

Bioenergy, Climate and Development: Linkages, Synergies and Conflicts

Transport, Communication and Sustainable Development
KTH, 24 April 2015

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Overview of Presentation

- Definitions of biomass and bioenergy
- Current use, future potential
- Conversion Options/platforms
- Traditional vs. modern bioenergy
- Biofuels for transport
- Examples: eucalyptus, sugar cane, sweet sorghum, jatropha
- Economics and Markets
- Food-Feed-Fuel: linkages/synergies/conflicts
- Energy balance, land use, GHG emissions
- Sustainability and biofuels policies

What is Biomass? – living matter from plants and animals:

Biomass ≠ Bio-energy!

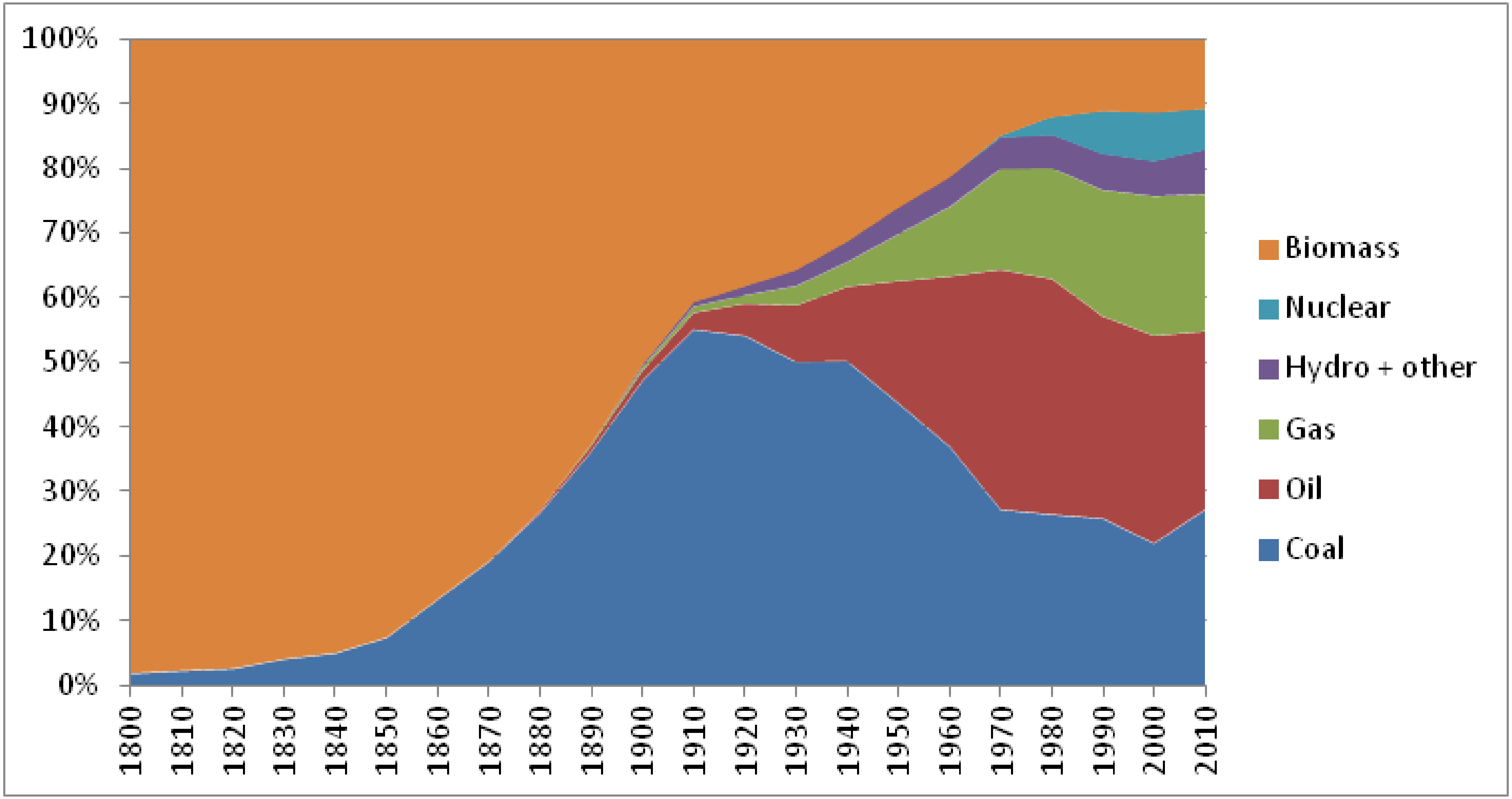
Many inter-connected and critical functions/services:

- The 4Fs: Food, Feed, Fibre, and Fuel.........
- ....and still more Fs: Fertiliser, Feedstocks, Flora, Fauna
- Shelter, housing, household materials
- Livelihoods, entrepreneurship, local business opportunities
- Maintenance of Biodiversity
- Ecosystem functions and integrity
- Nutrient cycles and functional synergies
- Water quality, erosion control, watershed maintenance
- Recreation, peacefulness, tranquillity, wildlife observation
- Contribution to human dignity and equality
- Shaping the role of citizens and communities as caretakers
- Resource Base for Future Generations

Energy-Environment-Development driving forces

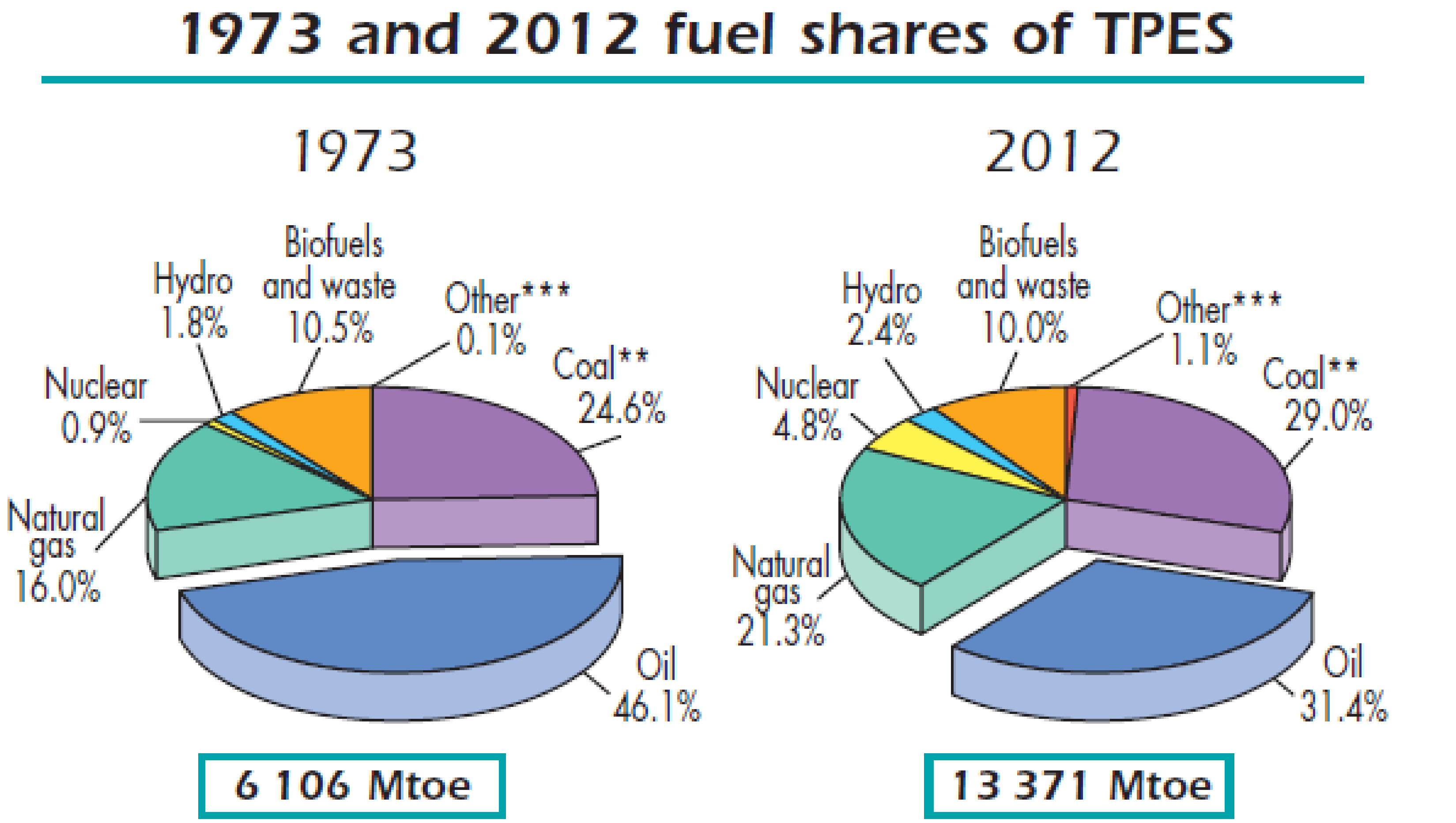
- Rural development - creation of sustainable livelihoods
- Relieving resource pressures and stresses
- Socioeconomics of urbanisation and migration
- Energy security: local – regional – global
- Rural health issues - indoor air
- Urban health issues – lead, air quality
- future competitiveness of agro-industries
- Kyoto Annex 1 countries seeking carbon credits
- Developing countries looking for foreign investment through Clean Development Mechanism (CDM)
- Dependence on fossil fuels in increasingly volatile market
- Reduced vulnerability of poor farmers through diversification

Shares of different fuels in the global energy mix over time



Sources: Grübler, 2004; IEA, 2011

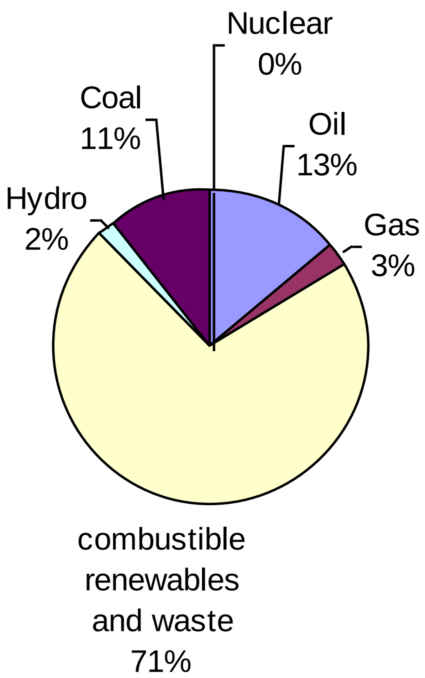
Total Primary Energy Supply (TPES) by fuel



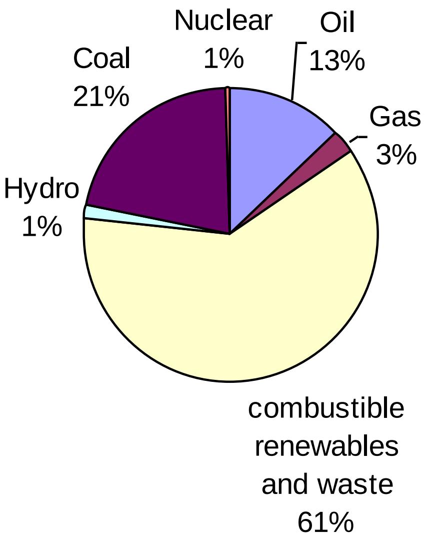
*World includes international aviation and international marine bunkers.
**In these graphs, peat and oil shale are aggregated with coal.
***Includes geothermal, solar, wind, heat, etc.

