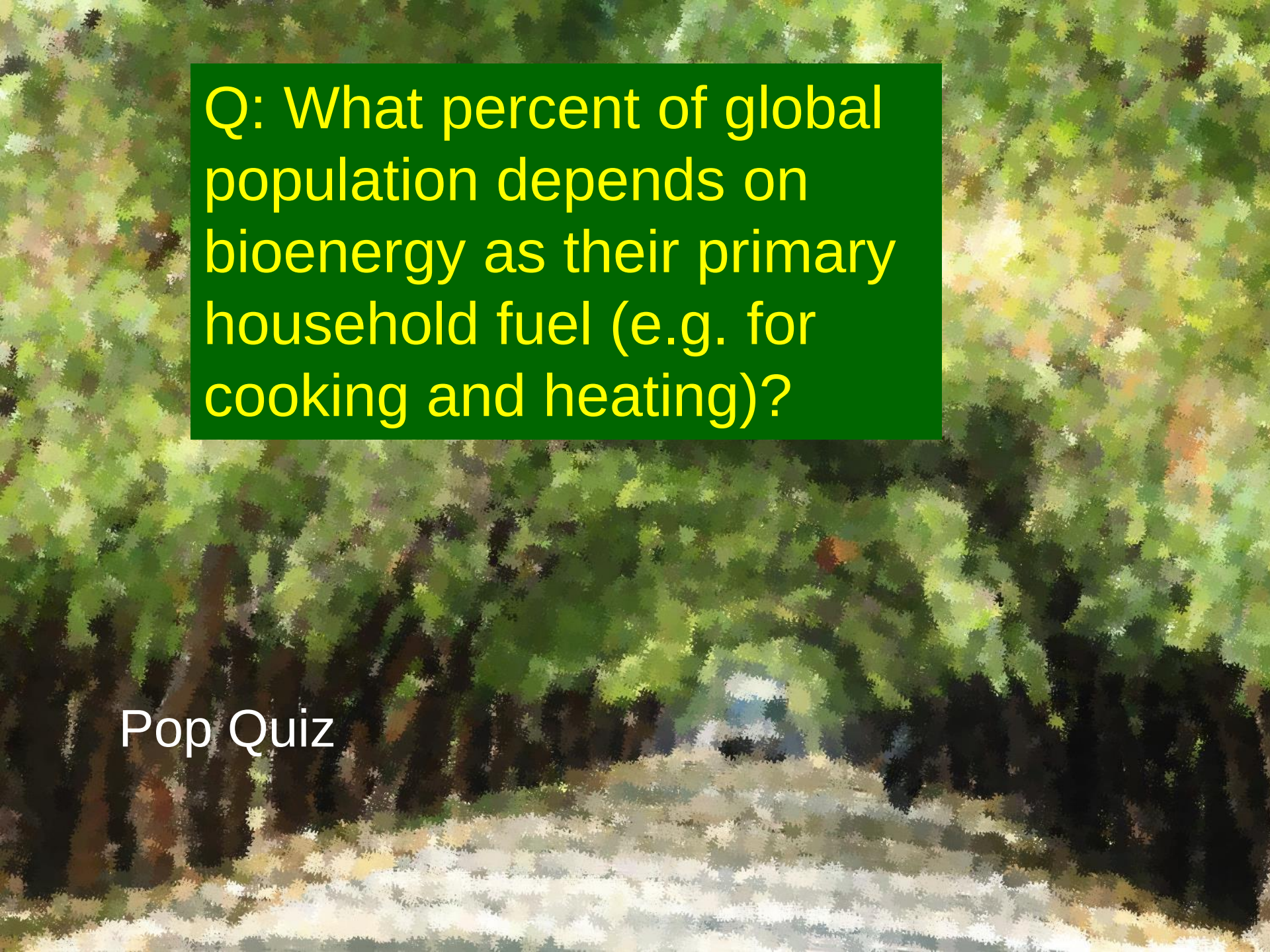
Photo credit: Ron Savage
http://sierravistaimages.zenfolio.com/


Q: What percent of global population depends on bioenergy as their primary household fuel (e.g. for cooking and heating)?
Pop Quiz

What percent of global population depends on bioenergy as their primary household fuel (e.g. for cooking and heating)?

Table 15.2: **People Relying on Traditional Biomass** (million)

	2004	2015	2030
Sub-Saharan Africa	575	627	720
North Africa	4	5	5
India	740	777	782
China	480	453	394
Indonesia	156	171	180
Rest of Asia	489	521	561
Brazil	23	26	27
Rest of Latin America	60	60	58
Total	**2 528**	**2 640**	**2 727**

A: 38% (2.5 billion out of 6.5 billion total pop. in 2006; considerable uncertainty with these data)

IEA World Energy Outlook Special Report (2006)

Traditional biomass (cooking) represents about 9% of primary global energy use. Q: What percent of primary global energy comes from liquid biofuels?

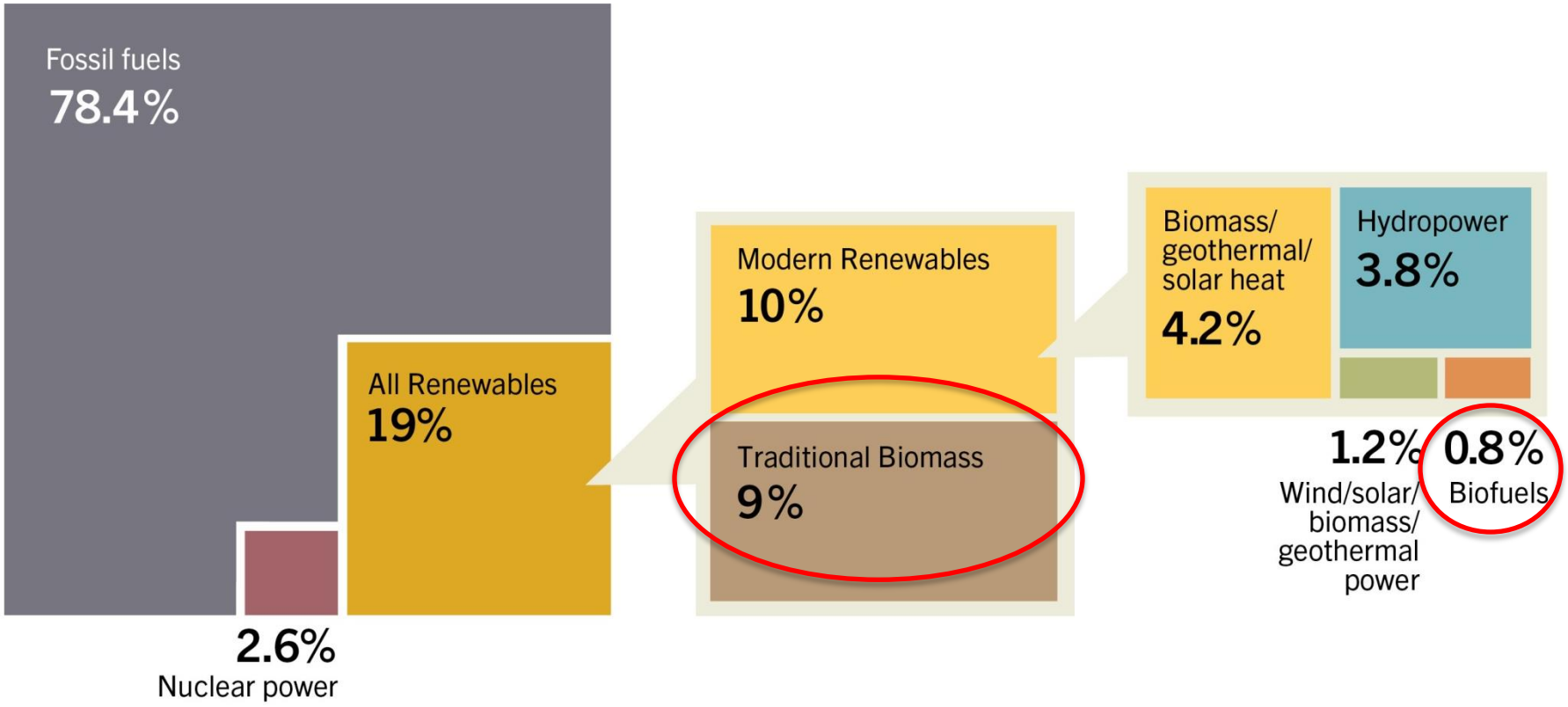
Pop Quiz

A: While traditional biomass represents about 9% of primary global energy use, less than 1% currently comes from liquid biofuels,

A: 0.8% (2012)

