SustainableBiomass Energy:

Resultsfrom Researchin Germany

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Research sponsored by the German Federal Ministry for Environment (BMU)

Overview

- Research Team + Project Specifics
- System boundaries and model approach
- Technology data for electricity, heat, biofuels (examples)
- Biomass Potentials and Scenarios
- Some Results
- Ongoing work + more info

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- **Energy & Climate**
- Industry & Infrastructure
- Environmental Law
- Products & Material Flows
- Nuclear & Plant Safety
- Transport

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Executive Board

7 honorary members

management member + CEO

2 staff members

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3,000 individuals

55 local authorities

private, non-profit environmental research, founded in 1977; staff > 100, local to global scope of (net)work

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Research Partners

Sustainable biomass

Institut Umwelt-, Sicherheits-, Energietechnik UMSICHT

Fraunhofer Institut UMSICHT, Oberhausen

Institute for Energy and Environment, Leipzig

Institute for Energy and Environment Research, Heidelberg

Institute for Future Energy Systems, Saarbrücken

TU Braunschweig – Institute for Geoecology

TECHNISCHE UNIVERSITÄT MÜNCHEN

TU Munich - Institute for Agricultural Economy, Weihenstephan

+ Fichtner, TU Berlin, and expert workshops

Project sponsored by

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Context (1)

Material-Flow Analysis for Sustainable Biomass Energy in Germany

Study sponsored by Ministry for Environment (BMU)

Criteria for Assessing Environmental, Economic, and Social Aspects of Biofuels in Developing Countries

Study commissioned by Ministry for Economic Cooperation and Development (BMZ)

Context (2)

- **renewables2004:**
  - role of traditional biomass (background paper)
  - China: 8 ExaJoule of biomass until 2020
  - Brazil: bioethanol exports (Mercosur/EU);
  - India: Japtropha (with DaimlerChrysler)
- **German activities:**
  - „Sustainable Bioenergy Trading Option in the EU“, sponsored by Ministry for Environment
- **EU:**
  - RE targets for 2020; „biomass action plan“
  - EEA: sustainable bioenergy potentials in EU-28
  - CAP reform, rural development in Member + Accession States

Project Specifics

- **Integrated analysis of national biomass flows from agriculture, forestry, waste + land potential for energy crops**
- **future technology development (learning curves) for all technologies**
- **all sectors in scenarios until 2030, massive environmental constraints**
- **analysis of human labor flows (direct + indirect employment)**
- **policy focus (EEG…)**

Project Tasks (1)

- **Publicly available, up-to-date and scientifically reviewed technology data for biomass energy**

used for

- **life-cycle comparison of biomass technologies for electricity, heat, transport**
- **validated data for policy counseling**