Sub-Saharan Africa energy consumption

Excluding South Africa

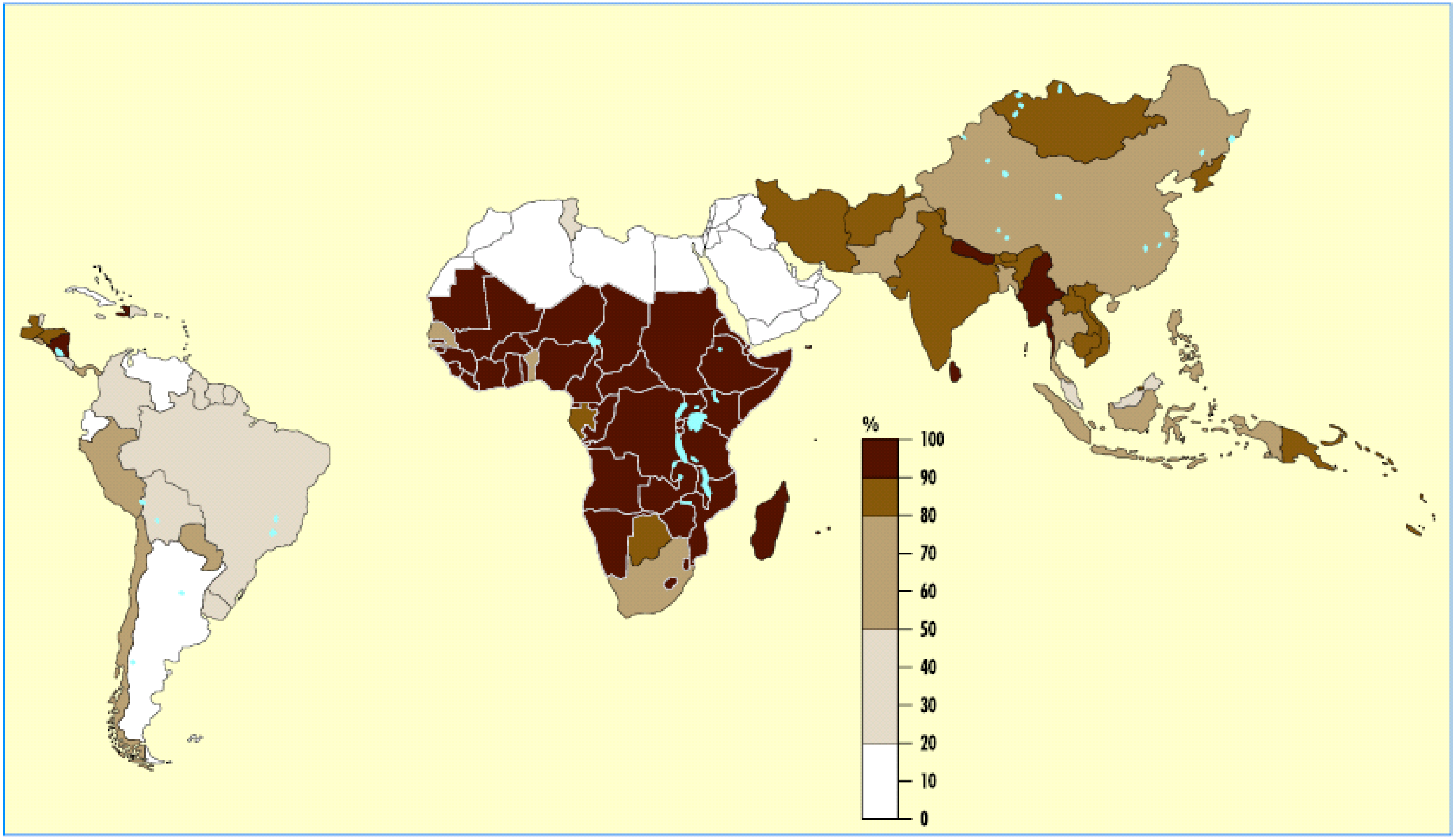


Including South Africa



Source: IEA and UNDP

Share of Traditional Biomass in Residential Consumption



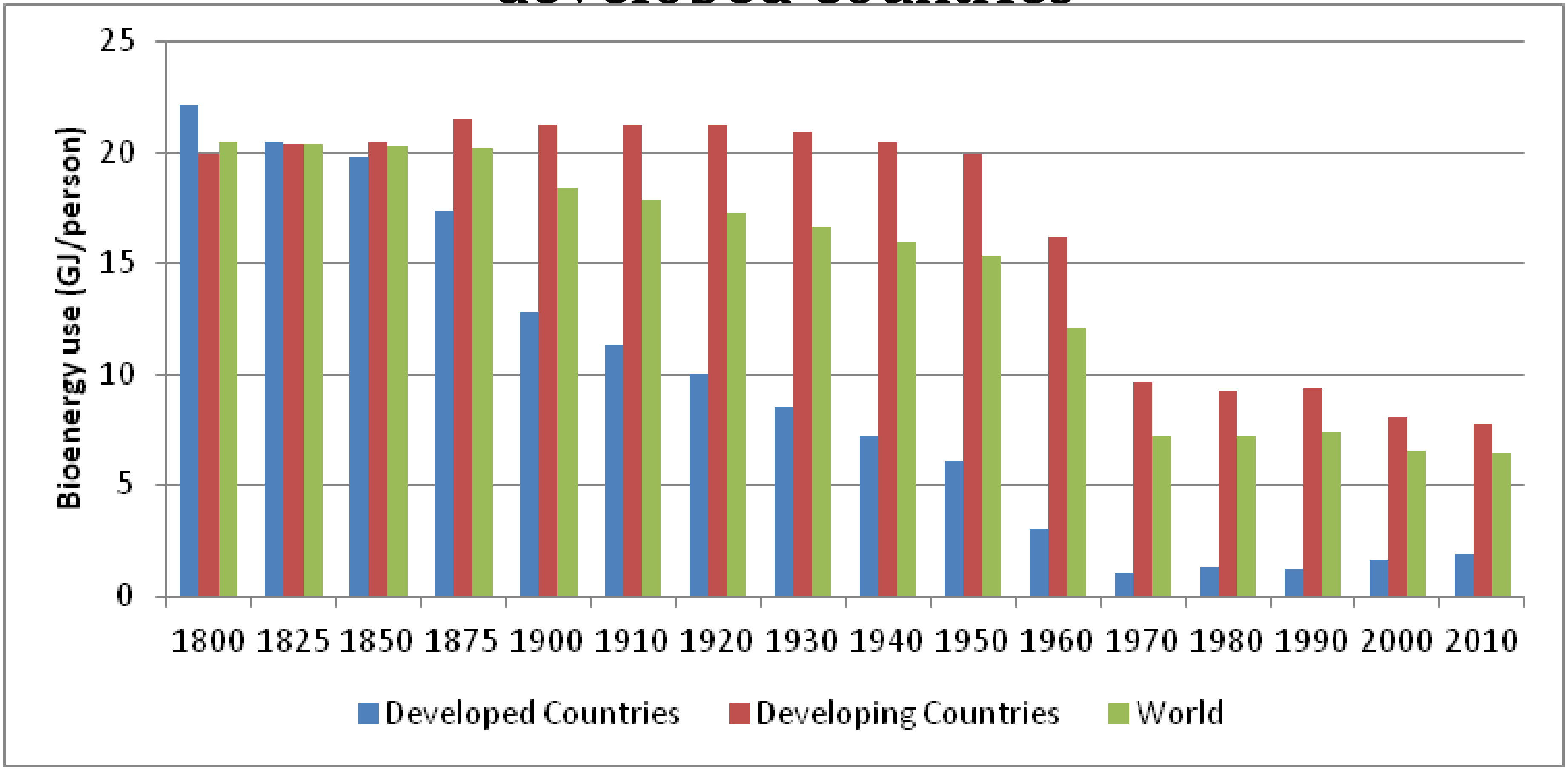
The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Source: IEA databases.

Source: IEA, World Energy Outlook

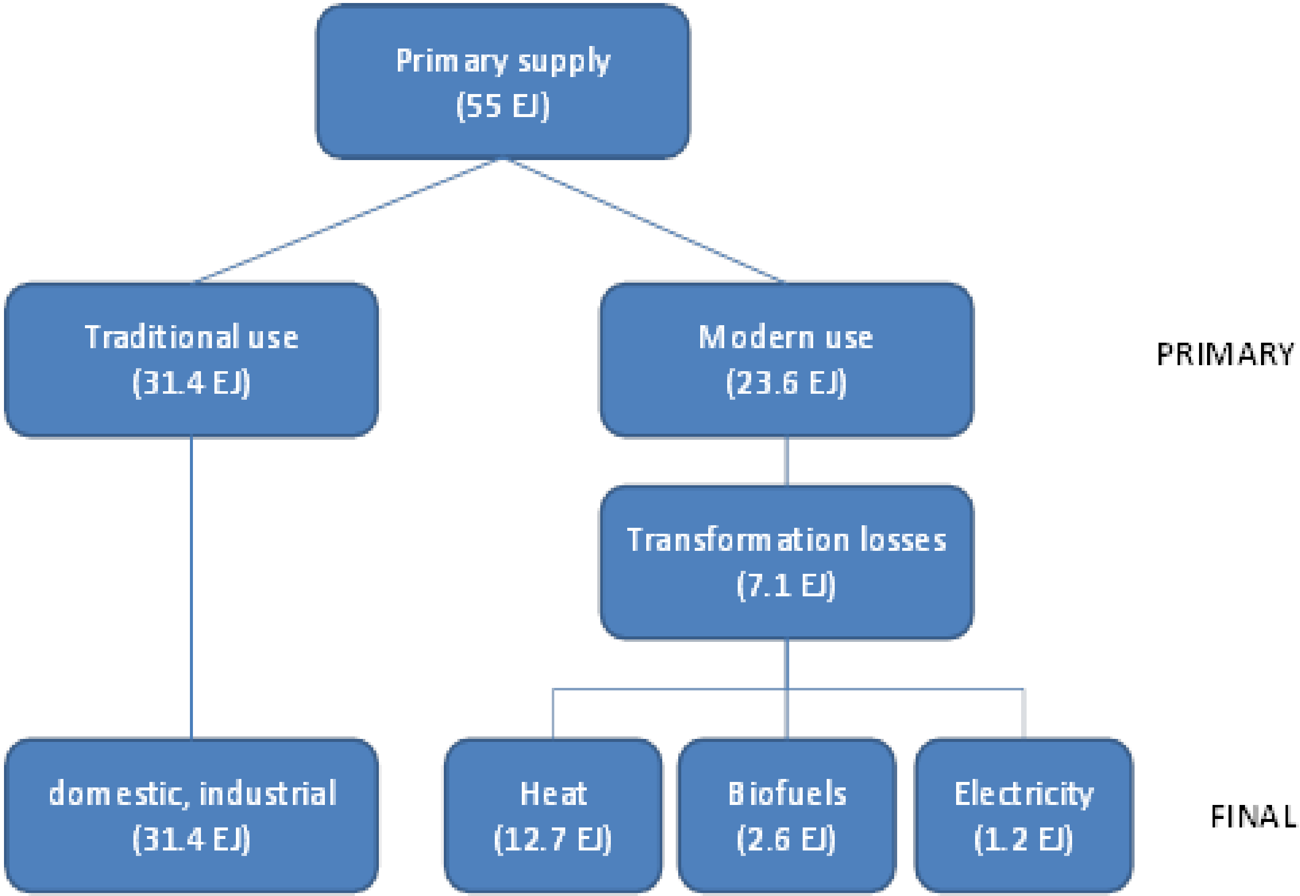
- *2.5 billion people depend on traditional biomass for cooking*

Per capita bioenergy use in developing and developed countries



Sources: Grubler (2004); IEA (2011)

Bioenergy for traditional and modern applications



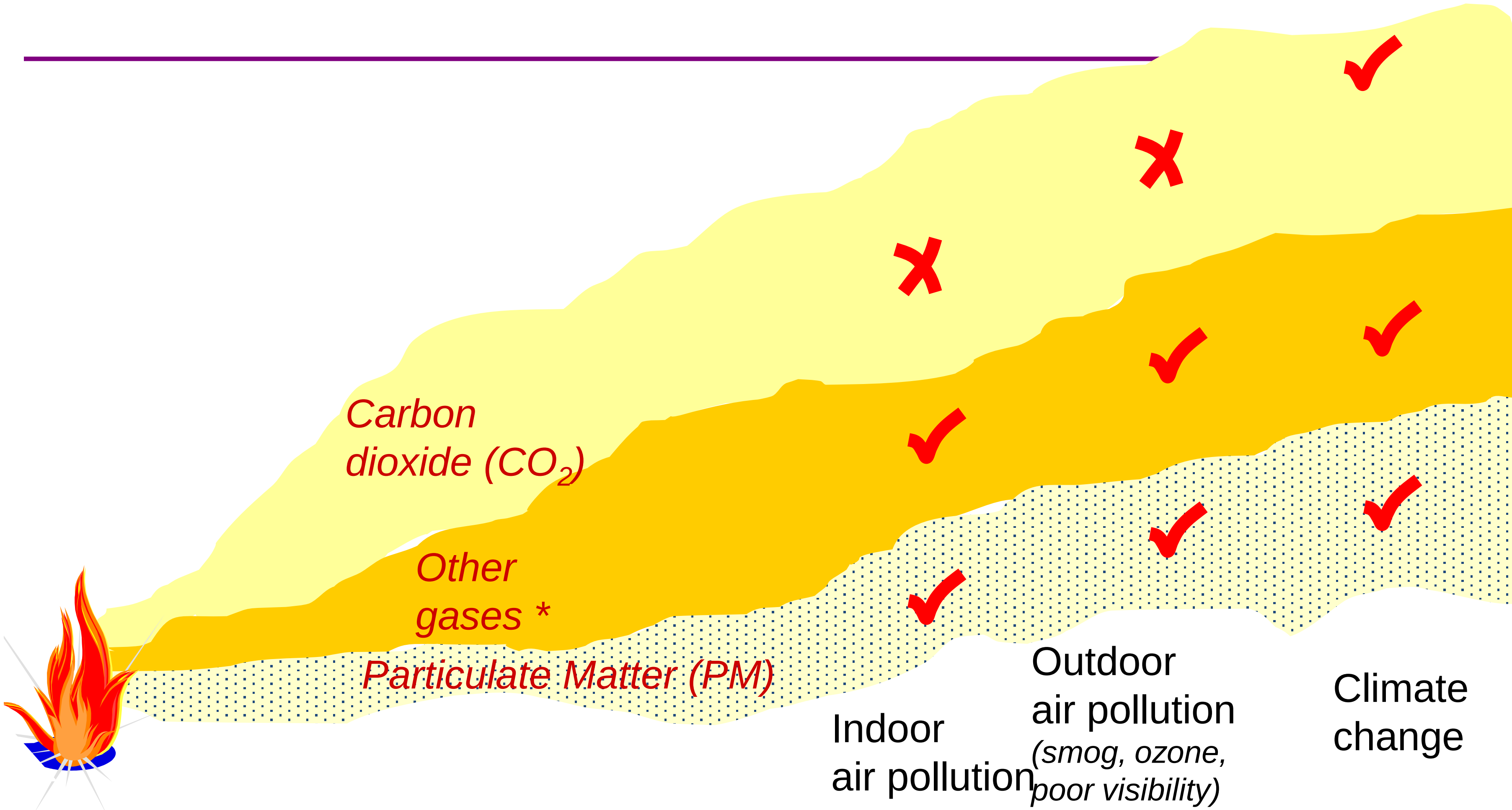
16.5 EJ = final use modern bioenergy

Source: Goldemberg, 2013

Socio-economic impacts and health impacts of traditional biomass

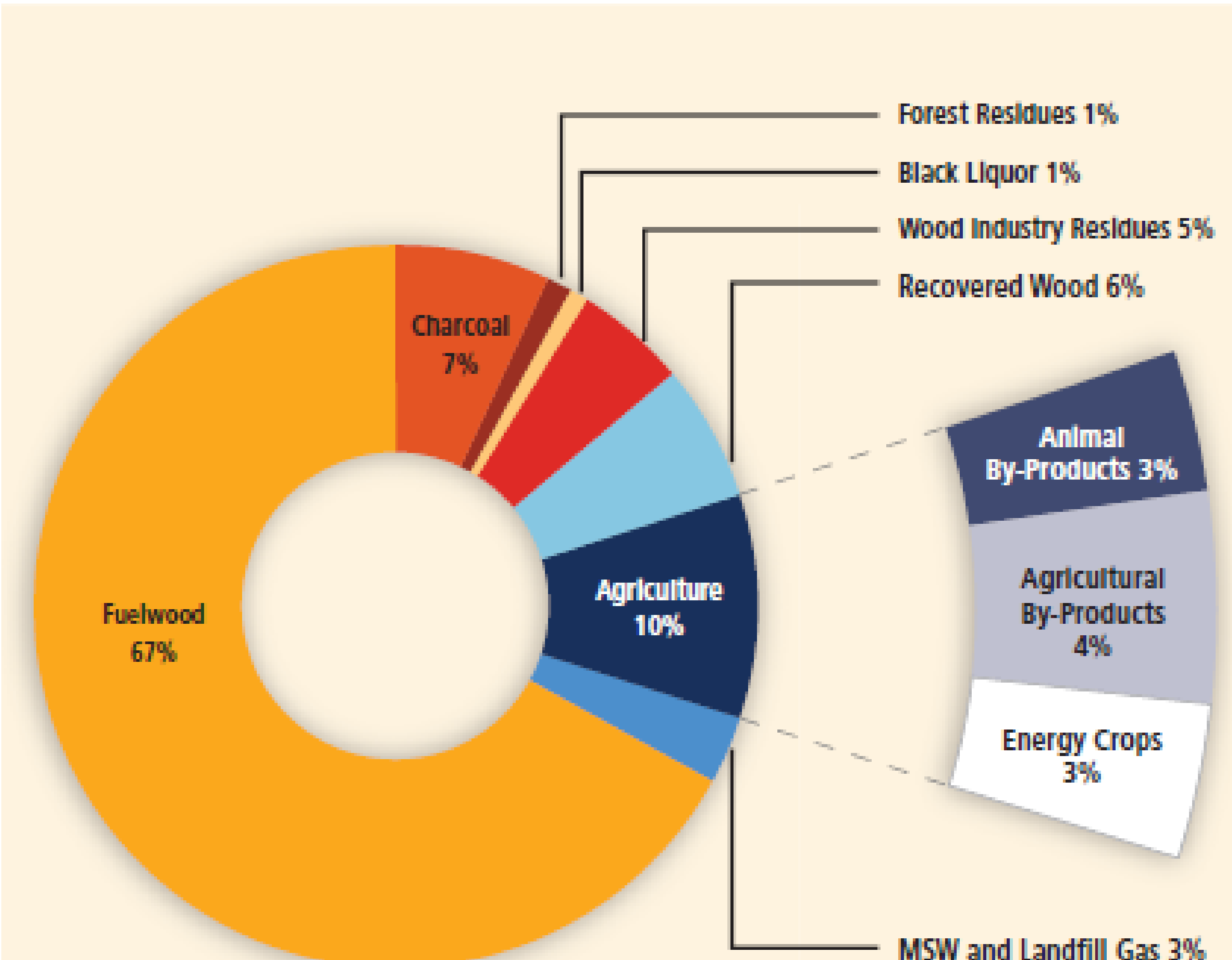
- Biomass for cooking contributes to Indoor air pollution (IAP), which contributes in some areas to more deaths annually than HIV or Malaria
- Deforestation and greenhouse gas (GHG) emissions
- Time cost and saefty risk for women and girls gathering fuelwood
- Low quality energy source compared to modern fuels
- Reliance on traditional biomass use as an energy-environment-development problem

Both the complete & incomplete combustion of biomass has health and environmental impacts



* Products of incomplete combustion (PICs):
Carbon monoxide (CO),
Methane (CH_4), Volatile organic compounds (VOCs)

Different forms of biomass energy



Covering a charcoal kiln

Charcoal bag distribution by truck
(note the driver having a nap underneath it)

Towards sustainable charcoal supply chains

Consumption

Wood production

Charcoal production

Transport

Wholesaling

Retailing

The Role of modern bioenergy

Modern bioenergy will play a leading role in the global transition to clean and sustainable energy due to two decisive advantages over other renewables:

(1) Biomass is stored energy. Like fossil fuels, it can be drawn on at any time, in sharp contrast to daily or seasonally intermittent solar, wind, and small hydro sources, whose contributions are all constrained by the high costs of energy storage.