What are current sources of biomass? Global consumption: traditional, heat

Estimated Renewable Energy Share of Global Final Energy Consumption, 2012

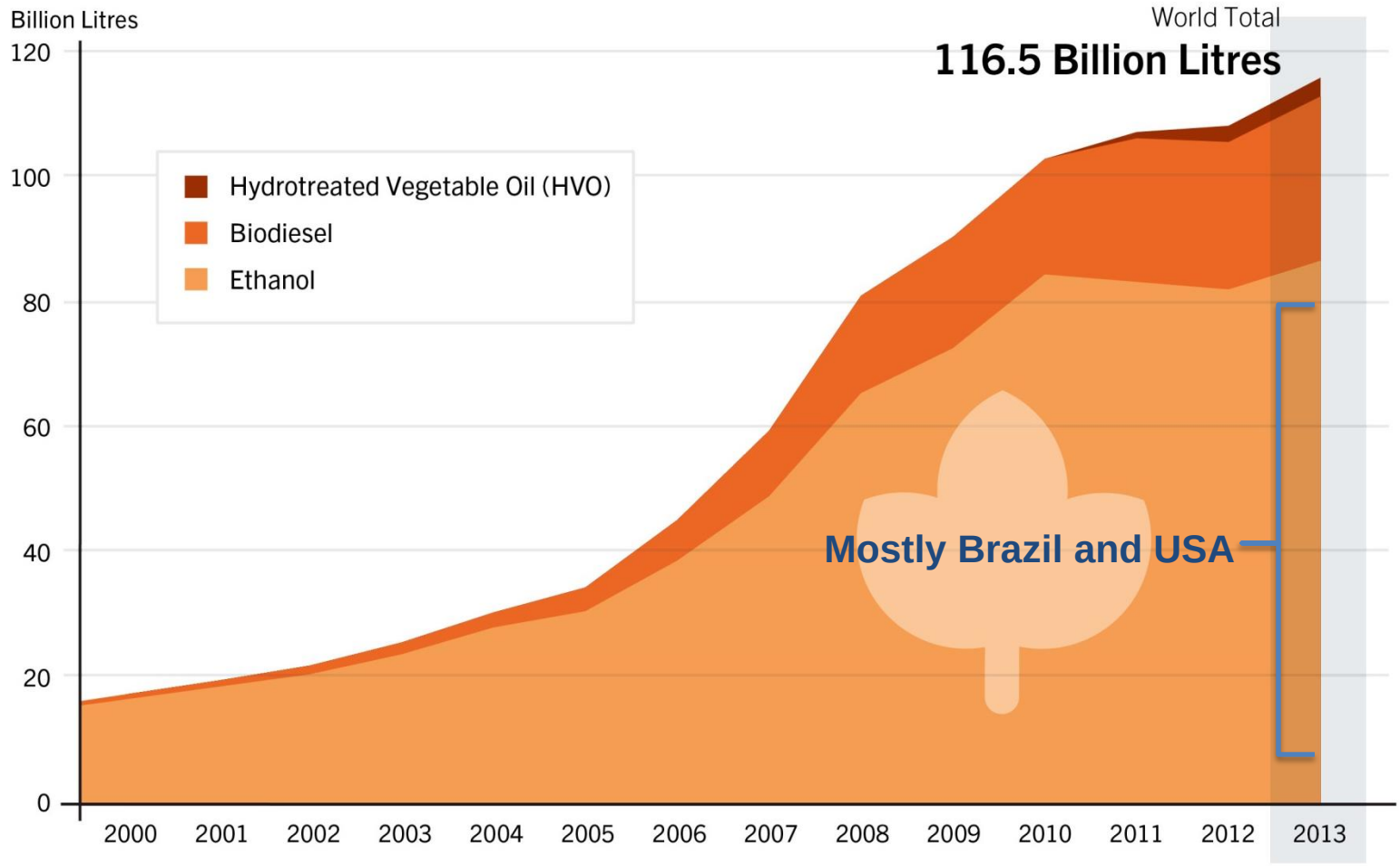


REN21. 2014. *Renewables 2014 Global Status Report* (Paris: REN21 Secretariat).

REN21 Renewable Energy Policy Network for the 21st Century

Current biomass sources: biofuels

Ethanol, Biodiesel, and HVO Global Production, 2000–2013

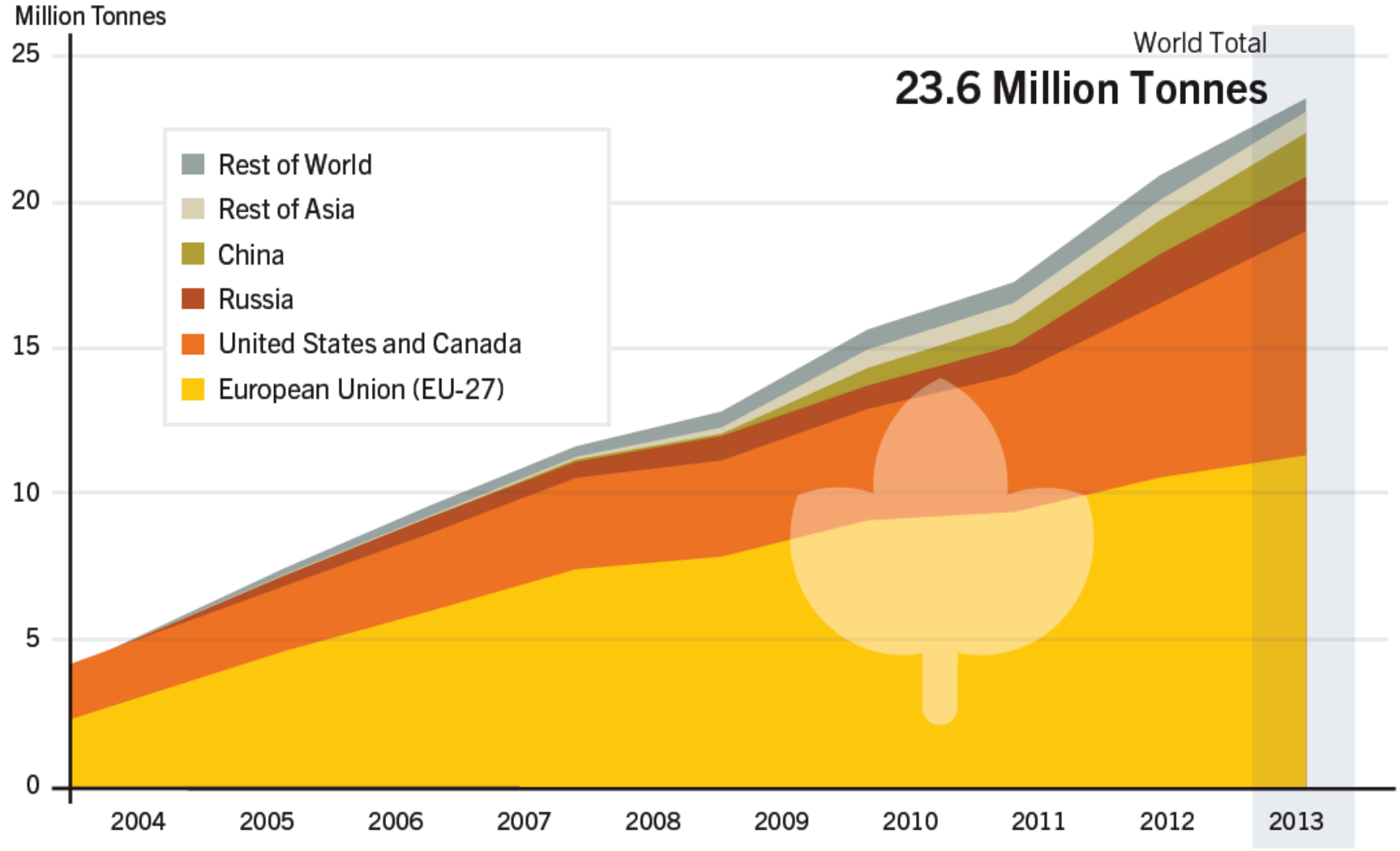


REN21. 2014. *Renewables 2014 Global Status Report* (Paris: REN21 Secretariat).