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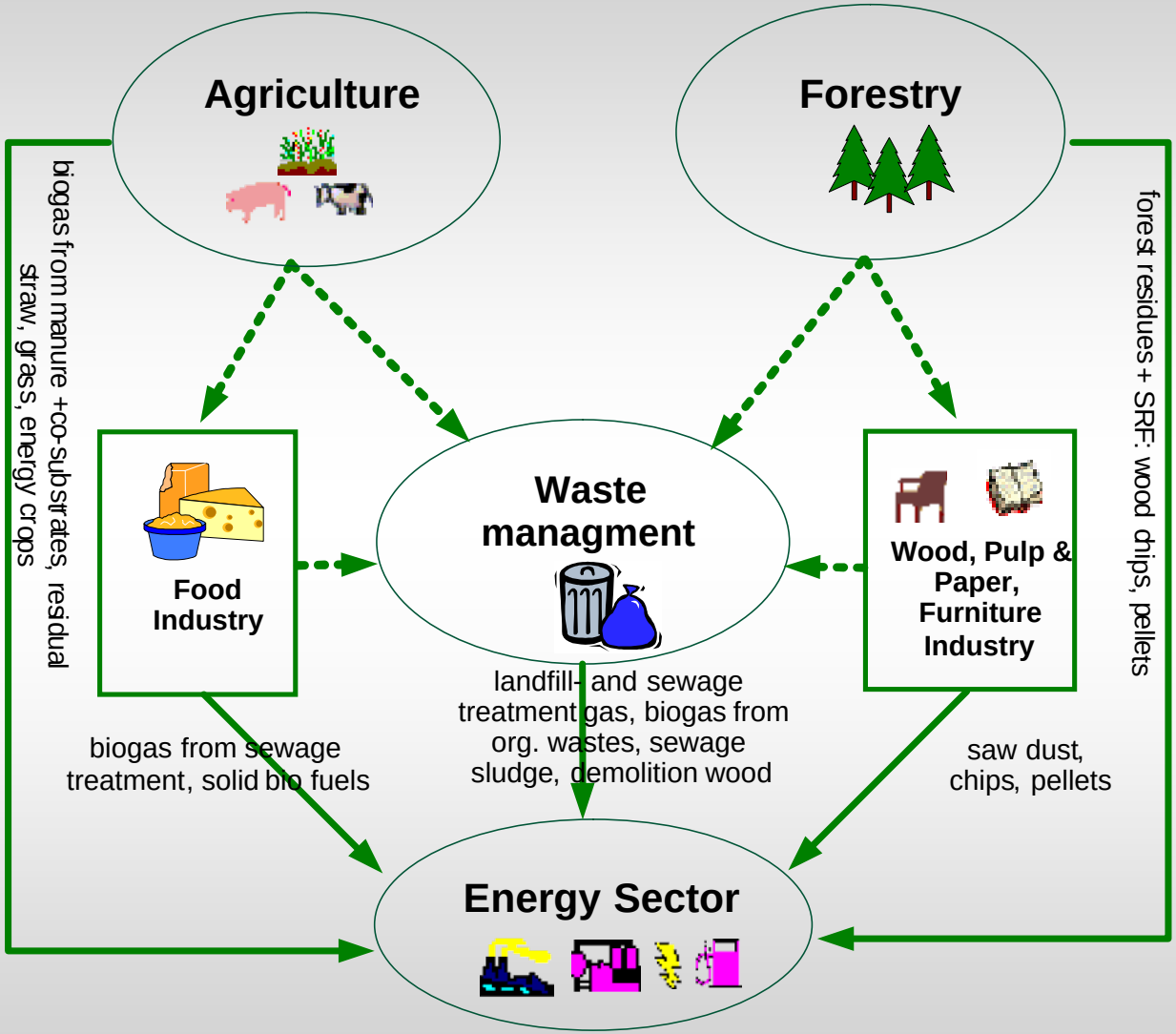
Biomass Flows

Sustainable biomass



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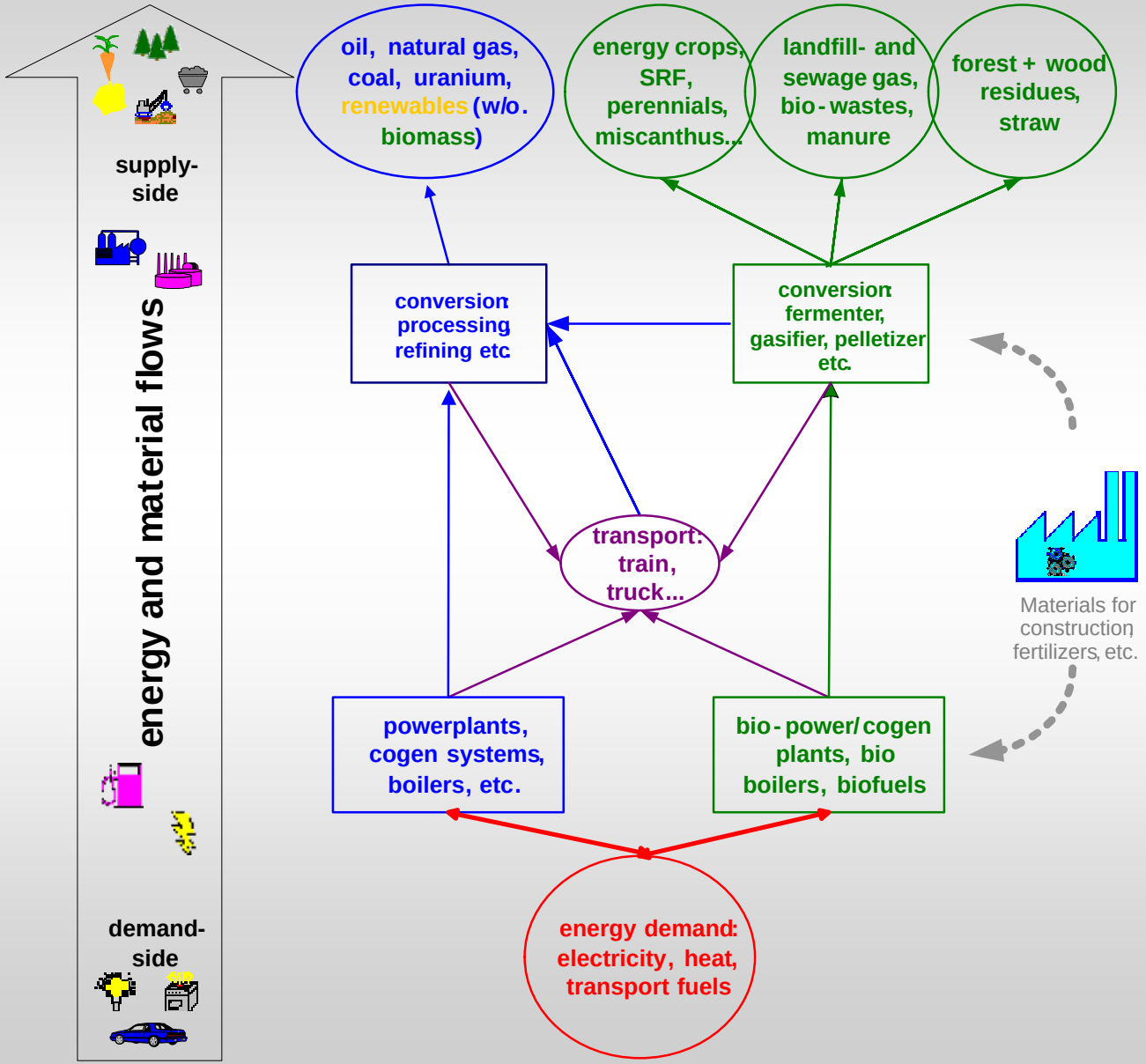
Energy/Material Flows