(2) Biomass can produce all forms of energy, i.e. energy carriers, for modern economies: electricity, gas, liquid fuels, and heat. Solar, wind, wave and hydro are limited to electricity and in some cases heat.

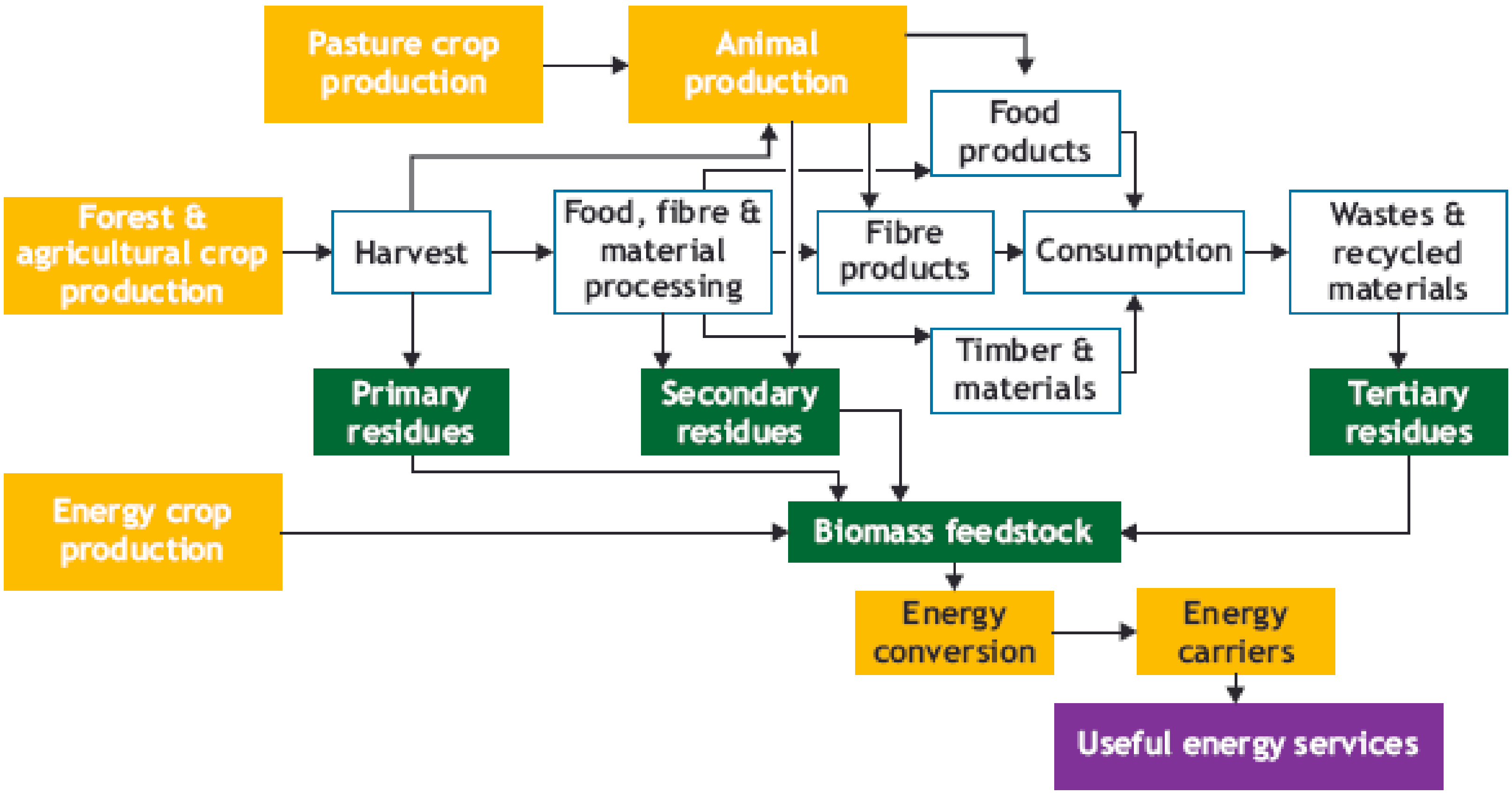
Modern bioenergy has several other advantages over other energy resources:

- provides rural jobs and income to people who grow or harvest the bioenergy resources; bioenergy is more labour-intensive than other energy resources;
- increases profitability in the agriculture, food-processing and forestry sectors. Biomass residues and wastes--often with substantial disposal costs--can instead be converted to energy for sale or for internal use to reduce energy bills;
- helps to restore degraded lands. Growing trees, shrubs or grasses can reverse damage to soils, with energy production and sales as a valuable bonus;

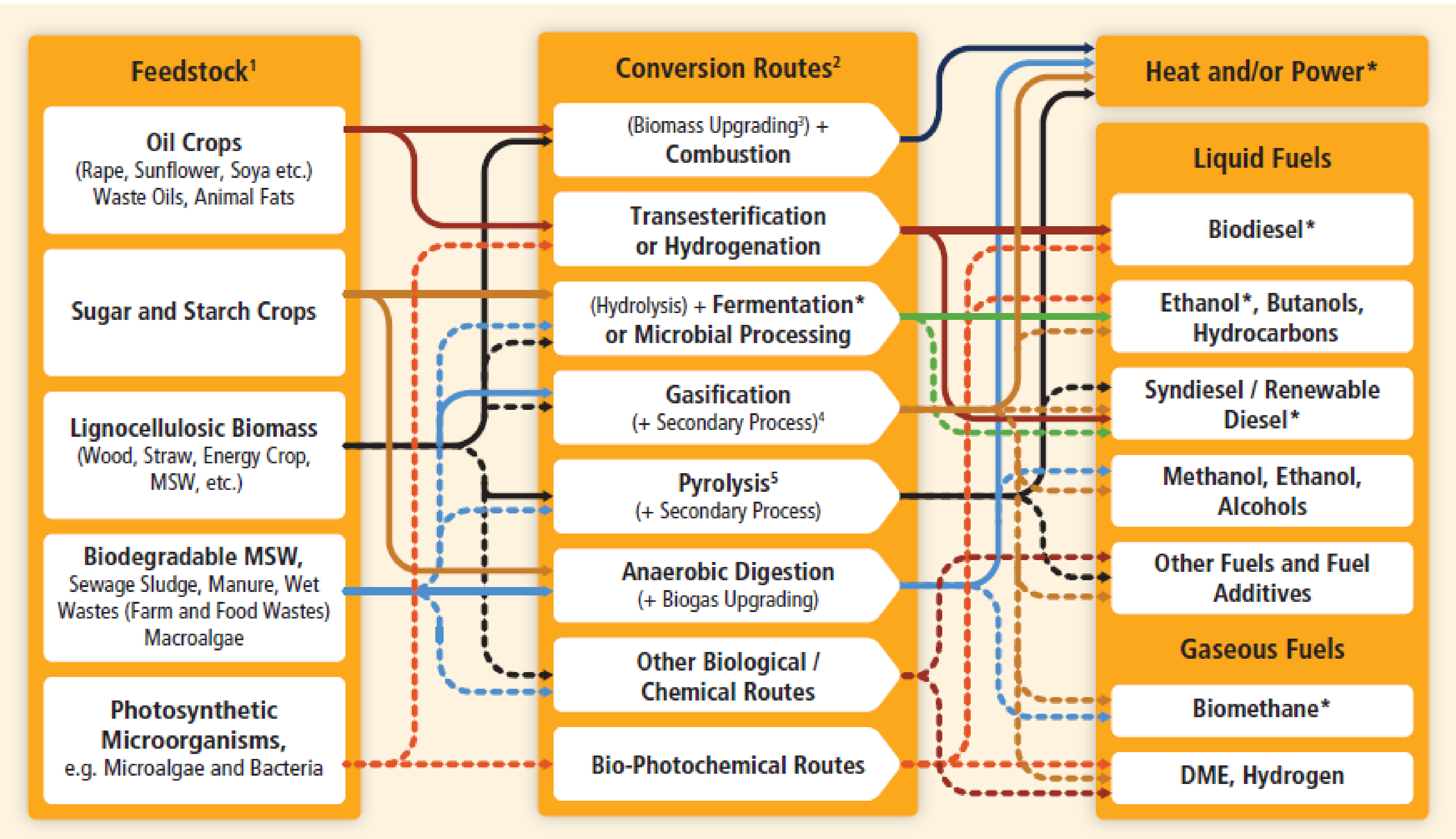
Different types and sources of biomass used for energy (yellow = agricultural)

Biomass type/source	**Woody biomass**	**Herbaceous biomass**	**Biomass from fruits or seeds**	**Others (including mixtures)**
Dedicated Feedstocks or extraction	Extraction from native forests, Forest plantations	Cereals (e.g. maize, wheat) Energy grasses (e.g. sugarcane, miscanthus)	Oilseed crops (e.g. jatropha, sunflower) Oil fruits (e.g. oil palm)	(mixed biomass sources can be used for some applications)
Residues (Direct)	Logging by-products Thinning by-products	Straw, Bagasse, husks	shells and husks, fruit bunches	Animal dung, Landscape management by-products
Residues (Indirect)	Sawmill wastes, Black liquor (from pulp/paper production)	Fibre crop processing wastes, Recycled fibre products	Food processing by-products Waste oils	Bio-sludge, Slaughterhouse by-products, Municipal solid waste (MSW)

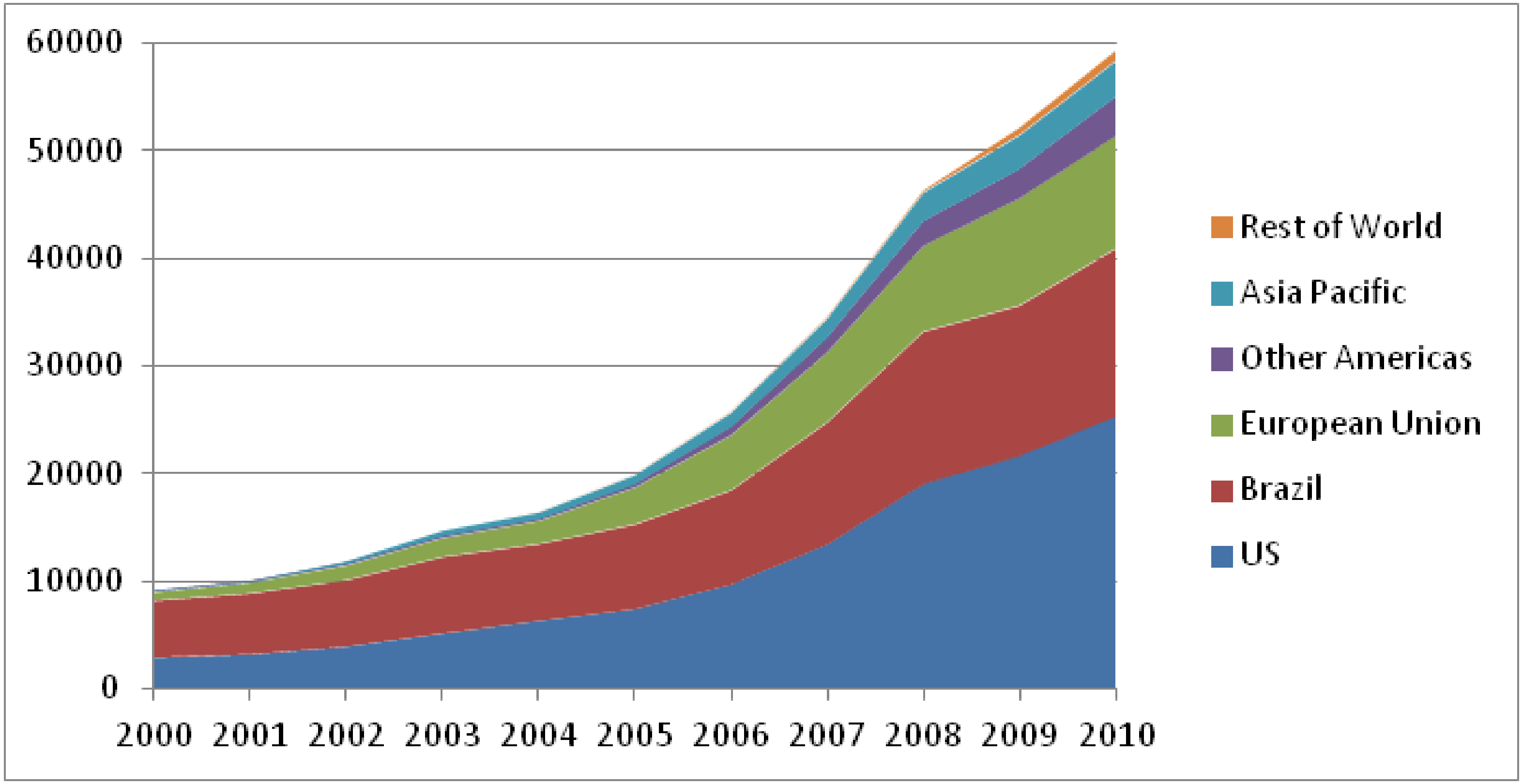
Biomass feedstocks arising from residues and energy crops



Schematic view of commercial (solid lines) and developing bioenergy routes (dotted lines) from biomass feedstock through therm-ochemical, chemical, biochemical and biological conversion routes to heat, power, CHP and liquid or gaseous fuels. Commercial products are marked with an asterisk (IPCC, 2014)