REN21 Renewable Energy Policy Network for the 21st Century

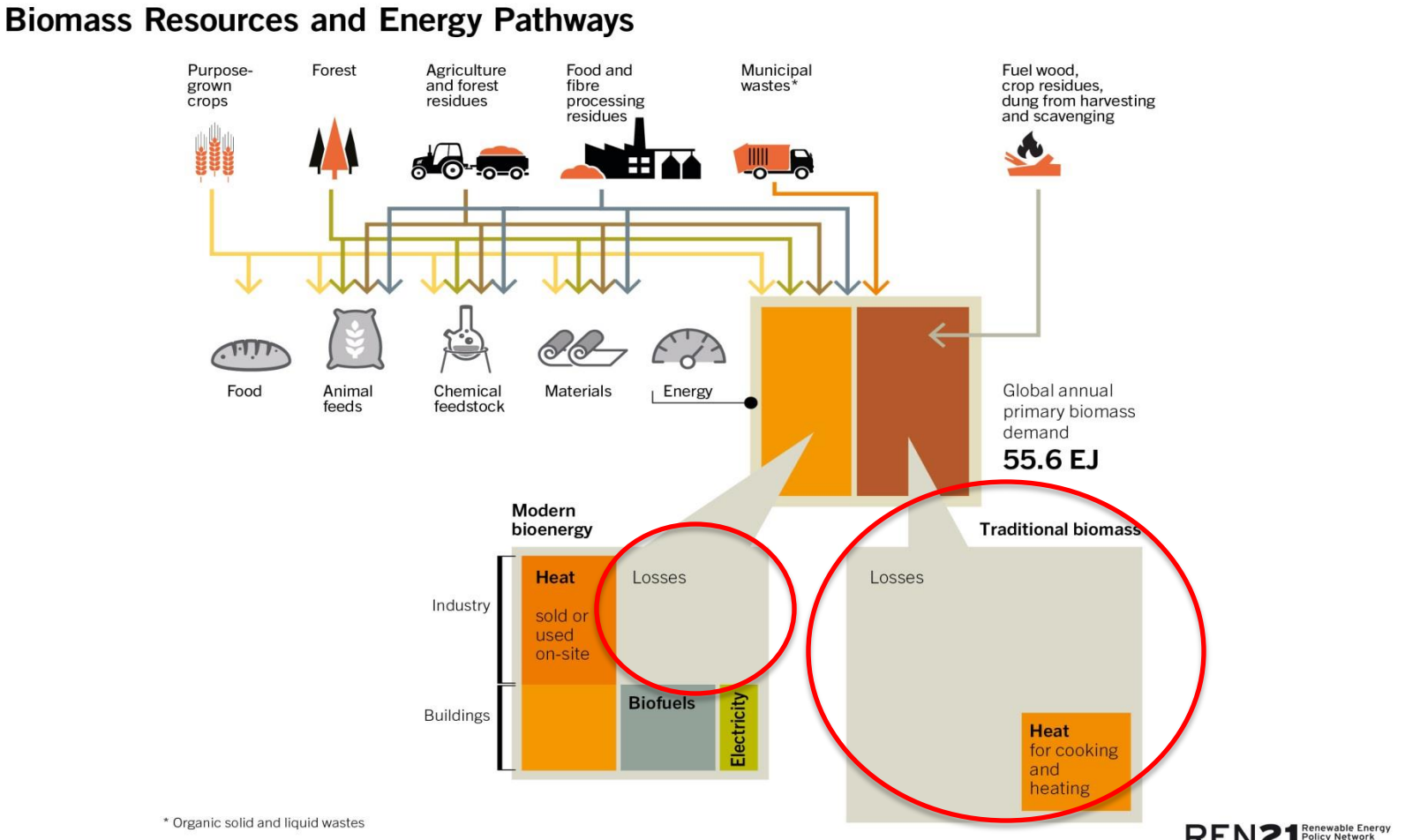
Current biomass sources: wood pellets

Figure 7. Wood Pellet Global Production, by Country or Region, 2000–2013



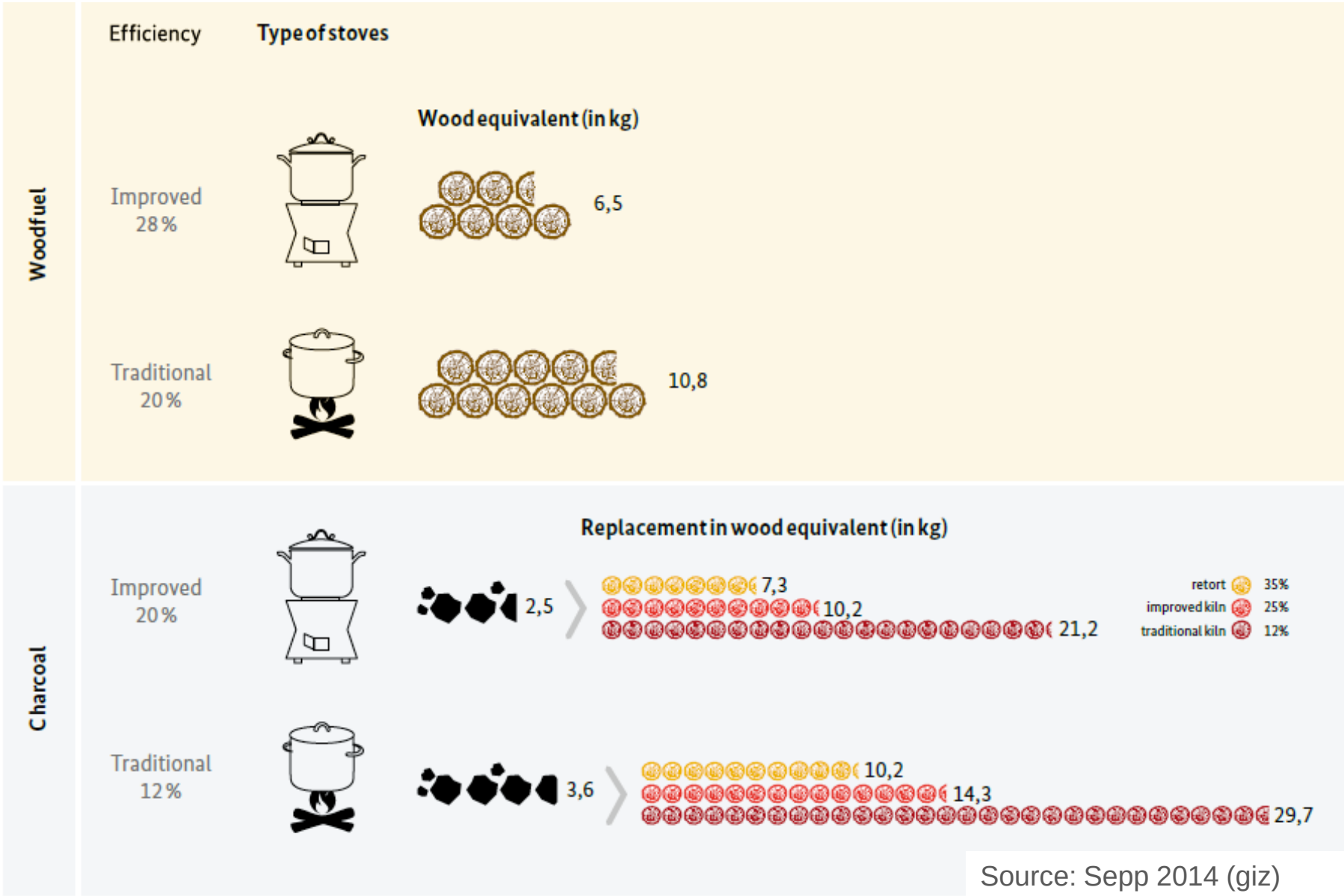
www.ren21.net

Current biomass sources: Large losses = opportunities for future improvement



REN21. 2014. *Renewables 2014 Global Status Report* (Paris: REN21 Secretariat).

1 Kg of LPG (liquid petroleum gas) is approx. equivalent to 6.5 to 30 kg of traditional biomass:



Source: Sepp 2014 (giz)

Biomass for bioenergy: Outline

- What?
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- Which crops preferable?
- Current sources
- **What are future sources?**
- Examples
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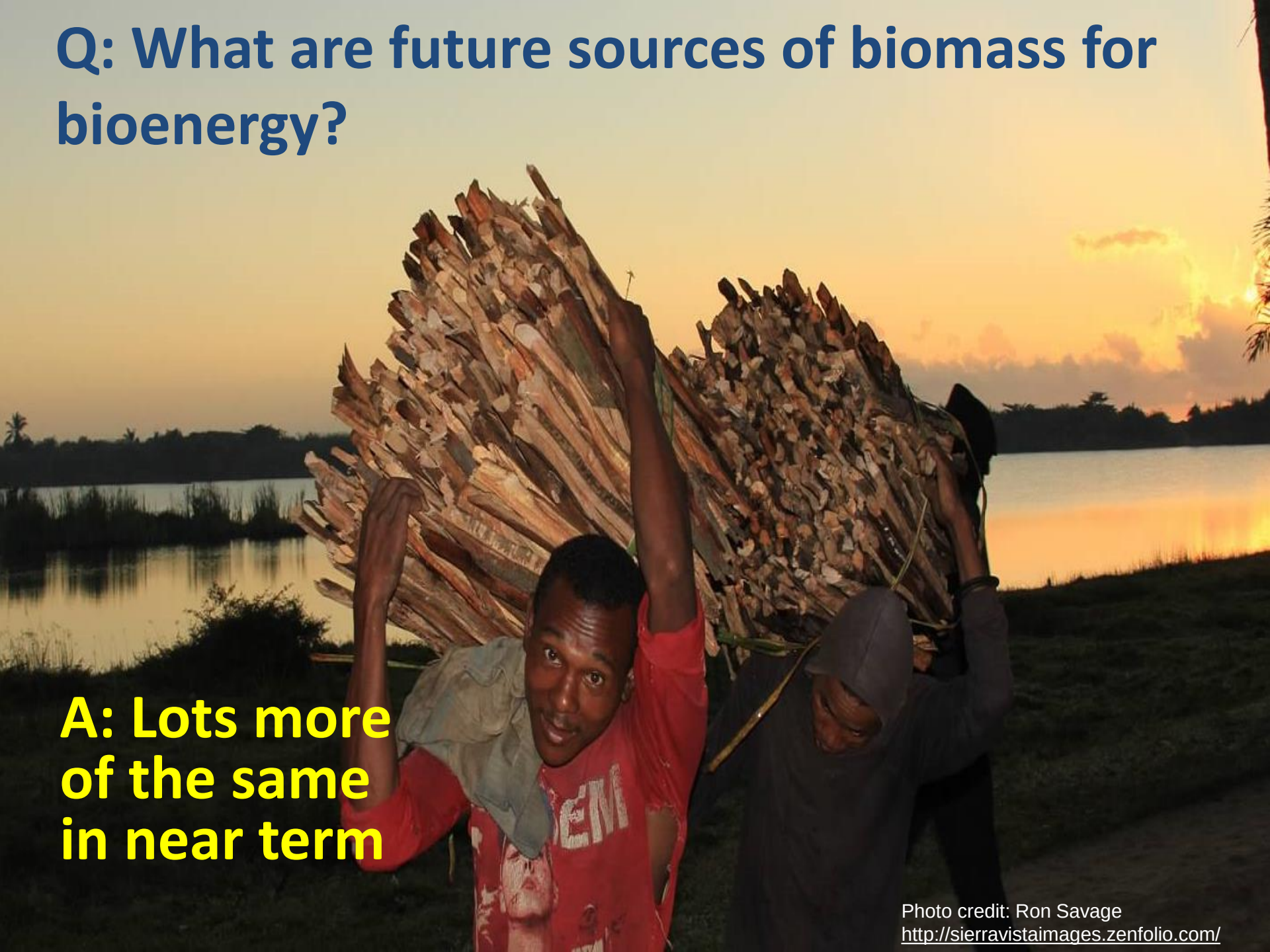
What are future sources of biomass for bioenergy?

Photo credit: Ron Savage http://sierravistaimages.zenfolio.com/

Q: What are future sources of biomass for bioenergy?