Sustainable biomass



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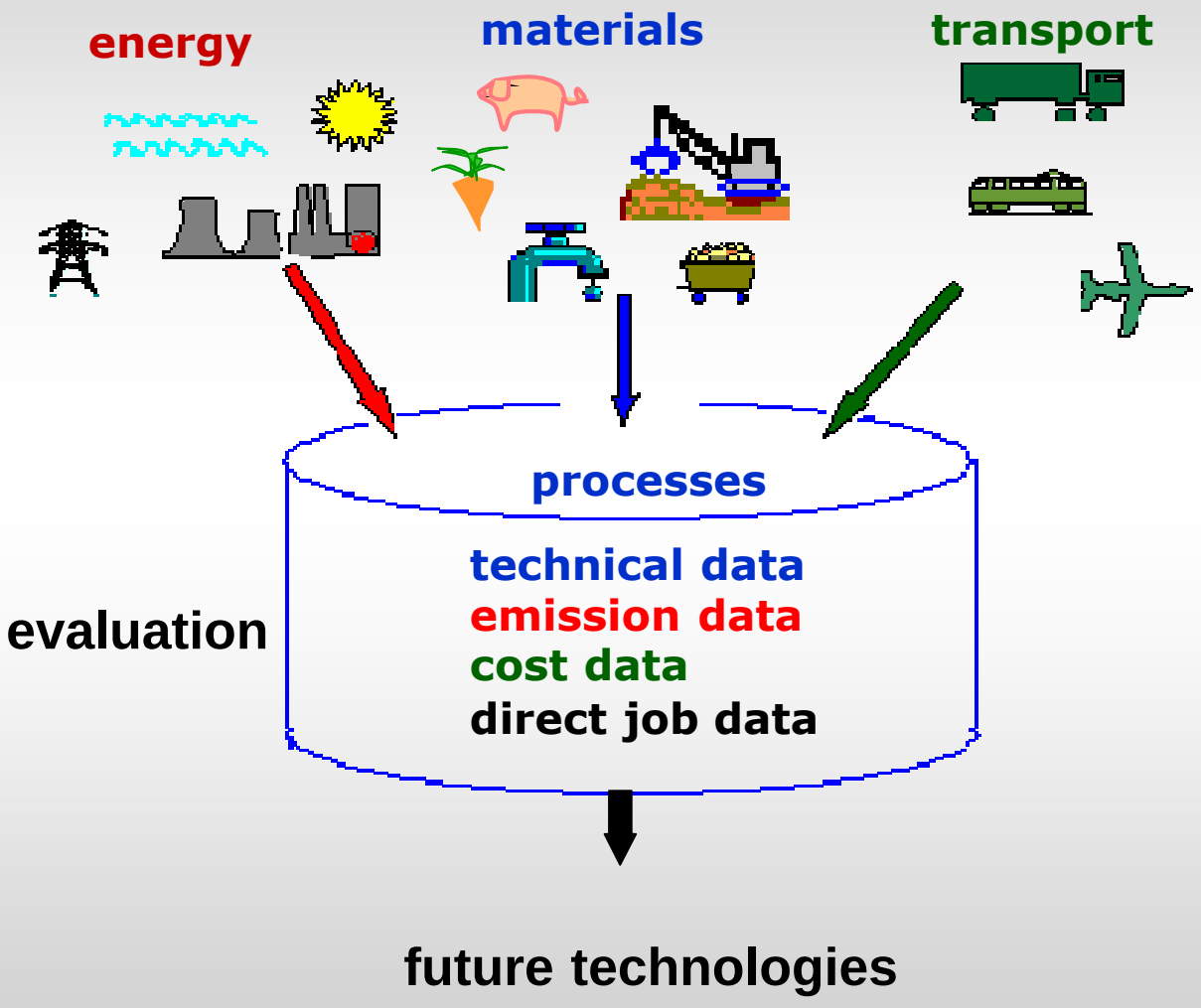
Technology Database