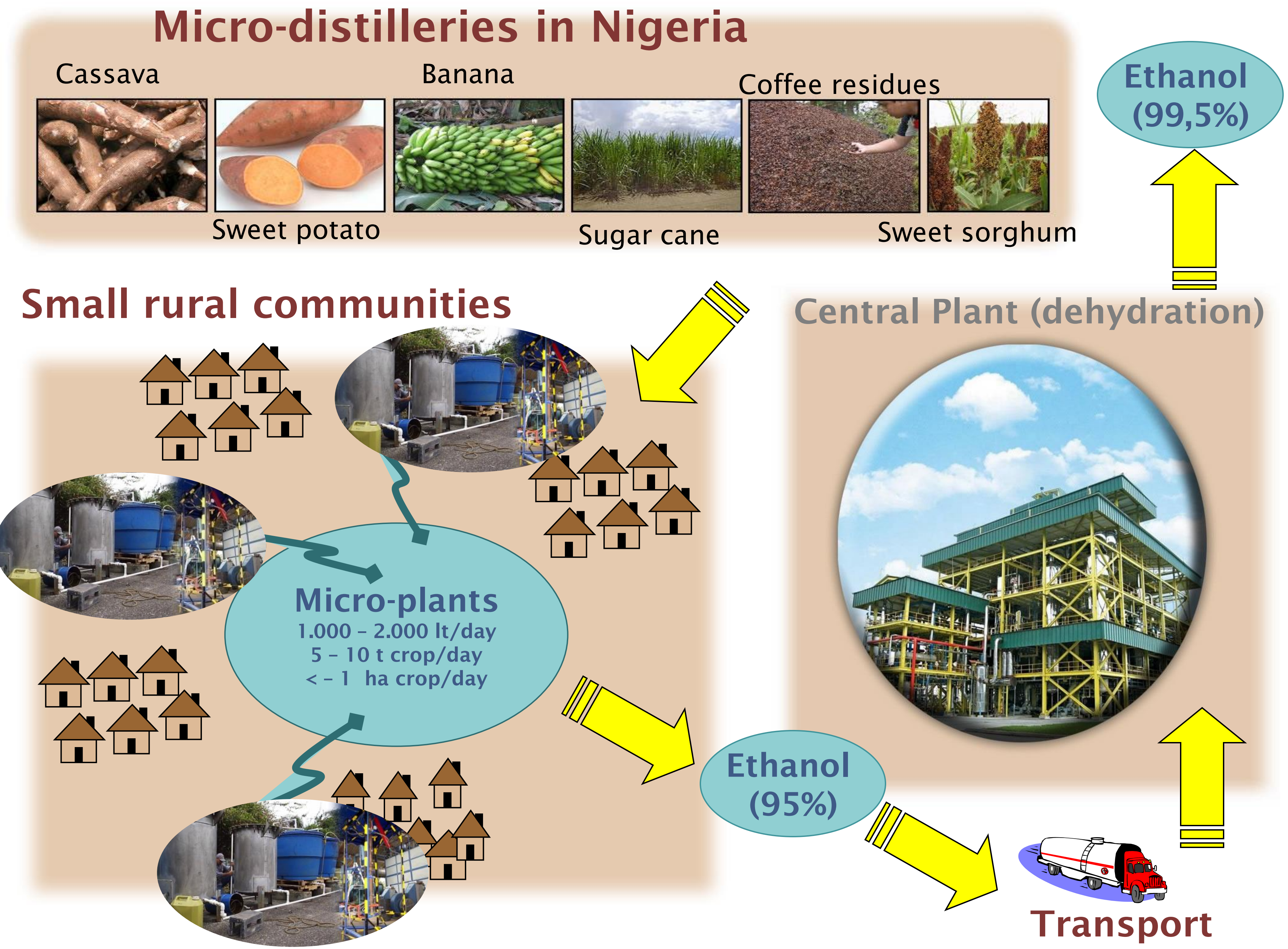
Recent development in biofuels markets (production)



Source: BP, 2011

Ethanol for cooking stoves

Charcoal stove (left) and Clean cooking stove (below) in Addis Ababa, Ethiopia (Photo: Gaia)


Micro-distilleries in Nigeria
Cassava
Sweet potato
Banana
Sugar cane
Coffee residues
Sweet sorghum
Ethanol (99,5%)
Small rural communities
Central Plant (dehydration)
Micro-plants
1.000 – 2.000 lt/day
5 – 10 t crop/day
< – 1 ha crop/day
Ethanol (95%)
Transport

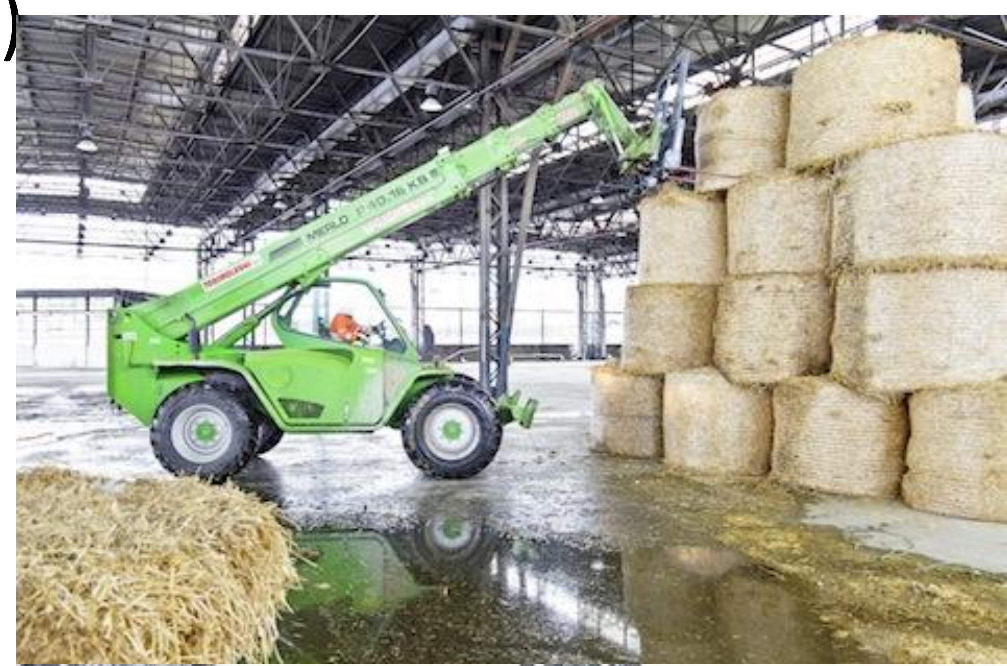
Characteristics of selected relevant agro-energy crops

	Latitude Range	Drought tolerance	Rainfall Requirement	Approximate biofuel yield (litres/ha)	GHG reduction (excludes land use change)	direct competition with food production	potential synergies with food production
Sugar crops							
Sugarcane	37°N – 31°S	poor	high	4000-8000	70-90%	minimal	some
Sweet Sorghum	adapted widely	excellent	low	3000-6000	50-80%	minimal	yes
Starch crops							
Cassava	30°N – 30°S	good	moderate	2000-3000	20-50%	yes	yes
Maize grain	adapted widely	poor-moderate	moderate	3000-5000	30-60%	yes	yes
Oil crops							
Jatropha	tropical	excellent	moderate	2000-3000	40-60%	no	some
Oil palm	10°N – 10°S	poor-moderate	very high	3000-7000	35-70%	yes	some
Soya bean	adapted widely	poor-moderate	moderate	400-1000	25-50%	yes	yes
Lignocellulosic (Second Generation)							
Maize cellulosic	adapted widely	poor-moderate	moderate	5000-8000	80-110%	minimal	yes
Eucalyptus	adapted widely	good	moderate	6000-18000	90-110%	no	no
Switchgrass	adapted widely	good	moderate	4000-10000	80-100%	no	no
Miscanthus	adapted widely	good	moderate	5000-15000	90-110%	no	no

Sources: Heaton et al, 2008; El Bassam, 2010; deVries, 2010; BEFS, 2010; Hoefnagels et al, 2010; Chum et al, 2011.

Crescentino, Italy: Second Generation (lignocellulosic ethanol plant (2G ethanol)

- Capacity: 75 million litres/year
- Beta Renewables + Novozymes
- Lower capital due to less biomass handling, simplified flows, no special equipment;
- fermentable sugars: ~22 ¢/kg;
- Cost of ethanol <$ 0.40/L;
- Cost-effective at modest scale;
- short supply chains;
- Feedstock-independent: agro-wastes, arundo donax, other
- Deployable worldwide;
- Pure lignin by-product provides power for plant;

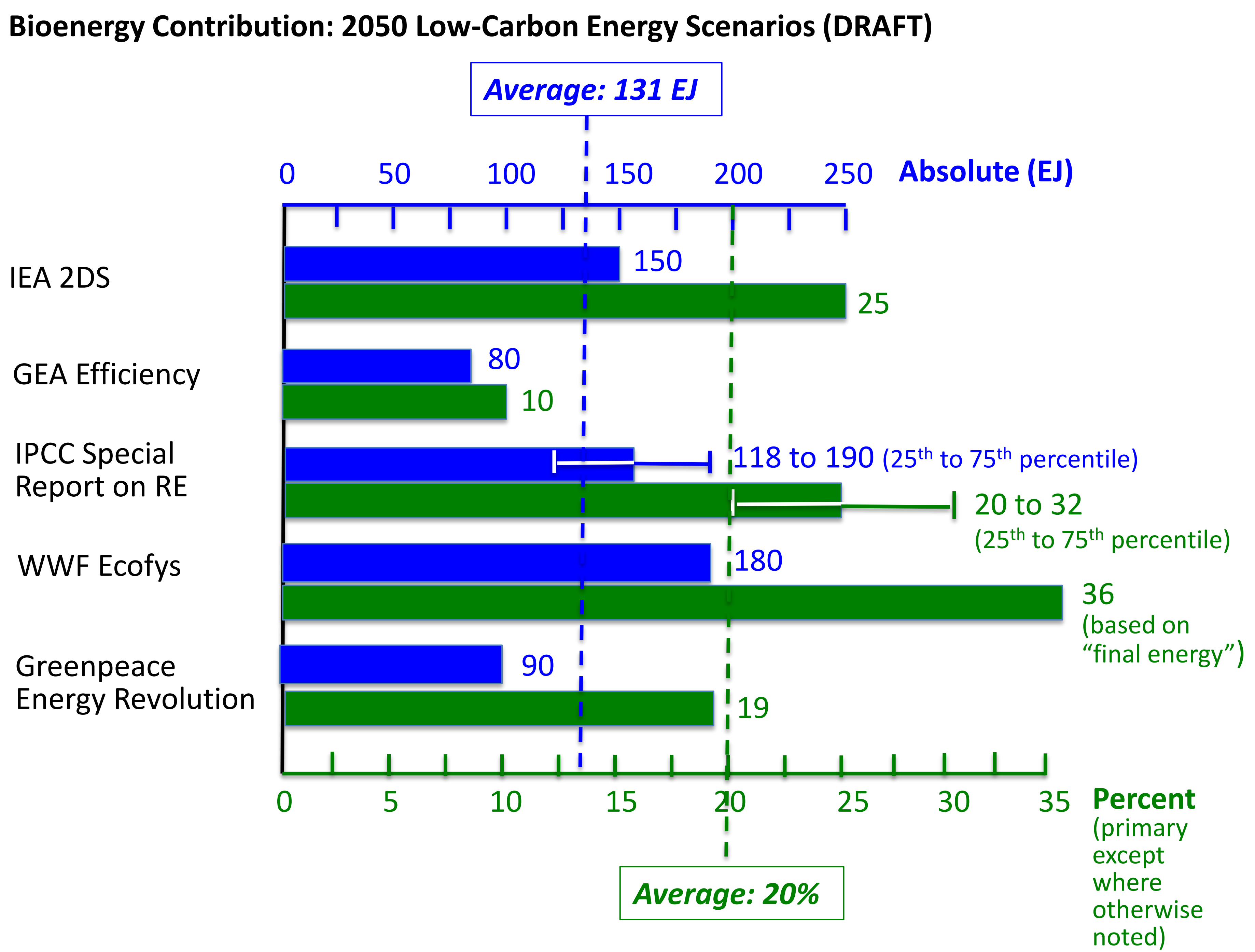


The Future Bio-economy

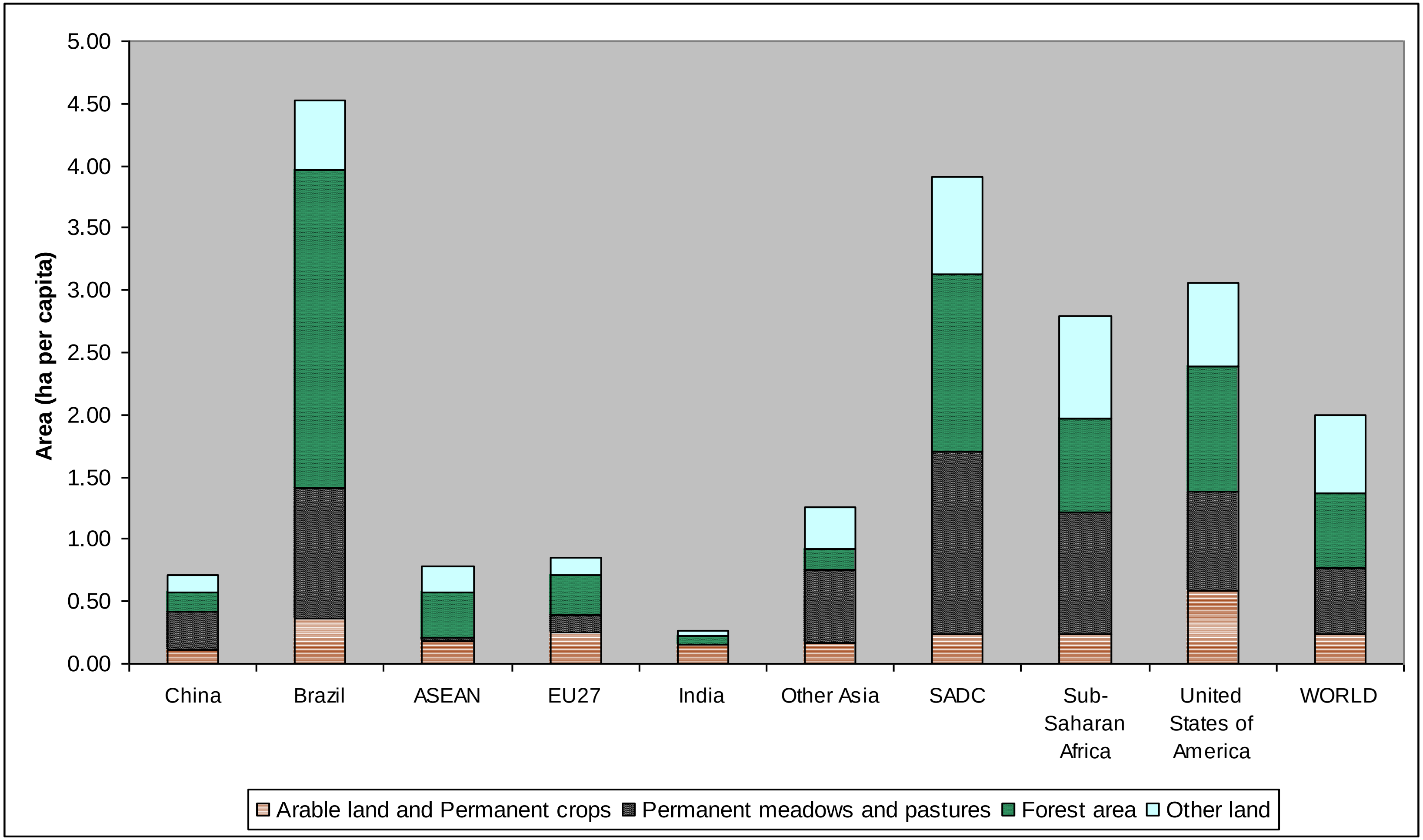
Moving the Factory into the Fields

Estimates/assumptions for physical bioenergy potential in 2050

	Hoogwijk et al (2005)	**Smeets et al (2007)**	**WBGU (2009)**	**Haberl et al (2009)**	**Van Vuuren (2010)**	**Beringer et al (2011)**
Potential of Residues and Wastes		50-100 EJ	50 EJ	119-135 EJ	80 EJ	100 EJ
Potential from dedicated bioenergy systems	311-657	215-1272	34-120 EJ	160-270 EJ	65-300 EJ	26-174 EJ
Share of IEA (2010) forecast total energy	30% - 65%	25% - 130%	8% - 17%	27% - 40%	14% - 38%	13% - 27%
Key land use assumptions	Use of abandoned agricultural lands	Significant improvements in yields and reductions in pasturelands	Competition with land for food and feed; water scarcity; weak institutions	Ecological constraints	Competition for land	Modest yield improvements; impacts of climate change and water scarcity