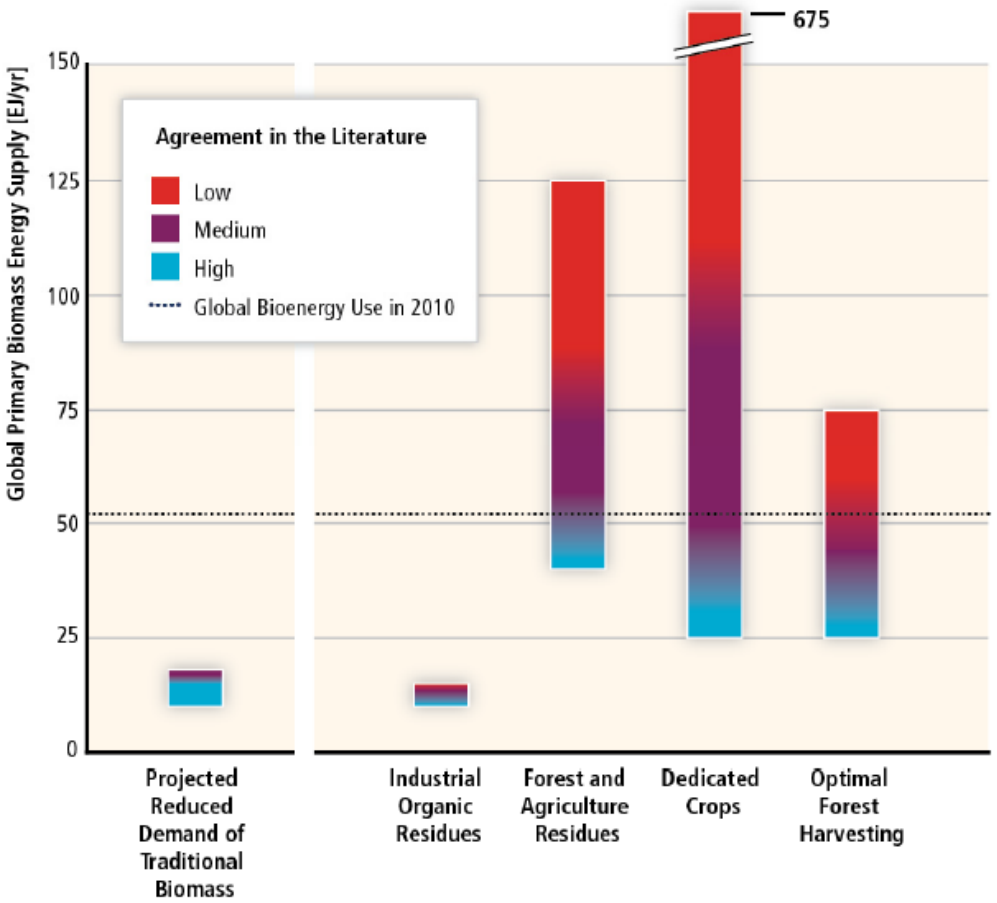


A: Lots more of the same in near term

Photo credit: Ron Savage
http://sierravistaimages.zenfolio.com/

Options exist that, if developed with care, could contribute to enhanced food AND energy security
Photo credit: Ron Savage
http://sierravistaimages.zenfolio.com/

Projections of future biomass resources depend on targets –> wide range of estimates:



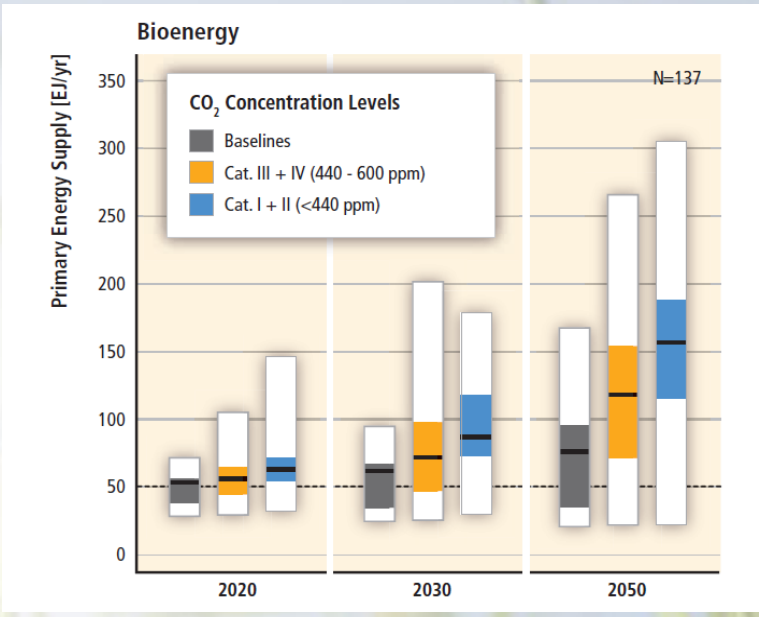
675 EJ

>50 EJ (less than current use)

Figure 11.20. Global Technical Bioenergy Potential by main resource category for the year 2050. The figure shows the ranges in the estimates by major resource category of the global technical bioenergy potential. The color grading is intended to show qualitatively the degree of agreement in the estimates, from blue (large agreement in the literature) to purple (medium agreement) to red (small agreement). In addition, reducing traditional biomass demand by increasing its use efficiency could release the saved biomass for other energy purposes with large benefits from a sustainable development perspective.

Why do global biomass potential estimates vary so much?

- "Technical Potential"
  750-1500 EJ per year (Smeets et al. 2007)
- "Sustainable potential"
  300-500 EJ per year
  - Dornburg et al. 2010
- "Conservative potential"
  - "impossible that bioenergy could physically provide more than 250 EJ /yr in 2050" -Haberl et al. 2013 (Environ. Res. Lett. 8)



IPCC 2012 Special Report on Renewables and CC Mitigation

***Assumptions* about land available without impacting food security are key to estimates.**

Slide adapted from Kline presentation to "Pathways to Climate Solutions: Assessing Energy Technology and Policy Innovation" Workshop organized by the Aspen Global Change Institute; 24-28 February, 2014. Aspen CO.

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IPCC Special Report Renewable Energy

"most likely range is 80-190 EJ" but estimates depend on land assumptions

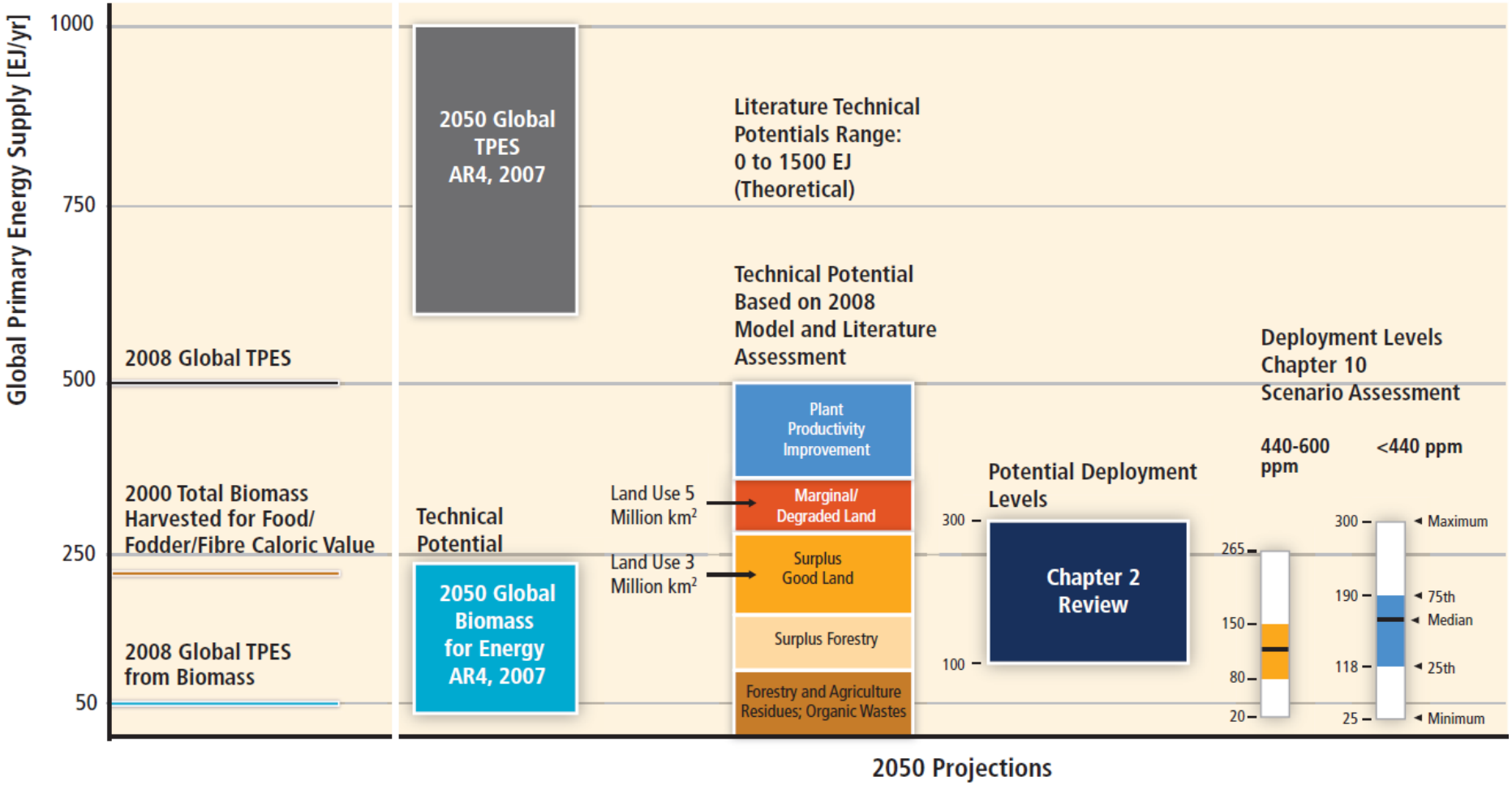

Figure 2.25 | On the left-hand side, the lines represent the 2008 global primary energy supply from biomass, the primary energy supply, and the equivalent energy of the world's total harvest for food, fodder and fibre in 2000. A summary of major global 2050 projections of primary energy supply from biomass is shown from left to right:

-IPCC 2012 Special Report on Renewables and Climate Change Mitigation

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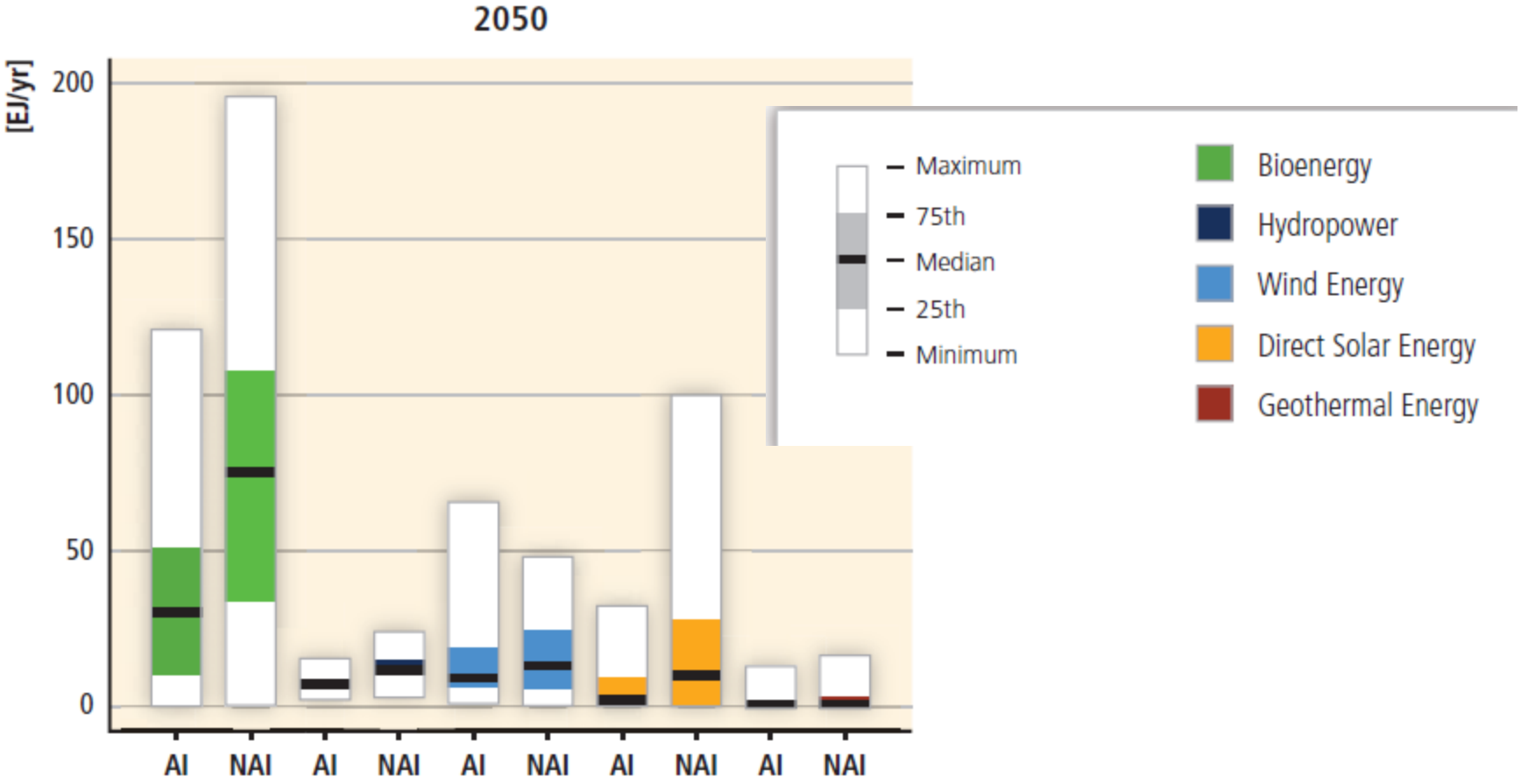
Future biomass for bioenergy sources must address perceived obstacles

- Markets: lack of security for investment in increased production
- Food security and land concerns
- LUC-related effects on biodiversity, carbon debt, water
- Distribution of benefits and costs
- Need for integrated policy across agriculture, forestry, waste management, urban planning, environment, energy…
- Sector- and nation-specific challenges: e.g., policies, "blend wall," distribution infrastructure

Source: Kline presentation to "Pathways to Climate Solutions: Assessing Energy Technology and Policy Innovation" Workshop organized by the Aspen Global Change Institute; 24-28 February, 2014. Aspen CO.

IPCC Special Report Renewable Energy

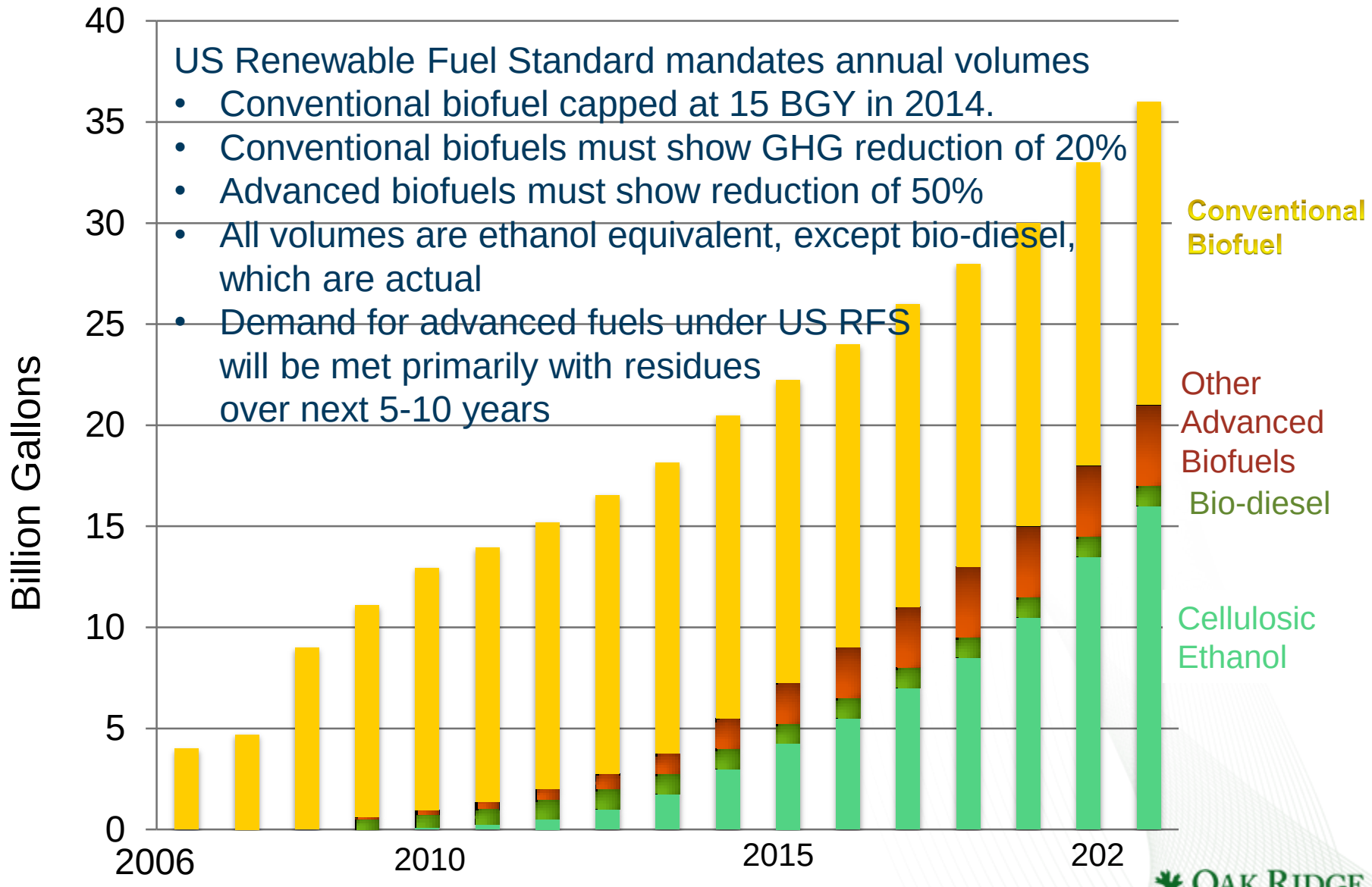
To achieve climate mitigation scenarios – BIOENERGY has important role relative to other potential renewable energy sources.



-IPCC 2012 Special Report on Renewables and Climate Change Mitigation

So we should figure out how to do it right! (more sustainably)

Where will biomass come from in the future? - Depends on laws and regulations



Source: http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm

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Biomass for bioenergy: Outline

- What?
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- Which crops preferable?
- Current sources
- What are future sources?
- **Examples of future sources, assessment**
- Discussion
- Resources for more information

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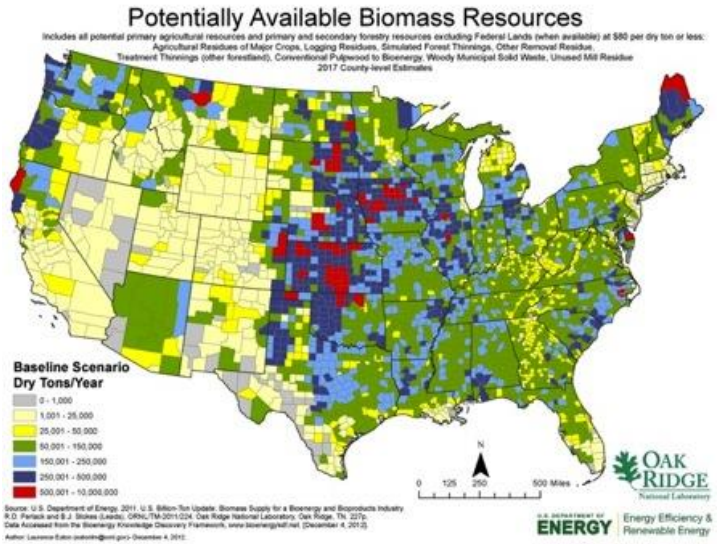
Future resources: US assessment