Sustainable biomass



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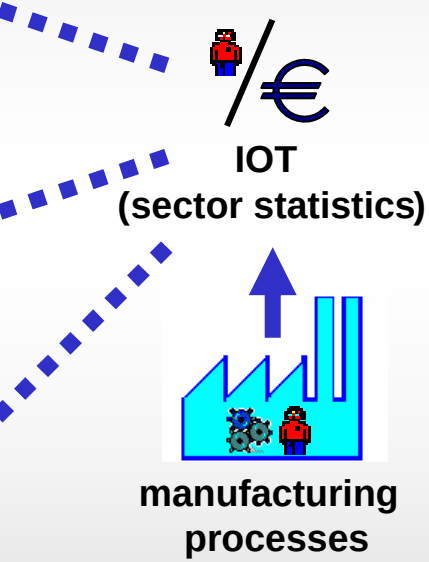
Employment Balance

Sustainable biomass

	Process	direct	indirect*
	farming/ harvest		
	transport		
	processing, conversion		
	transport		
	use		



* = from invest costs; operating costs neglected

Model: GEMIS (freely available)

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Biomass Technologies

- Data for costs, employment, and emissions include technology-specific learning
- more life-cycle results for electricity, heat + transport fuels available via GEMIS
- land use not included here (in scenarios)

note: via EEA project, EU-28 data July 2005!

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Bio-Electricity (Biogas)

Sustainable biomass

	costs 2010 c/kWh$_{el}$	2030	jobs pers./TWh$_{el}$	CO_2-eq. g/kWh$_{el}$	SO_2-eq. g/kWh$_{el}$
fossile reference systems					
natural gas CC	**4,9**	**5,7**	**79**	**420**	**0,4**
hard coal (import) ST	**5,0**	**4,4**	**142**	**913**	**1,4**
biogas from wastes					
c+p-300-ICE-cogen-25	**14,0**	10,0	**1.468**	-329	**1,5**
c+p-300-ICE-cogen-100	**12,7**	8,6	1.476	-269	1,4
c+p-300-ICE-cogen-200	**11,0**	7,6	1.186	-296	1,4
c+p-1500-ICE-cogen-200	7,8	5,5	746	-317	1,4
c+p-1500-ICE-cogen-500	6,9	4,5	642	-241	1,3
c+p-1500-ICE-cogen-1000	**6,6**	4,6	585	-212	1,2
biowaste-only-ICE-cogen-500	8,1	5,9	**522**	-372	**0,7**
manure-only-ICE-cogen-500	9,6	8,1	898	-240	1,1
biowaste-4000-ICE-cogen-500	**3,5**	2,0	539	-339	**0,6**
manure+maize-ICE-cogen	**18,5**	15,2	518	-187	**1,9**
manure+maize-org.-ICE-cogen	**24,0**	19,9	920	-233	1,2
"wet route" ICE-cogen	**10,2**	7,7	**5.233**	**-182**	**1,6**