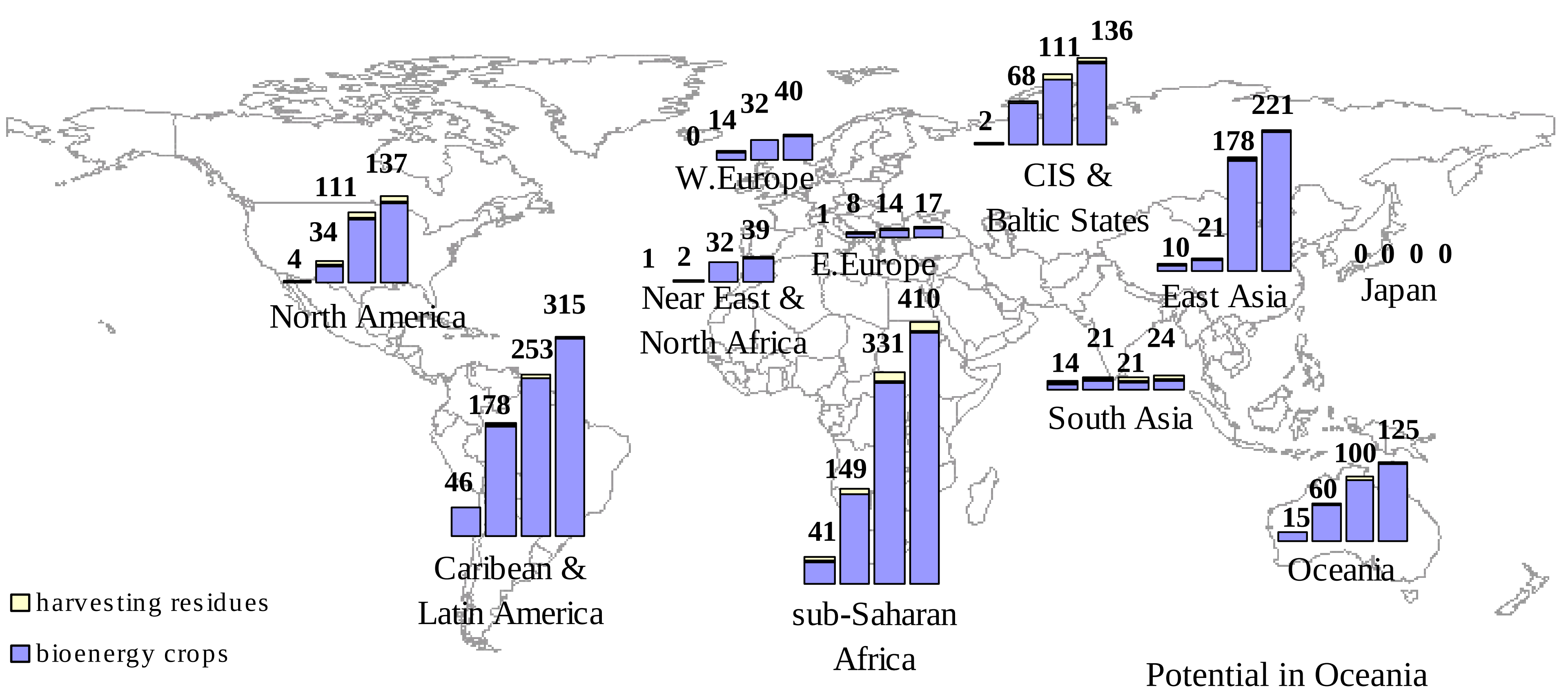

Bioenergy Contribution: 2050 Low-Carbon Energy Scenarios (DRAFT)
Average: 131 EJ
0
50
100
150
200
250
Absolute (EJ)
IEA 2DS
150
25
GEA Efficiency
80
10
IPCC Special Report on RE
118 to 190 (25th to 75th percentile)
20 to 32 (25th to 75th percentile)
WWF Ecofys
180
36 (based on "final energy")
Greenpeace Energy Revolution
90
19
0
5
10
15
20
25
30
35
Percent (primary except where otherwise noted)
Average: 20%

Land area per capita by type and major countries or regions



Source: FAOSTAT, 2008

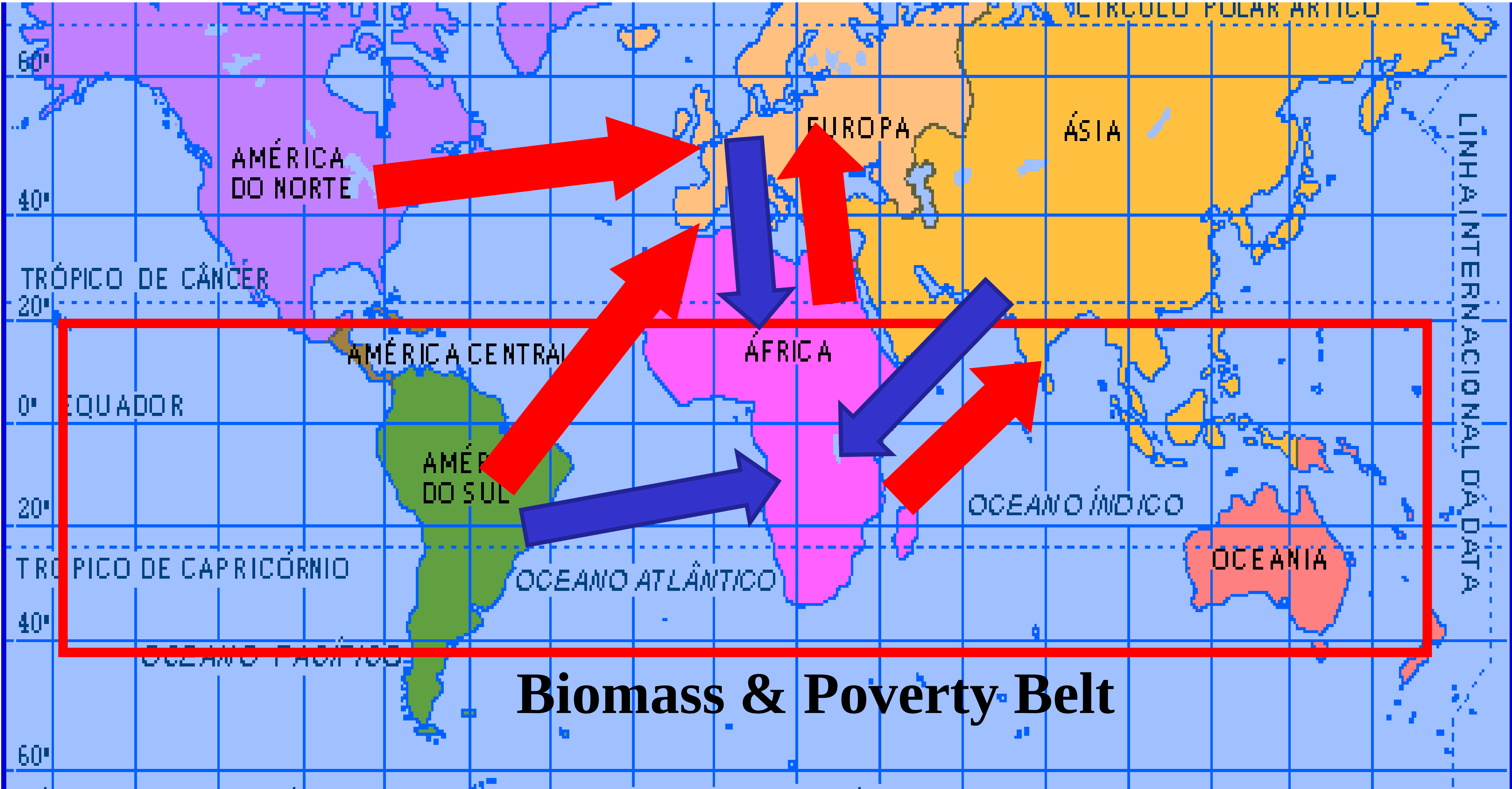
Bio-energy production potential in 2050 for different scenarios



Potential in Oceania is 4-6 times projected primary energy use

Source: E. Smeets, A. Faaij, I. Lewandowski – March 2004
A quickscan of global bio-energy potentials to 2050: analysis of the regional availability of biomass resources for export in relation to underlying factors, Copernicus Institute - Utrecht University, NWS-E-2004-109.

Potential market context for bioenergy and development: flow of bioenergy commodities, technology transfer, investment

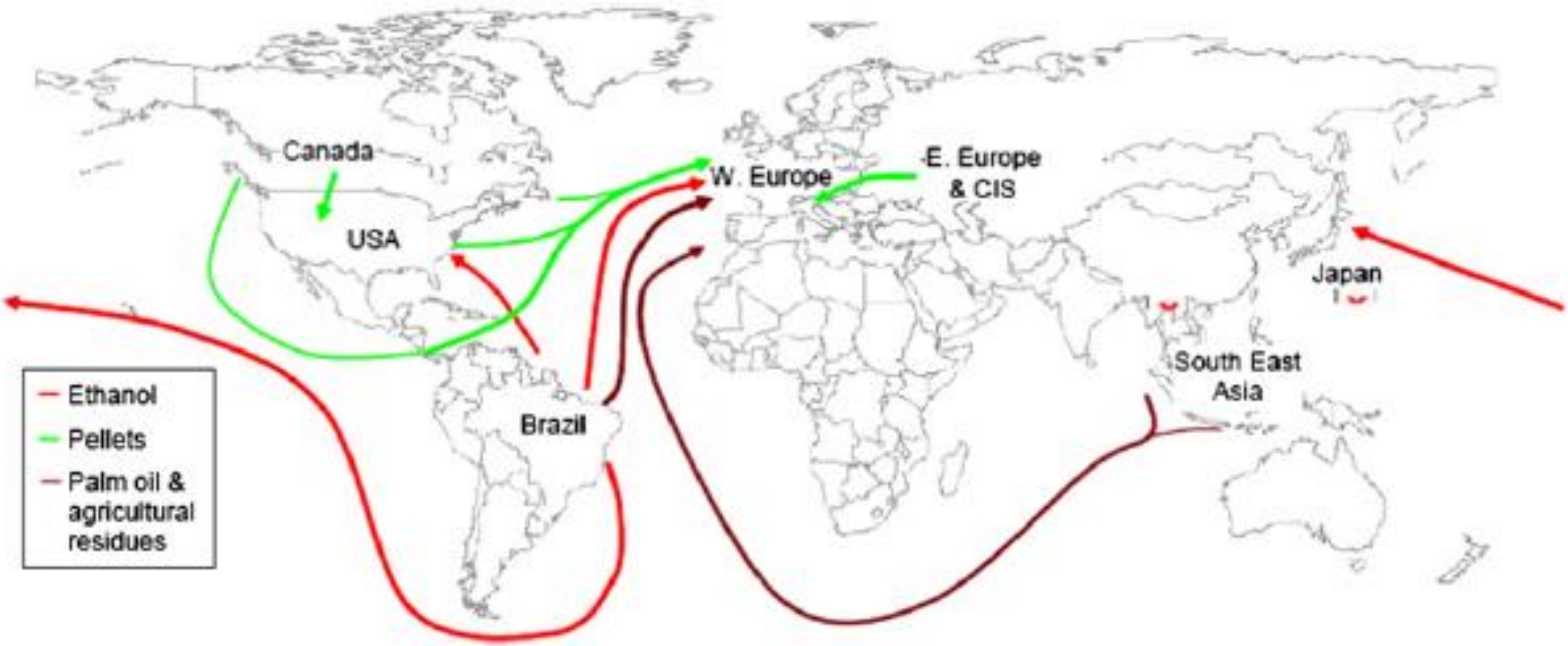


RED ARROW = biomass/bioenergy flow

BLUE ARROW = technology and investment flow

International Trade in key bioenergy products: Africa has largely been bypassed thus far

**TRADE creates new investment opportunities that cannot be obtained through AID



Source: Hoffman et al, 2013

Towards a Green Economy – job creation

Energy source	***Jobs per TWh output***
Nuclear	75
Small hydro	120
Natural gas	250
Big hydro	250
Oil	260
Oil offshore	265
Coal	370
Traditional biomass (wood)	733 - 1.067
Wind	918 - 2.400
Ethanol (in Brazil)	3.711 - 5.392
Solar	2.958 – 10.700

Source: Delcio, 2007

Bioenergy Development Options - Scale matters

Large Scale

1. Sugarcane to EtOH
2. Palm / Soy Biodiesel

Mill-owned estate

Very competitive globally

Lower Value Added to Local Communities
*lowest risk

Export potential

Small-holder led

Higher cost base
Less globally competitive

Higher Value Added to Local Communities
*moderate risk

Export potential

Small Scale

1. Sweet Sorghum – micro-distillery
2. Woodlot gasification elec.

Multi-product or multi-crop

e.g. sweet sorghum

Economics Uncertain

Complex-Value Added to Local Communities
*high risk

Local Markets
Social Issues
Crop not well characterised

Single Bioenergy Product

e.g. multi-species woodlot

Value Added to Local Communities
*high risk

Complex food-fuel-cash-crop interactions

SOURCE: Woods, J. Foucs 14: IFPRI, 2006

Palm oil in Indonesia: small-scale ownership, large-scale production (refining)

Jatropha plants/shoots in Zambia

Jatropha production: small-scale options

Eucalyptus plantation in Brazil

Harvesting of eucalyptus trees for wood products (~85%) and energy (~15%)

Sugar Cane: large-scale monocrop system

Semi-mechanical Sugar Cane Harvesting

Burning prior to harvest still common in Africa (to remove pests and extraneous matter)

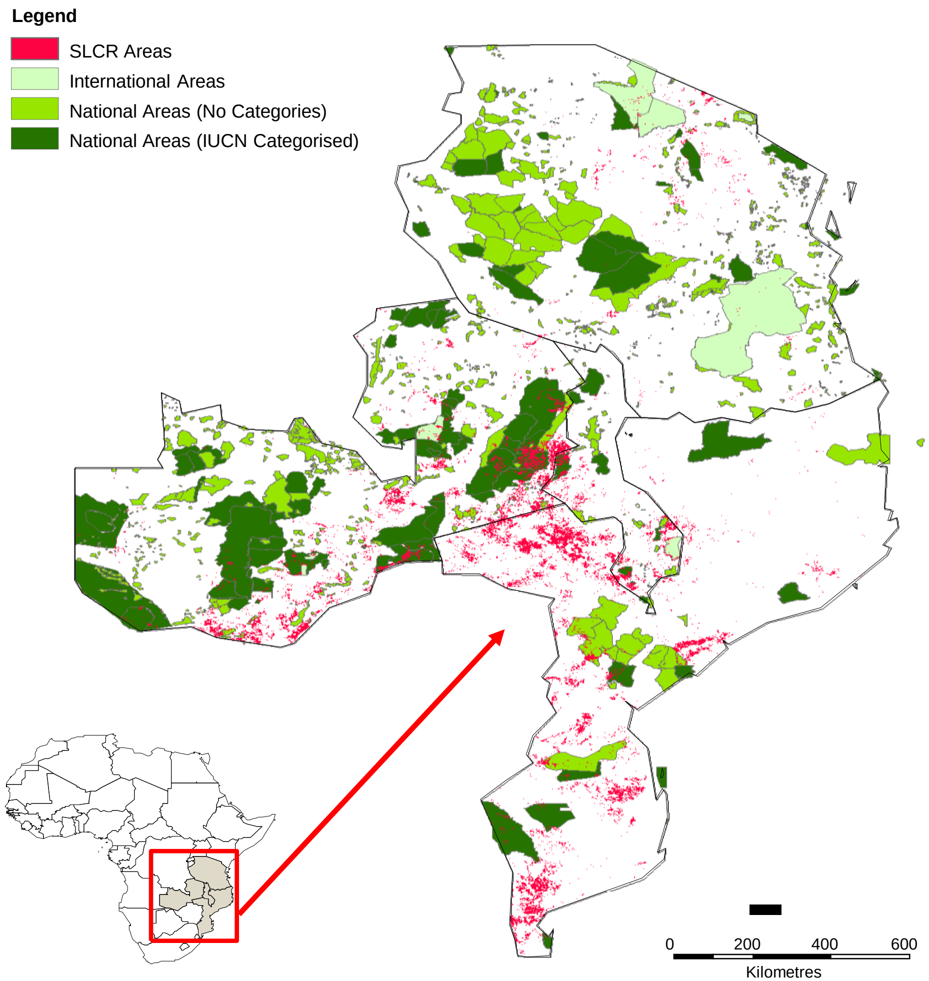
Up in smoke: more than 50% of the available biomass energy is lost when sugarcane is burned before harvesting

(More than 90% of sugarcane is burned before harvest in Africa)

Assessing Land Suitability for specific energy crops: an example for sugarcane in 4 African countries

	Malawi	Mozambique	Tanzania	Zambia	Total
Estimated suitable/available land (1000 ha)	206	2338	124	1178	3856
Estimated suitable/available land (%)	2.2	3.0	0.2	1.6	1.5
Ratio of maximum to current production	10	585	5	69	61

- Potential small, medium and large scale areas (rain fed & irrigated) suitable and available for sugarcane in **Malawi, Mozambique, Tanzania, and Zambia**



Source: UKwZN 2007, South Africa

rapid growth of sweet sorghum (3-4 months)

Envars önskevagn

MORRIS 1936

å den svenska marknaden.