- Billion-Ton Study of 2005 helped support US renewable fuel volumes
- Billion Ton Update of 2011 included county-level cost & supply projections
- Conclusion: US has ample feedstock to replace up to 1/3 of petroleum with advanced biofuels
- Feedstock is roughly 1/3 cost of fuel: cost reductions and efficiency in feedstock supply are imperative
- Multi-institutional effort (DOE & USDA)
  - 20-year projections of economic availability of biomass at county level at any year
  - price, location, scenario
- Primary Resources
  - Forest resources (residues)
  - Ag resources (corn stover)
  - Energy crops (switchgrass)



U.S. Bioenergy supply model Billion Ton Update (USDOE 2011)

- Forecasts of potential biomass
  - POLYSYS partial equilibrium model of US agricultural and forestry sectors.
  - 20-year projections of economic availability of biomass (price, location, scenario)

- Forest resources
  - Logging residues
  - Forest thinnings (fuel treatments)
  - Conventional wood
  - Fuelwood
  - Primary mill residues
  - Secondary mill residues
  - Pulping liquors
  - Urban wood residues
  - [Algae is separate study]
- Agricultural resources
  - Crop residues
  - Grains to biofuels
  - Perennial grasses
  - Perennial woody crops
  - Animal manures
  - Food/feed processing residues
  - MSW and landfill gases
  - Annual energy crop (added for 2011)

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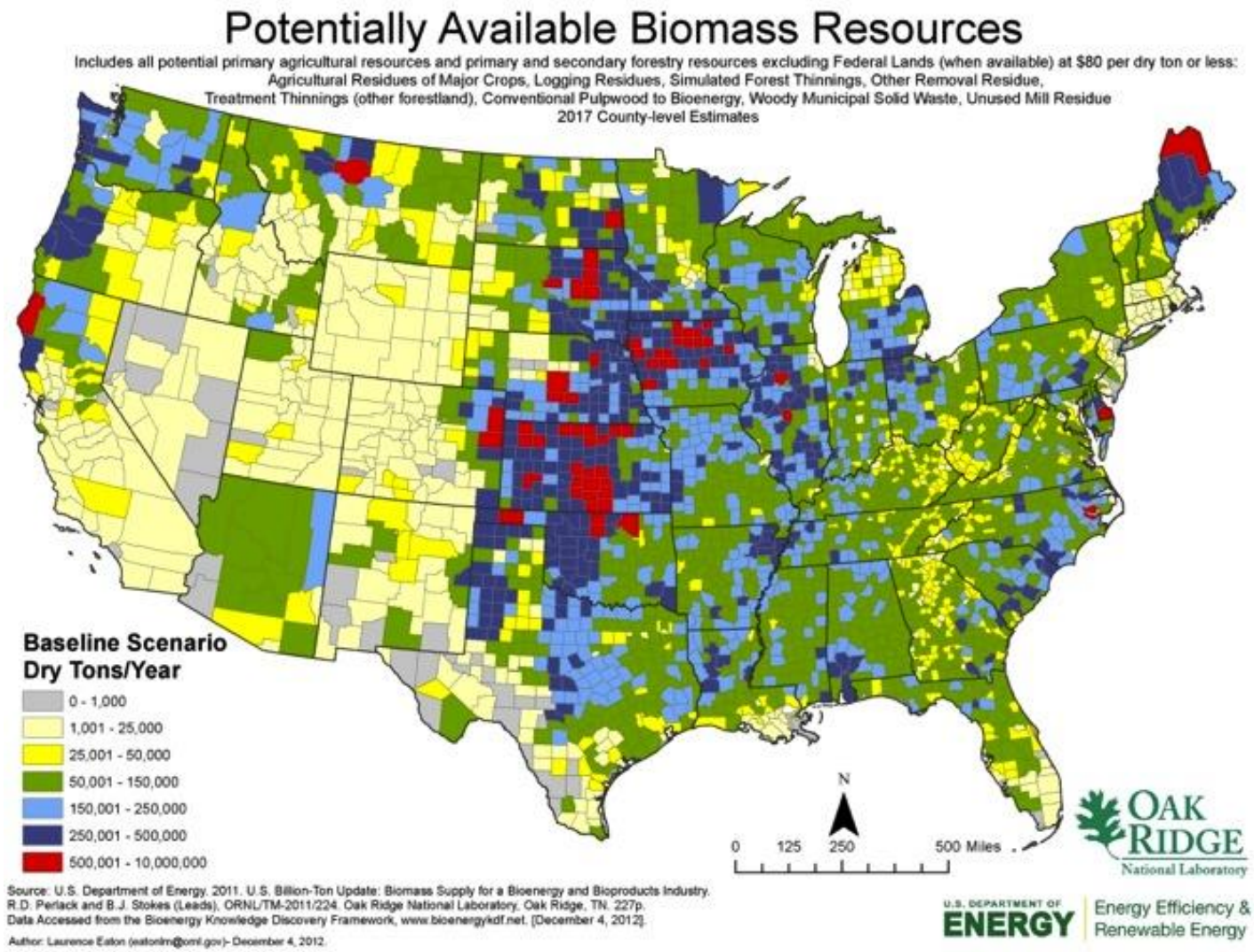
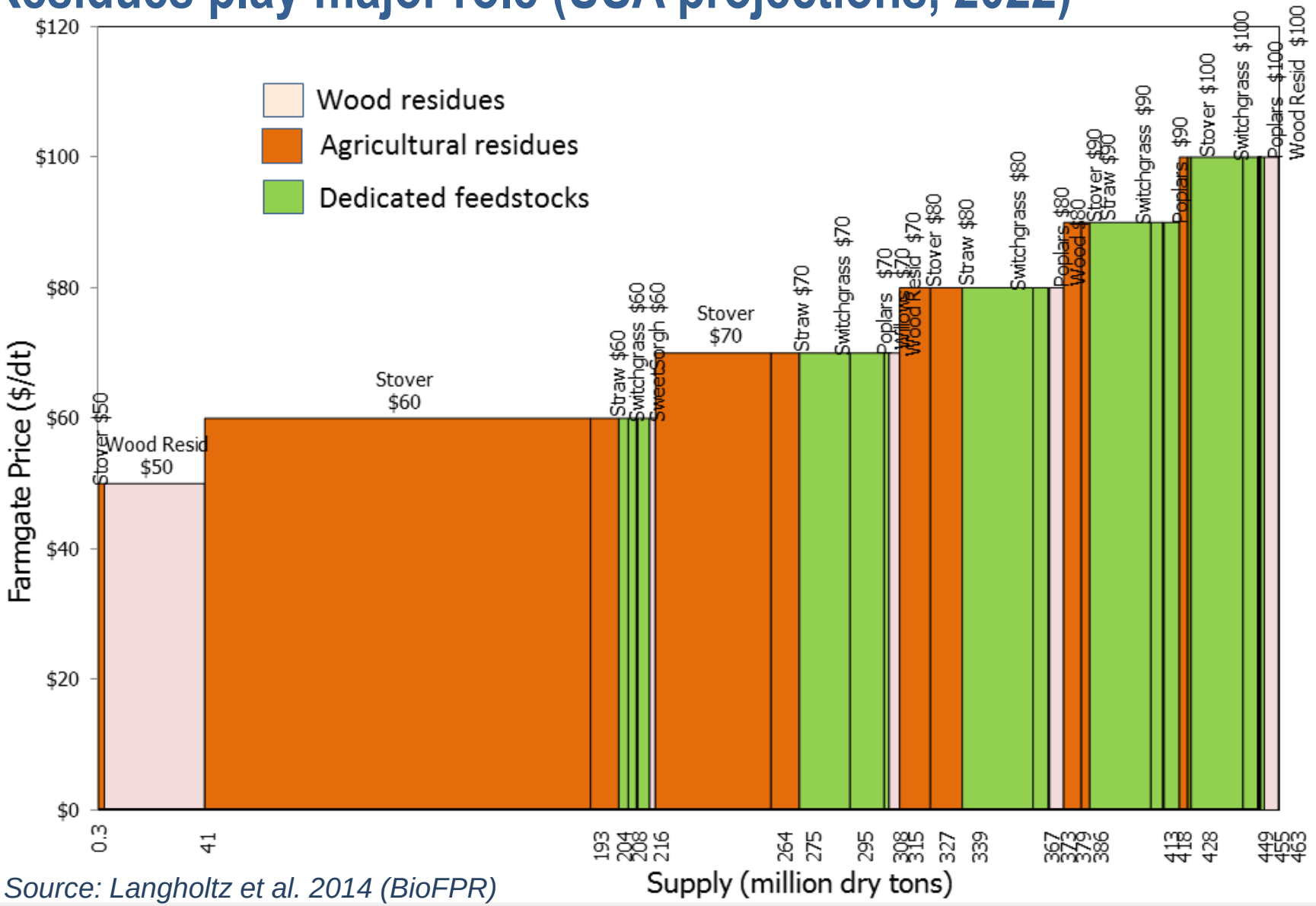
Example: US county-level Supply Projections

All feedstocks -- Baseline scenario -- $60 dry ton^{-1}



155 million DT/yr by 2017 is required to meet EISA targets (85 gal/ton conversion efficiency)

Future sources depend on supply costs and yields – Residues play major role (USA projections, 2022)



Source: Langholtz et al. 2014 (BioFPR)