PRIS FRÅN KR. 2995:—

MORRIS

En brittisk kvalitetsprodukt

42

Stilfullt utförande, komfortabel inredning, rymlig och bekväm • Hydrauliska bromsar, synkroniserad växellåda, 5,25—16" ringar • Bensinförbrukning endast ? liter pr mil — skatt kronor 60:— pr år.

En vagn som i allt är en stor vagn utom i priset

Begär katalog över 1936 års modeller

FÖRENADE BIL AKTIEBOLAGET

MALMÖ	GÖTEBORG
Ö. Tullgatan 6. Tel. 280 43.	St. Badhusgatan 18. Tel. 205 13.

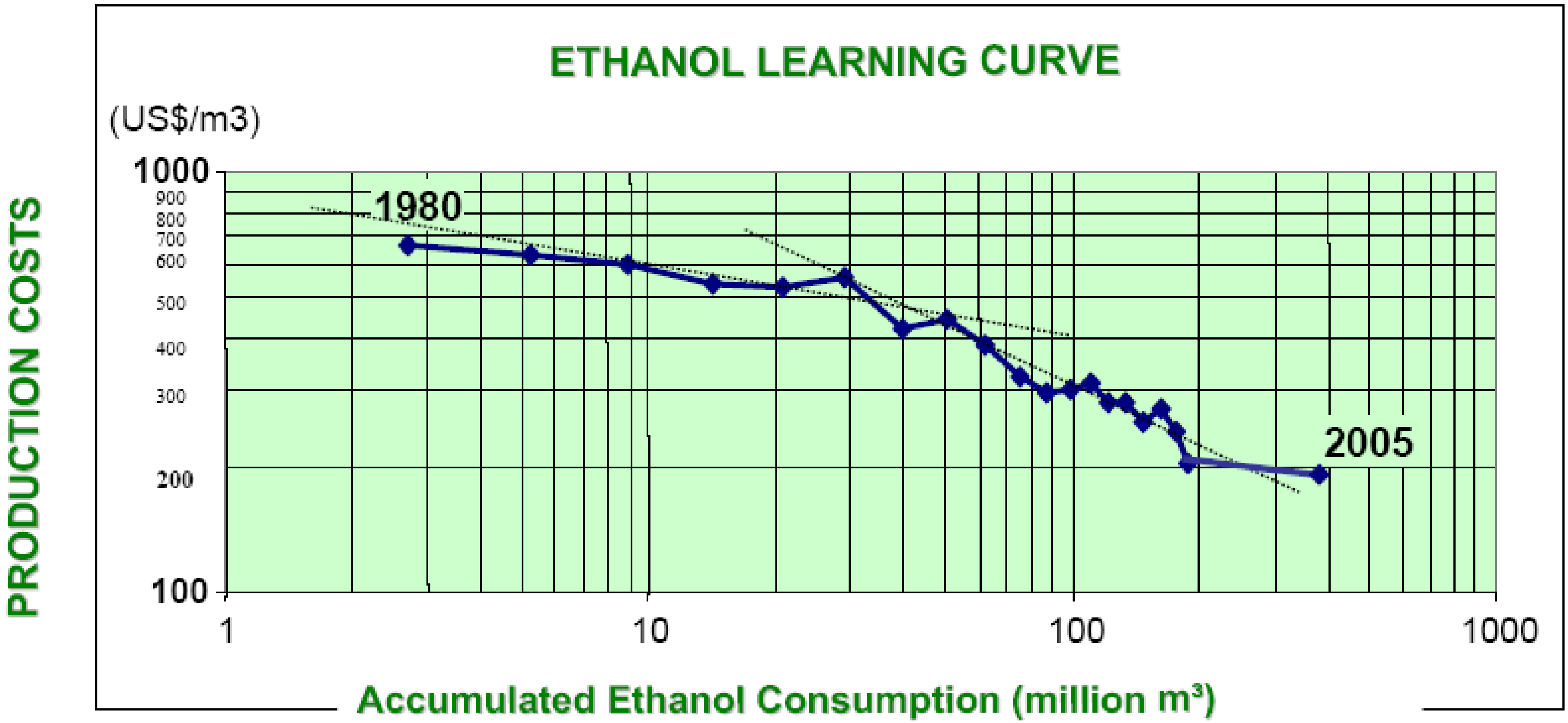
Återförsäljare antagas å de platser, där vi icke tidigare äro representerade.

Average fuel consumption new Swedish cars 2010: 8.3 l/100km

Average fuel consumption new EU cars 2010: 6.5 l/100km

1925: first tests with alcohol in engines in Brazil

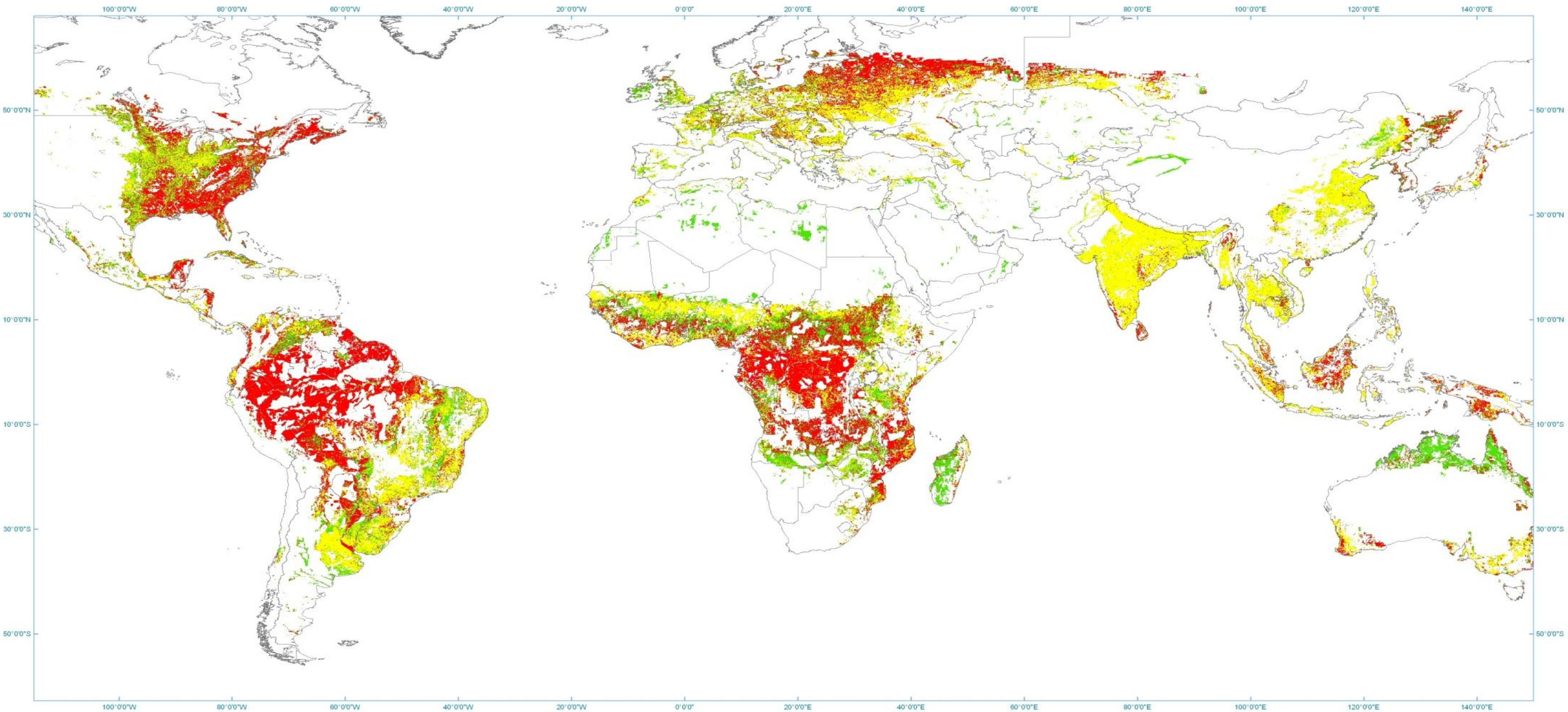
Ethanol Production Cost Reductions over time in Brazil



SOURCE: COPERSUCAR – MME - 2005

Price of ethanol (alcool) and blended petrol (gasolina) in Sao Paulo, Brazil

Competition over land



Legend

- Unsuitable or otherwise Unavailable
- Suitable Land under Forest Cover
- Suitable Land under Agriculture
- 'Available'

0 750 1,500 3,000 4,500 6,000 km

1:29,000,000

Source:
Crop Suitability Data derived from IIASA (2002)
Land Cover Data derived from ESA (2006)
Protected Area Data derived from WDPA (2009)

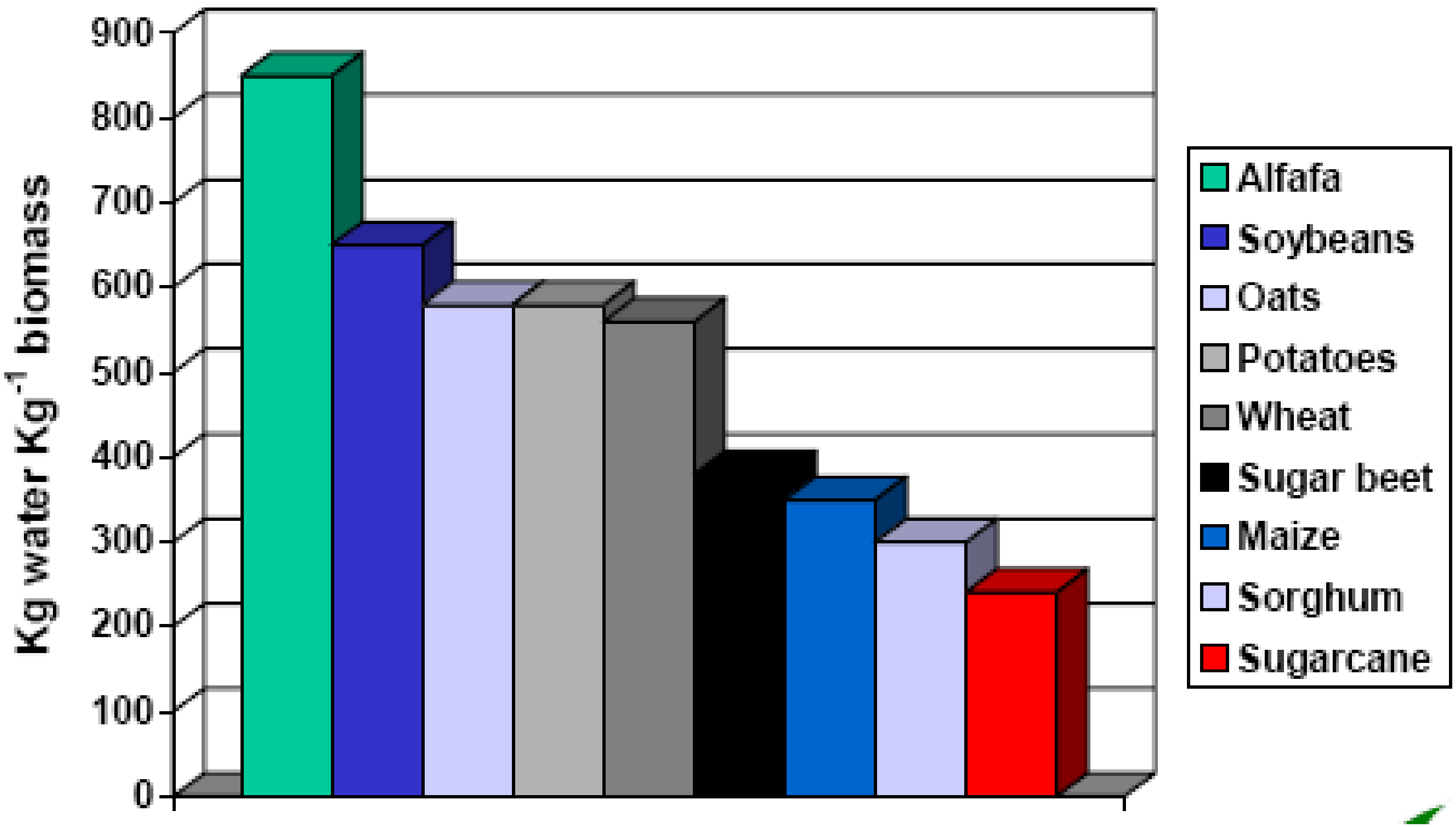
Note:
* Biofuel feedstock considered in this analysis are sugarcane, maize, sugarbeet, oil palm, soybean, rapeseed, and sunflower
* Feedstock considered suitable when moderate to very high yields are attainable (suitability index (SI) > 25), under high input and under irrigated and rain-fed conditions
* Land considered 'otherwise unavailable' includes land with a protected status and artificial areas.

land currently available and suitable for biofuels is constrained by low efficiency of agriculture in some world regions