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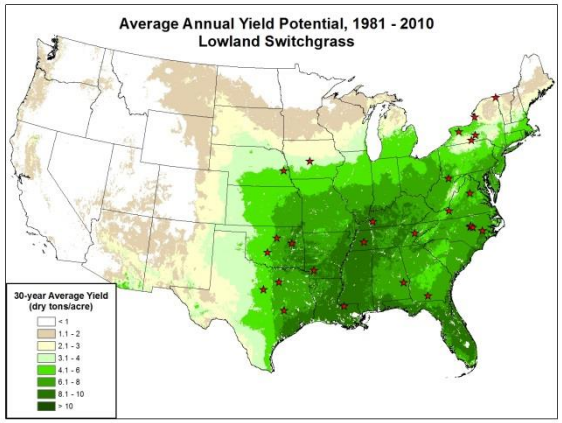
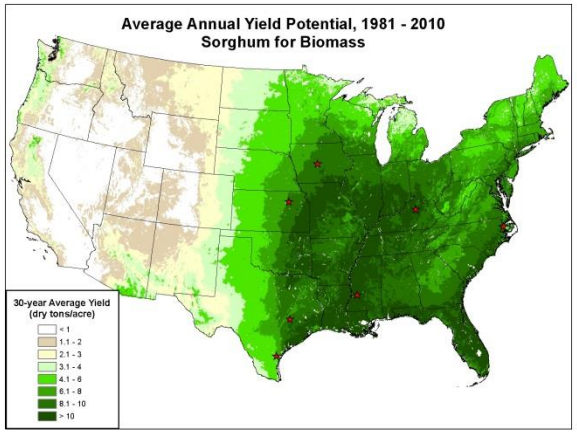
Herbaceous Energy Crops- yield modeling

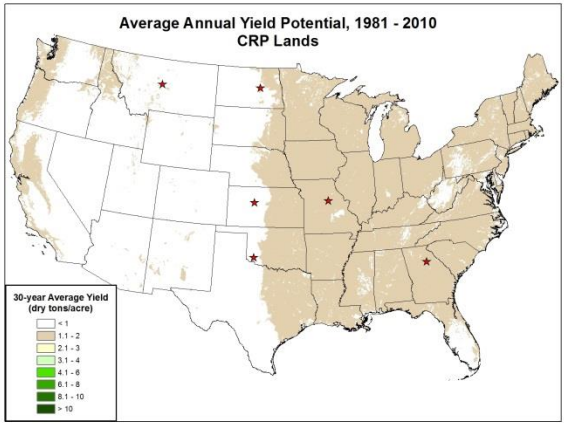
Lowland Switchgrass

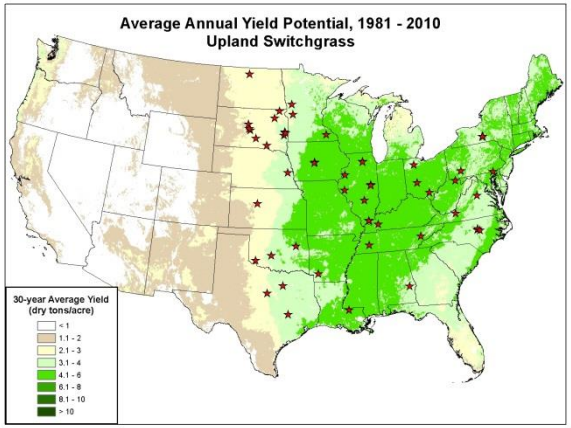


Sorghum

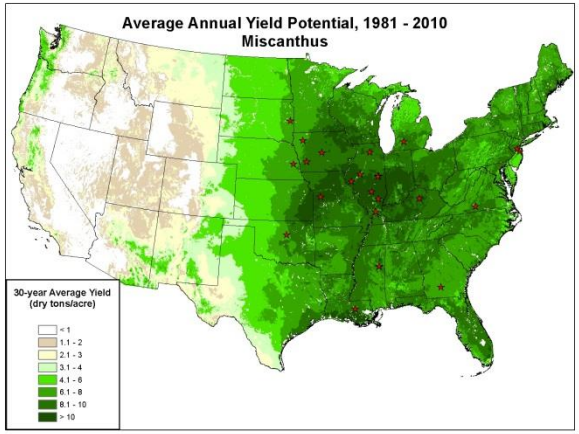


CRP Grasses

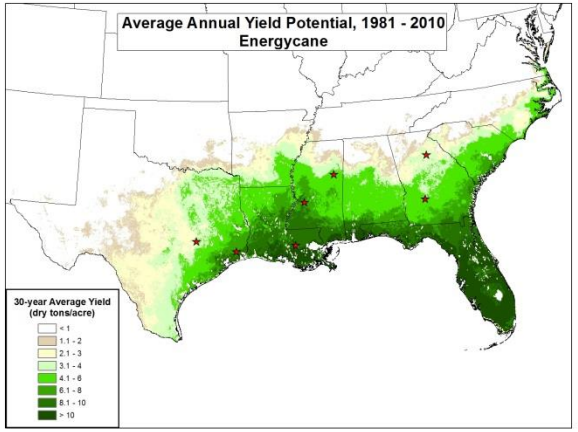




Upland Switchgrass



Miscanthus x *giganteus*



Energycane

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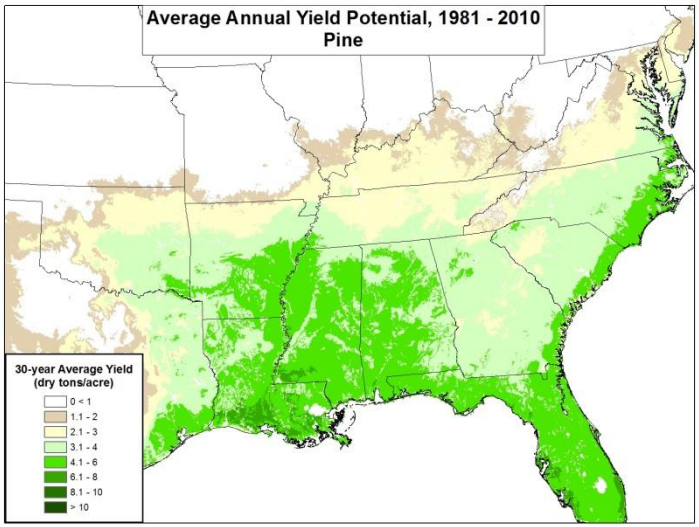
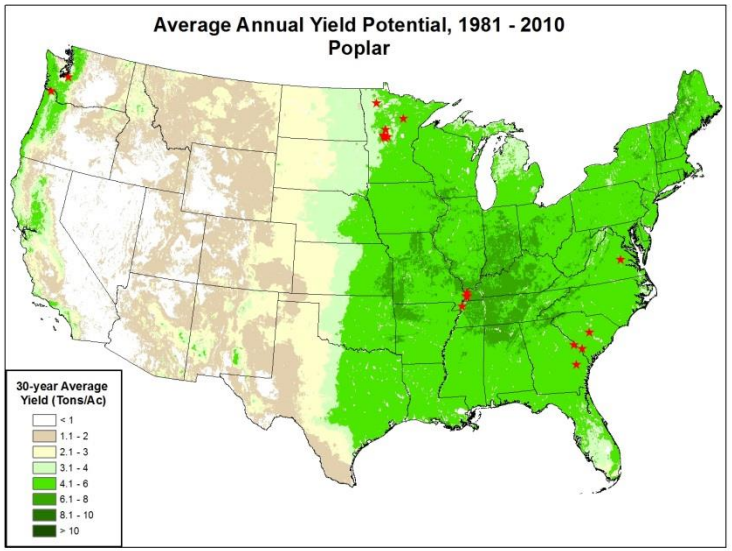
Woody Energy Crops- yield modeling

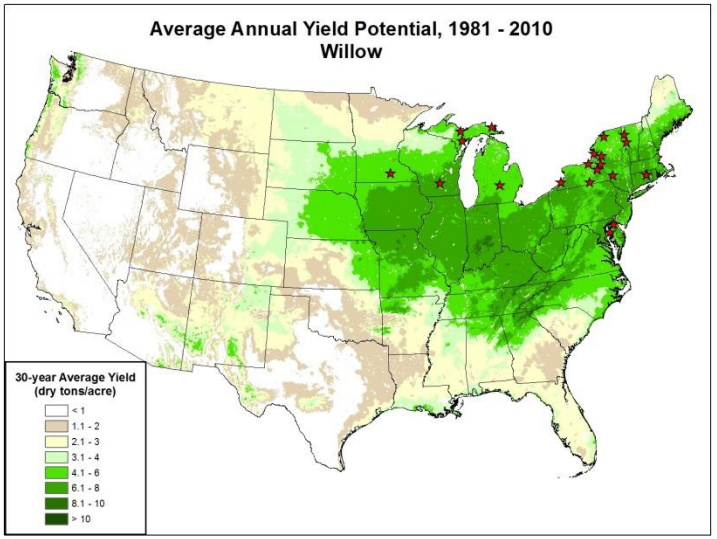
Pine



Poplar



Willow



Plus eucalypts and others…

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Current and future sources: woody and vegetative wastes

INEOS, Vero Beach, FL

- Expected to produce 8 million gallons per year of cellulosic ethanol and 6 MW of power from wood and vegetative waste
- initiated commercial production of cellulosic ethanol in July 2013
- First commercial production of cellulosic ethanol in the U.S.

Credit: Jim Spaeth, Bioenergy Technologies Office

Current and future sources: crop residues (sorghum grits)

Myriant Succinic Acid Biorefinery , Lake Providence, LA

Biochemical conversion of sorghum grits to succinic acid.

Expected to process 50 dry tons/day to produce 30 Million Lbs/year of succinic acid and gypsum

Credit: Jim Spaeth, Bioenergy Technologies Office

Current and future sources: corn stover (maize residue) for ethanol

POET-DSM Project LIBERTY, Emmetsburg, IA

- Expected to produce 20 million gallons per year of cellulosic ethanol at full capacity
- Ribbon cutting 2014

Credit: Jim Spaeth, Bioenergy Technologies Office

Current and future sources: corn stover (maize residue) for ethanol and electricity

Credit: Jim Spaeth, Bioenergy Technologies Office

Biomass for bioenergy: Outline

- What?
- Why?
- Which crops preferable?
- Current sources?
- Future sources?
- Examples
- **Discussion**
- Resources for more information

"You can't know where you're headed if you don't know where you've been"

And it helps to understand where you are right now.