Most severe land use competition is in Asia due to high population density

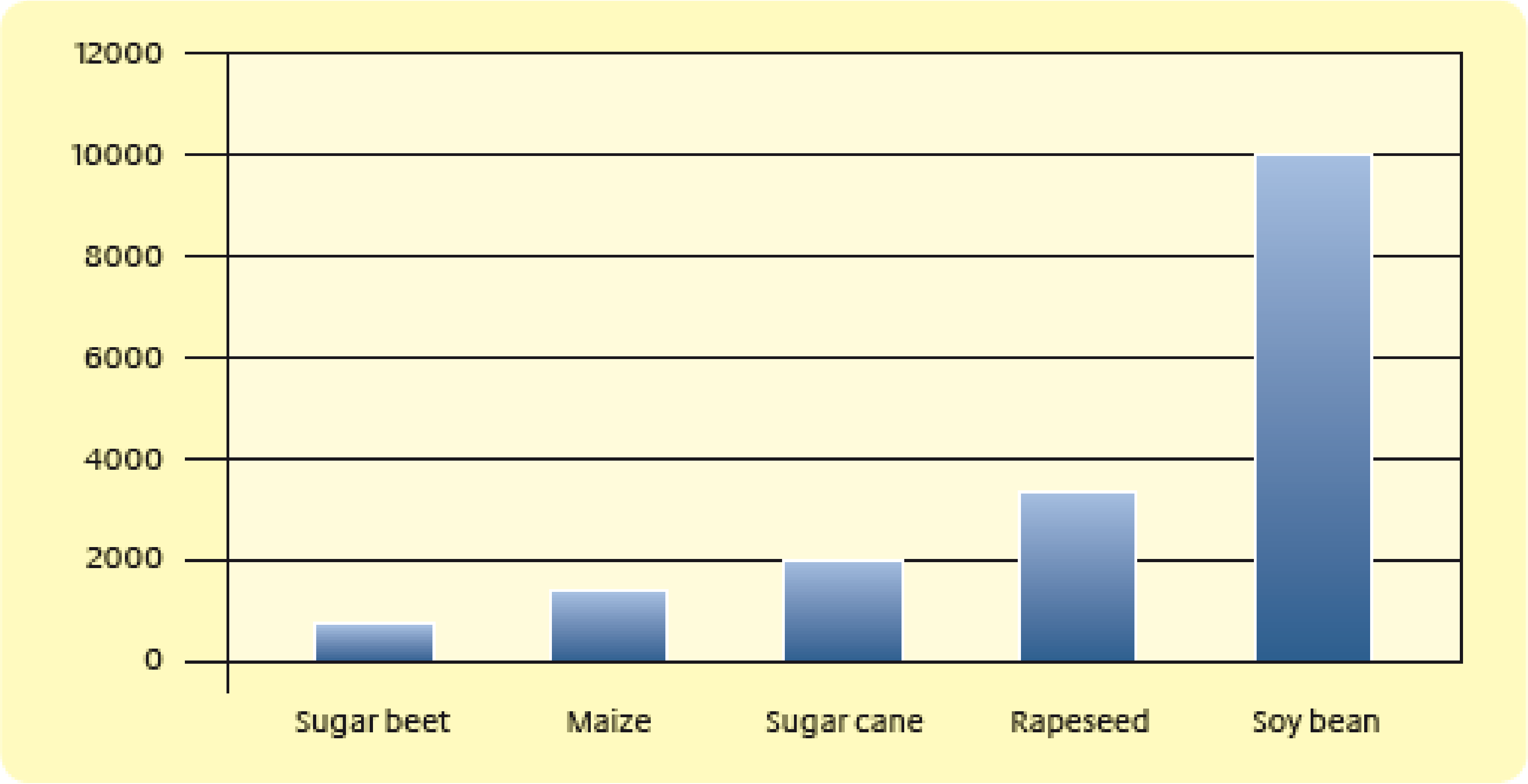
Intensity of agricultural cultivation remains low in most world regions

Water Use per unit biomass



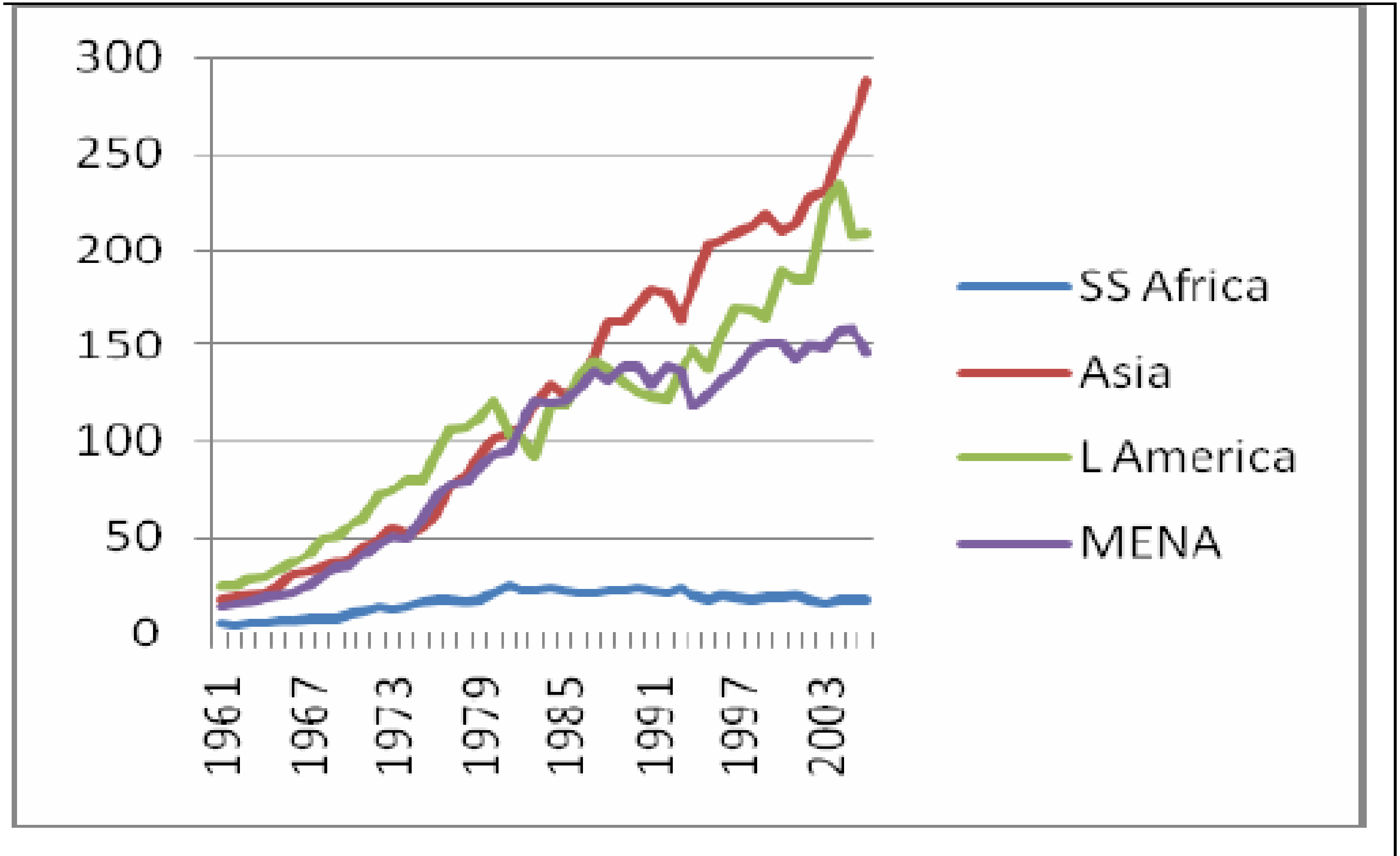
Source: SASRI, 2007

Water use intensity of selected biofuels (litres of water evaporated per litre of biofuel produced)

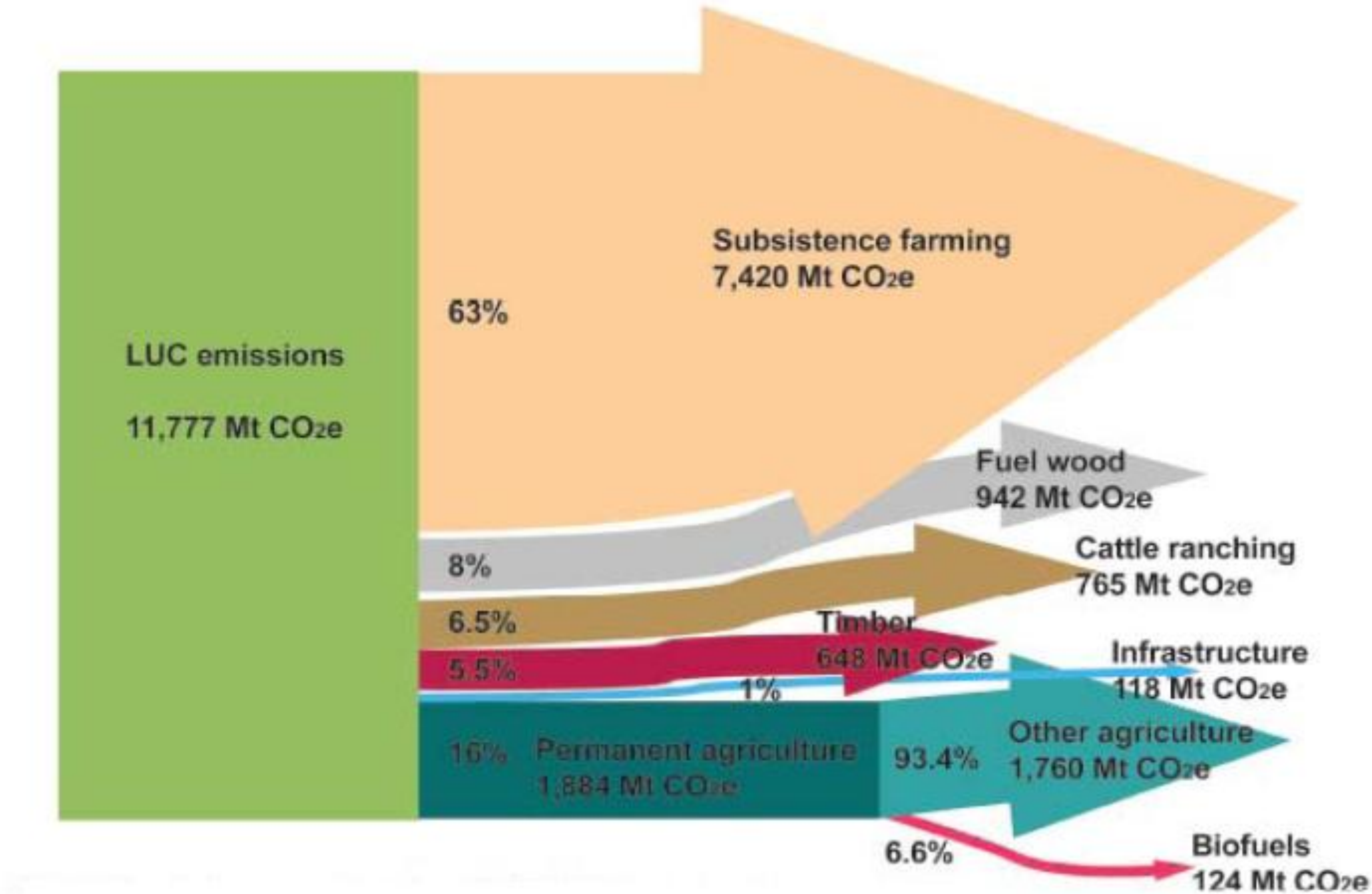


Source: Hoogeveen et al. (2009)

Fertiliser use: kg/ha (equivalence)

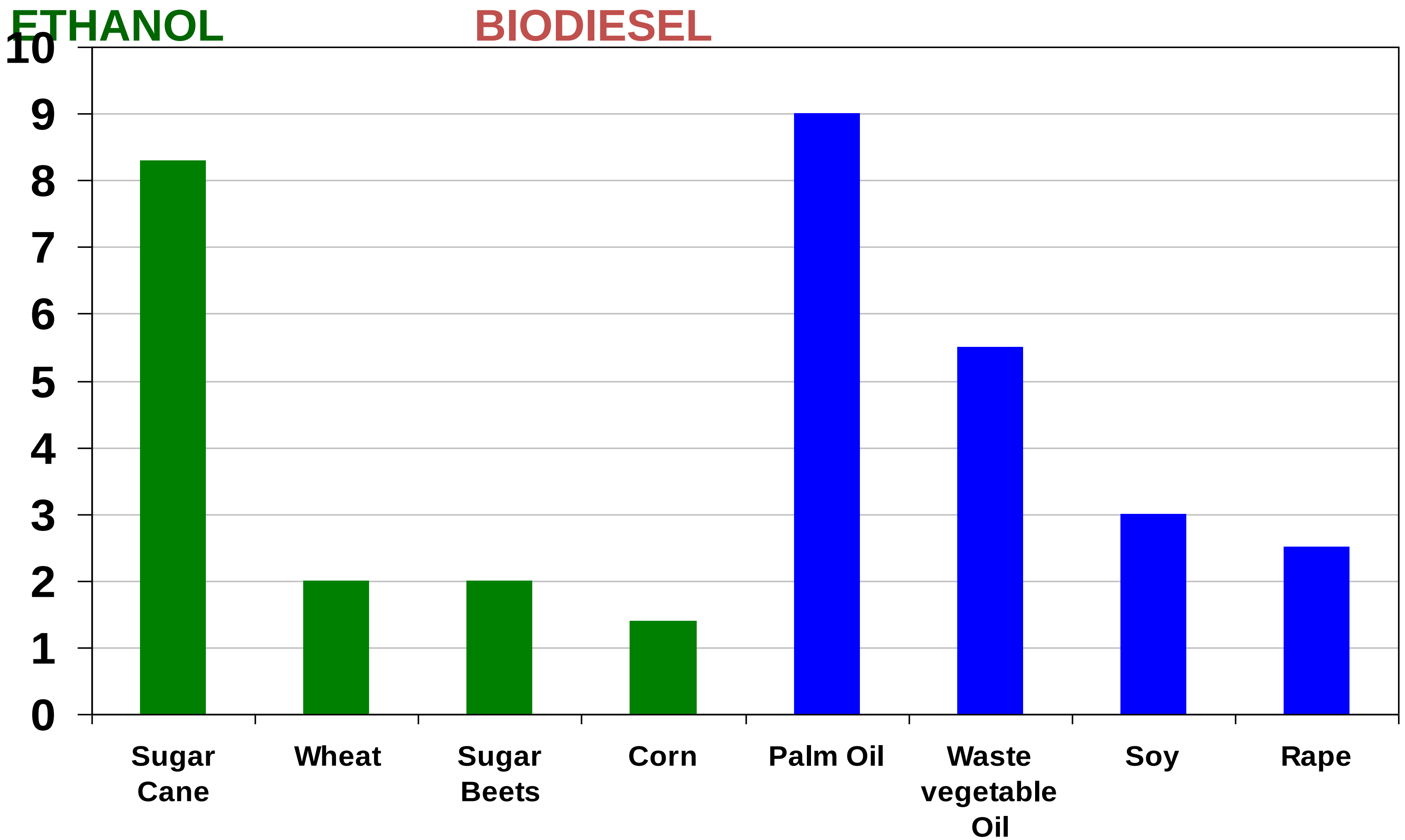


GHG emissions due to various types of land use change



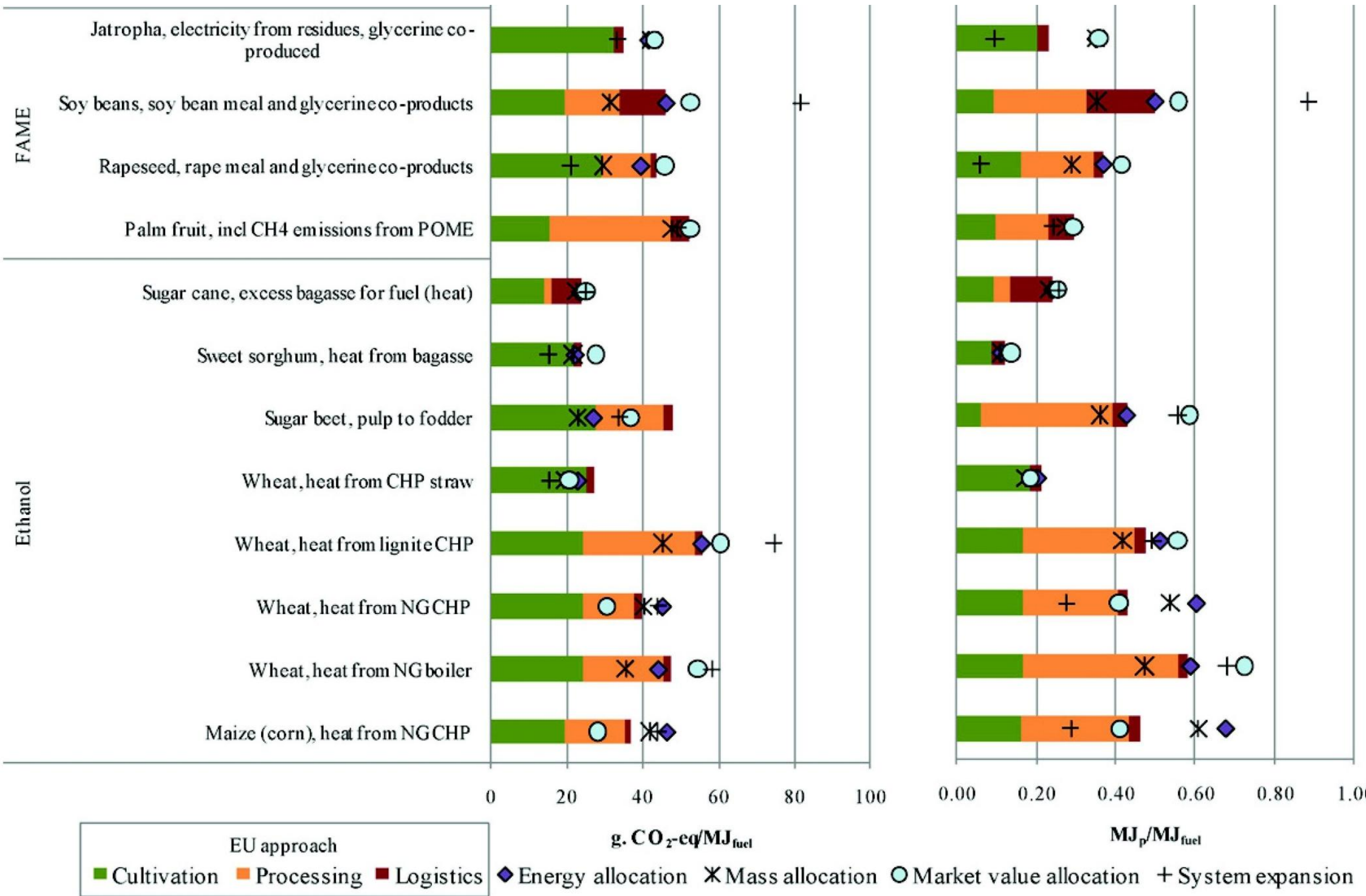
Source: EP 2011 (PE 451.495)

FOSSIL ENERGY BALANCE
Energy output per unit of fossil fuel input



Source: Various, compiled by World Watch Institute, 2006.

GHG and energy yield estimates for biofuels (per MJ fuel) under different assumptions; *Source: Hoefnagels et al, 2010*



All energy crops are not created equal

Ethanol and Biodiesel GHG emission reduction for selected paths – Renewable Energy Directive default values (land use change emissions are not included).

Biofuel and path	***GHG emission reduction (%)***
Sugar beet ethanol	52
Wheat ethanol (process not specified)	16
Wheat ethanol (natural gas in CHP plant)	47
Wheat ethanol (straw as fuel in CHP plant)	69
Corn ethanol (natural gas in CHP plant)	49
Sugarcane ethanol	71[1]
Rape seed biodiesel	38
Sunflower biodiesel	51
Soybean biodiesel	31
Palm oil biodiesel (process not specified)	19
Palm oil biodiesel (with methane capture at oil mill)	56
Hydro-treated vegetable oil from rape seed	47
Lignocellulosic ethanol	70 – 85[2]
Fischer-Tropsch diesel	93 - 95[2]

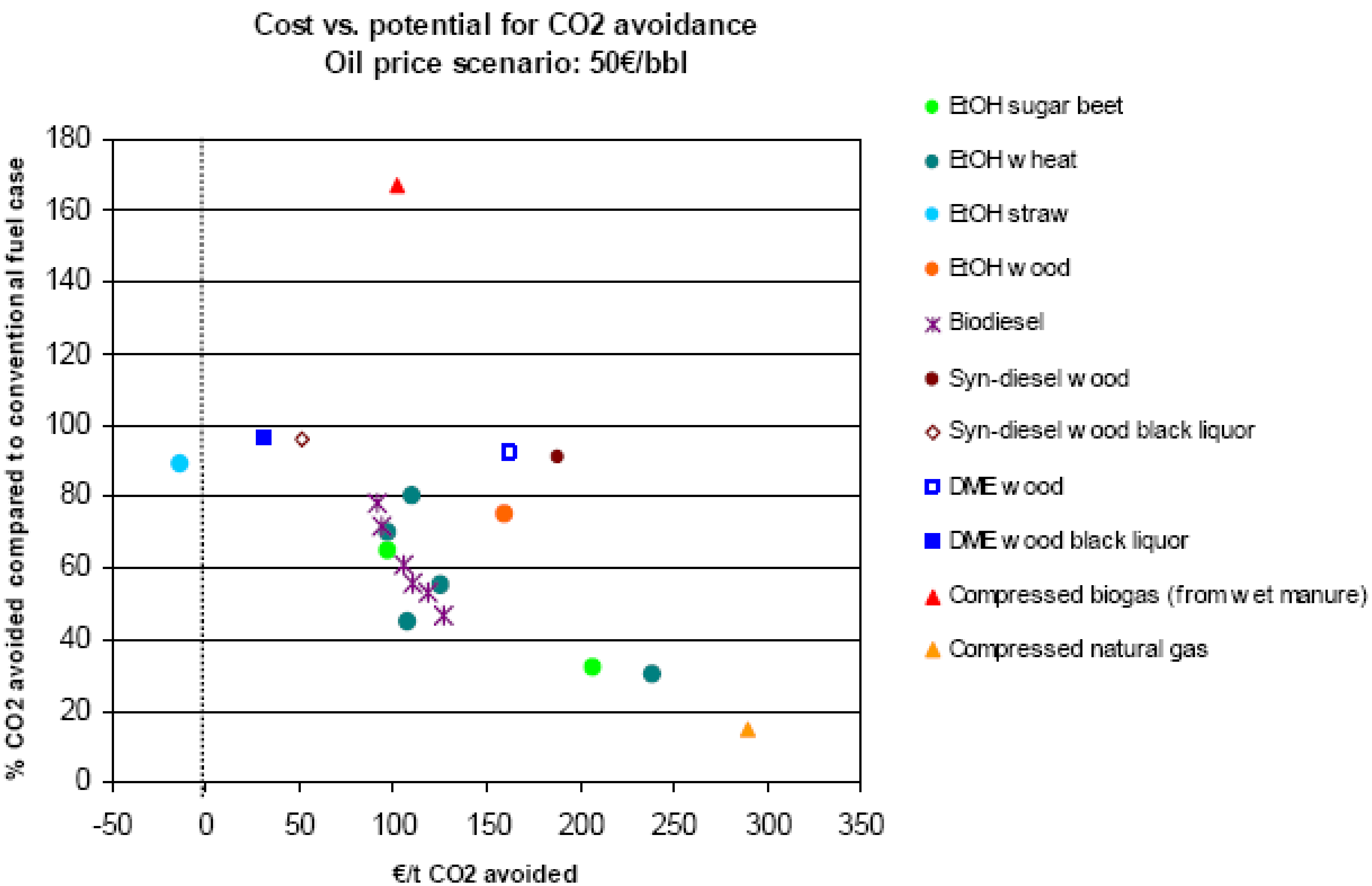
Notes: 1. Includes transport emissions from Brazil to EU;
2. Range for different feedstocks.

Source: (EC, 2009).

2G ethanol - potential

	Agricultural Residues	Energy Security	Growth	Jobs	CO_2
China	221 mio dry ton	China could displace up to 37% of its gasoline consumption in 2030	779 bn USD	2.87 million man years	29%
US	180 mio dry ton	The US could displace up to 16% of its gasoline consumption in 2030	663bn USD	1.37 million man years	11%
Brazil	177 mio dry ton	Brazil could displace 83% of gasoline consumption in 2030. This is on top of sugarcane ethanol	622 bn USD	1.25 million man years	67%
India	110 mio dry ton	India could displace up to 100% of its gasoline consumption in 2030 and still produce 4bn litres for export	329 bn USD	0.91 million man years	80%
Europe	151 mio dry ton	The EU27 could displace 68% of its gasoline consumption in 2030	532 bn USD	1.18 million man years	54%
Argentina	39 mio dry ton	Argentina could replace up to 100% of its gasoline consumption by 2030 and potentially export ethanol	65 bn USD	0.30 million man years	80%
Australia	16 mio dry ton	Australia could replace up to 19% of its gasoline consumption by 2030	58 bn USD	0.12 million man years	17%
Mexico	20 mio dry ton	Mexico could displace up to 7% of its gasoline consumption in 2030,	70 bn USD	0.15 million man years	5%

Source: Bloomberg new Energy Finance 2012


Cost vs. potential for CO2 avoidance
Oil price scenario: 50€/bbl
% CO2 avoided compared to conventional fuel case
€/t CO2 avoided
180
160
140
120
100
80
60
40
20
0
-50
0
50
100
150
200
250
300
350
EtOH sugar beet
EtOH wheat
EtOH straw
EtOH wood
Biodiesel
Syn-diesel wood
Syn-diesel wood black liquor
DME wood
DME wood black liquor
Compressed biogas (from wet manure)
Compressed natural gas

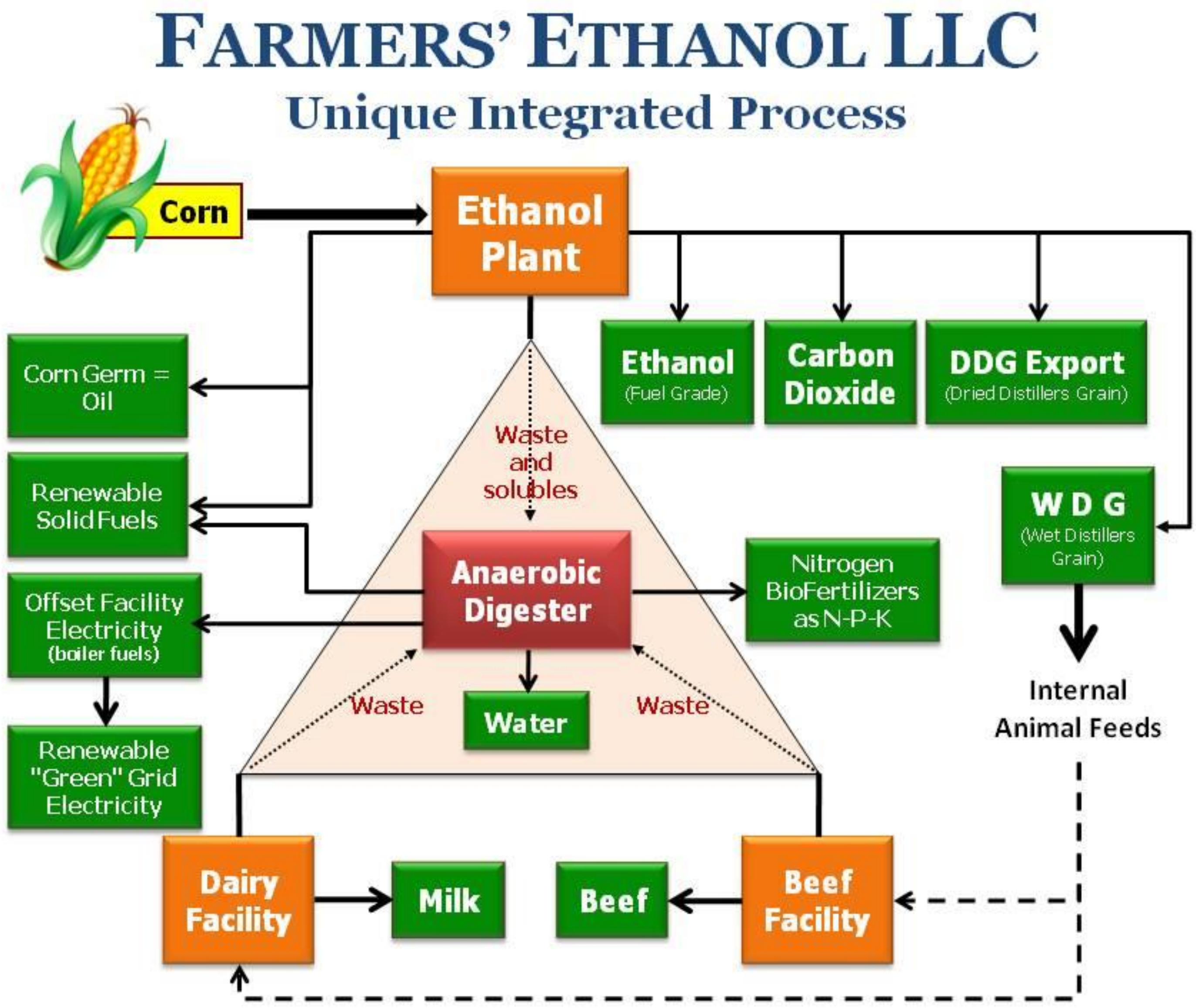
Potential of bioenergy on degraded lands

Source	Lands included	Area (million ha)	Biomass yield (t/ha/year)	Bioenergy Potential (EJ/year)	Ratio to projected EU Biofuels consumption in 2020	Ratio to projected Global Biofuels consumption in 2020
Van Vuuren et al, 2009	Global degraded lands not in use as forest, cropland, pastoral land or urban.	n/a	2.5 - 33	31	15	4
Hoogwijk et al, 2003	Abandoned agricultural land and degraded grassland systems	430-580	1 - 10	8 - 110	4-54	1-15
Tilman et al, 2006	Agriculturally abandoned and degraded lands	500	4.74	45	22	6
Field et al, 2008	Abandoned pastoral lands and croplands not in use as urban or forest	386	3.55	27	13	4
Campbell, 2008	Abandoned pastoral lands and croplands not in use as urban or forest	385-472	4.3	32-41	16-20	4-6
Nijsen et al (2011)	Based on downscaling of lands classified in GLASOD database	1836	2.2 – 10.1	344	169	48
Wicke et al, 2011	Salt-affected soils (suitable for woody biomass)	971	3.1	56	28	8

Landscape ecology: multi-use, multi-product systems

Landscape management vision to more fully integrate economic, environmental, and social aspects of agriculture into integrated systems to produce food, feed, fiber, and fuel sustainably ; Source: INEL, 2009

Integrated Food Energy Systems: Example



Concluding Comments

- SCALE: multi-scale rather than scale *per se*
- SCOPE: multi-use, multi-product, multi-service, multi-landscape systems
- TIMEFRAME: energy/resource transitions take time – decades or centuries
- COMMODITISATION: to improve efficiency and facilitate trade
- LAND USE GOVERNANCE: across all sectors and uses, cannot analyse bioenergy separately
- CARBON MANAGEMENT: carbon storage, ecosystem function

Cannot afford the risks of doing bioenergy badly, but also cannot afford to forego the benefits of doing bioenergy well

Thanks for your attention

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