"Prediction is very difficult, especially about the future"

-Niels Bohr, Danish physicist.

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Thoughts for discussion

- Many studies of global biomass potential begin with assumed limitations of land. Is land the primary constraint to biomass production? - No -
  - Social, political, economic/market issues
  - Institutions, governance, water…
- Needed: Incentives for improved soil/water (resource) management
  - Increase carbon and nutrient retention
  - And capacity to store carbon
- On the sustainability radar:
  - Integrated land-use plans and production systems (ILUP)
  - Urban food-energy systems for nutrient, water and energy recycling

Source: Kline presentation to "Pathways to Climate Solutions: Assessing Energy Technology and Policy Innovation" Workshop organized by the Aspen Global Change Institute; 24-28 February, 2014. Aspen CO.

Conclusions – we have no shortage of biomass

Different places, contexts, needs and goals require unique solutions.

We need to

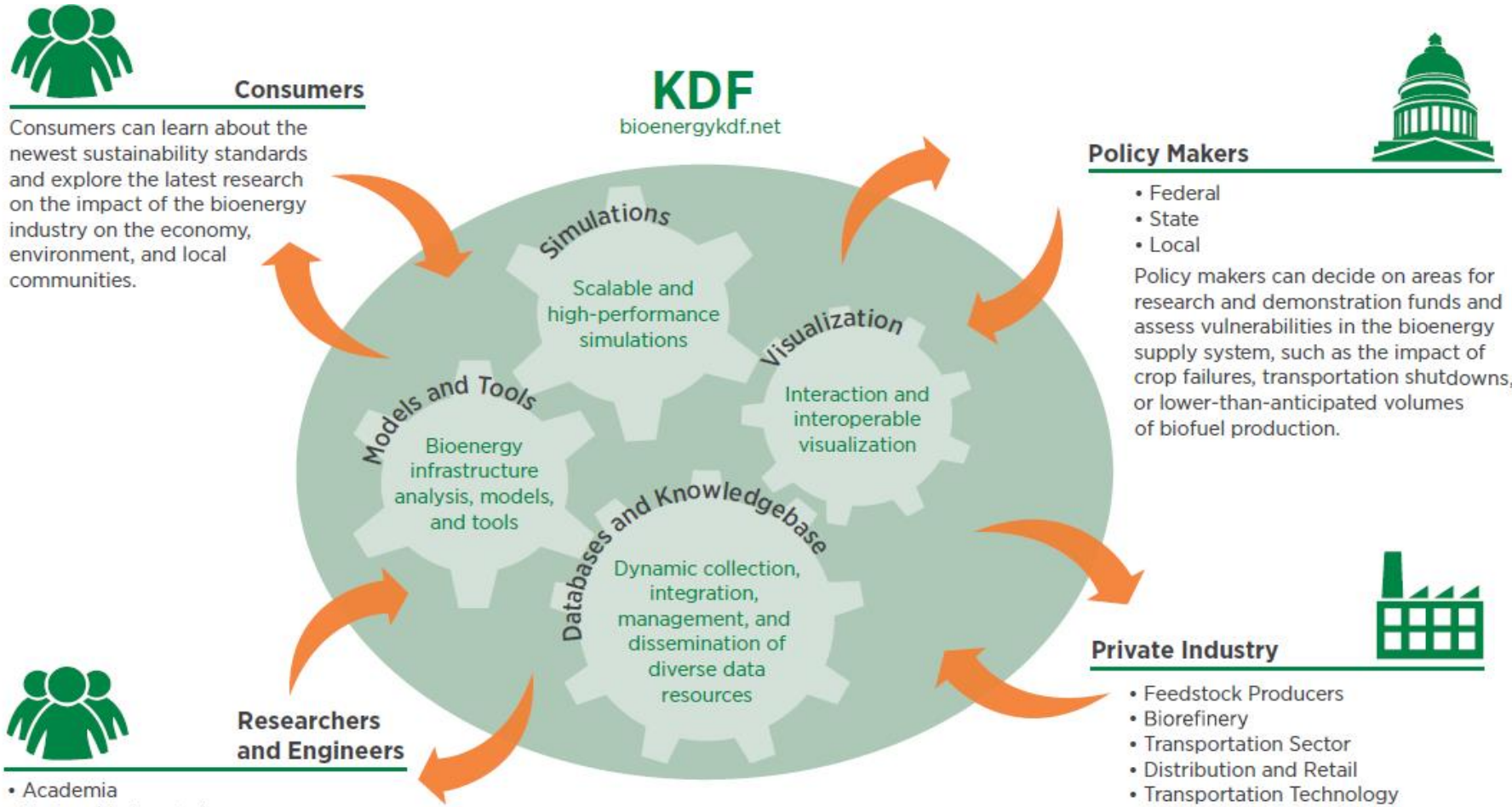
- Learn from experiences
- Build partnerships
- Develop and apply a suite of metrics that reflect local stakeholder priorities for “sustainability”

Thank you!

http://www.ornl.gov/sci/ees/cbes/

For more information: Bioenergykdf.net

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



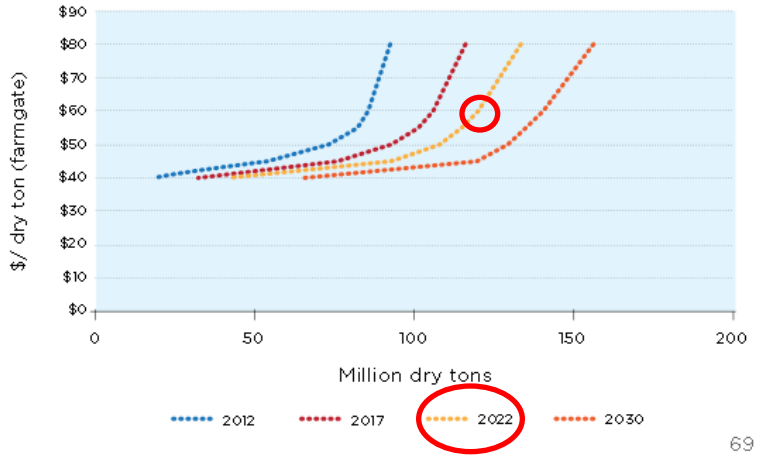
For video, see: https://www.youtube.com/watch?v=sm1Yt-kPZpE&list=UUSRLqX2RF5hWFxb2AY891wg

Bioenergy KDF Resources

- Billion Ton Data Explorer
  - Visualize custom supplies from the BT2 findings
  - Available for all potential resources identified as new biomass sources

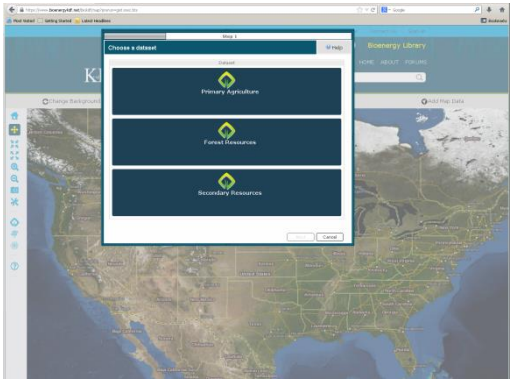
Corn Stover Supply

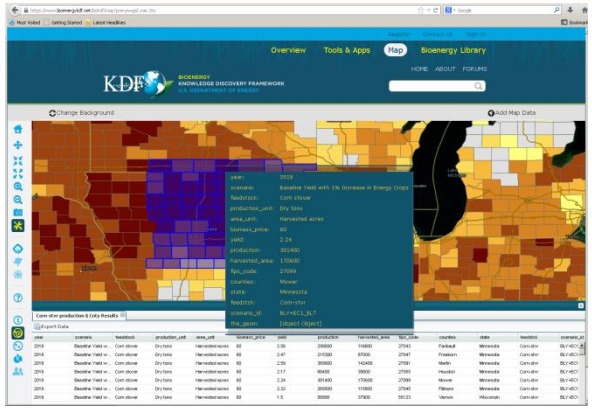
Figure 4.11 Supply curves of potential corn stover production for various years under baseline assumptions



69

Online Tool Workflow





https://bioenergykdf.net/

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Thank you

Center for Bioenergy Sustainability

http://www.ornl.gov/sci/ees/cbes/

See the website for

- Reports
- Forums
- Other presentations
- Recent publications

- Bibliography and extra slides follow

CBES
Center for BioEnergy Sustainability

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The views in this presentation are those of the author/presenter who is responsible for any errors or omissions.

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Jobs are important for social and political sustainability – Fossil fuels = boom/bust cycles, while…

i - Employment information for large-scale hydropower is incomplete and not included.

Source: www.ren21.net

Win-Win LUC Opportunities

Improve soil & water management	• Precision management and nutrient recycling • Reduce disturbance/tillage intensity • Crop mix, rotations, cover crops • Land restoration • Technology (seed, microbe, equipment)
Increase Efficiency	• Reduce inputs/increase ***yields*** • Open, transparent markets • Minimize transaction costs • Prioritize, incentivize, measure
Diversify	• Uses and markets • Substitution options • Bases of production
Adopt Systems Perspective	• Multi-scale • Long term and adaptive • Integrated land-use plans

Source: K.Kline presentation to Coordinating Research Council CRC, Argonne IL, 13 Oct 2013

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Research challenges to better address issues about food security and biofuels

- Accurate representations based on clear **definitions** for variables and conditions of concern:
  - land attributes
  - management practices
  - baseline trends and dynamics
- **"Causal analysis"** that can be validated at multiple scales
- Adequate empirical **data** to test models and hypotheses
- Multi-disciplinary, multi-institutional **learning** and problem-solving mechanisms

Source: adapted from K.Kline presentation to Coordinating Research Council CRC, Argonne IL, 13 Oct 2013