Data include bonus for cogenerated heat (based on gas); cost @ 7% real interest

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Bio-Electricity (Wood)

Sustainable biomass

material flow/technology	costs 2010 c/kWh$_{el}$	2030 c/kWh$_{el}$	jobs pers./TWh$_{el}$	CO_2-eq. g/kWh$_{el}$	SO_2-eq. g/kWh$_{el}$
natural gas CC	**4,9**	**5,7**	**79**	**420**	**0,4**
hard coal (import) ST	**5,0**	**4,4**	**142**	**913**	**1,4**
forest residues					
chips cofiring coal-cogen	**5,3**	5,3	**97**	38	0,4
chips SE-cogen	10,9	8,6	368	-1329	1,3
chips ORC-cogen	10,8	8,0	23	-1625	1,5
pellet stirling-cogen	**25,6**	**20,4**	144	-1010	1,4
FB-ICE-cogen	**19,3**	14,6	**1.426**	-273	0,7
FB-micro-GT-cogen	**17,8**	12,6	**1.446**	-191	0,4
aCFB-ICE-cogen	8,8	6,5	291	-274	0,6
pCFB-CC	9,6	8,2	394	219	0,9
SG-FC-SO-cogen	**13,1**	11,9	683	312	0,5
syngas-FC-SO-cogen	**11,4**	10,7	625	8	0,2
short-rotation forestry					
chips cofiring coal-cogen	8,8	8,8	2.203	71	0,7
chips SE-cogen	22,6	19,5	5.712	-1205	3,7
chips ORC-cogen	23,4	19,7	4.615	-1343	3,9
FB-ICE-cogen	26,3	21,0	4.538	-203	1,2
FB-micro-GT-cogen	24,7	18,6	2.706	-124	0,9
aCFB-ICE-cogen	14,0	11,5	1.966	-224	1,1
pCFB-CC	13,1	11,9	1.908	272	1,4
SG-FC-SO-cogen	17,2	14,3	-184	346	0,7

Data include bonus for cogenerated heat (based on gas); cost @ 7% real interest

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Bio-Heat (Wood)

Sustainable biomass

	costs 2010	2030	jobs	CO_2-eq.	SO_2-eq.
	c/kWh$_{th}$		pers./TWh$_{th}$	g/kWh$_{th}$	
gas heating 10 kW	**10,2**	11,4	**266**	**296**	**0,36**
oil heating 10 kW	**10,6**	11,2	**333**	**383**	**0,42**
wood residues					
chips heating 10 kW	7,6	7,5	378	29	0,5
chips heating 50 kW	6,1	6,1	289	29	0,5
pellet heating 10 kW	**11,3**	11,5	446	34	0,4
pellet heating 50 kW	**10,9**	11,1	420	33	0,4
pellet heatplant 0.5 MW + grid	**8,3**	8,7	**796**	40	0,4
chips heatplant 1 MW + grid	**5,3**	5,3	340	33	0,4
chips heatplant 5 MW + grid	**5,4**	4,8	358	32	0,4
SRF-poplar/Miscanthus					
pellet heating 10 kW	**13,7**	14,1	1.322	56	0,6
pellet heating 50 kW	**13,2**	13,7	1.277	55	0,6
pellet heatplant 0.5 MW + grid	**10,8**	11,4	1.728	64	0,6
chips heatplant 1 MW + grid	**6,9**	7,1	1.275	52	0,6
chips heatplant 5 MW + grid	**6,7**	7,0	1.272	50	0,6
miscanth.heatplant 1 MW + grid	**6,4**	6,6	413	53	1,5
miscanth.heatplant 5 MW + grid	**7,0**	7,3	430	47	1,0

Cost data @ 7% real interest

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Biofuels(Transport)

Sustainable biomass

	person transport	costs 2010 c/P*km	2030	jobs pers./bn P*km	CO_2-eq. g/P*km	SO_2-eq.
DIESEL-CAR	**fossil diesel with tax**	**5,4**	6,2	**5**	**195,9**	**0,4**
	dito, without tax	**1,6**	2,5			
	rapeseed oil	2,5	2,8	186	**92,6**	**0,7**
	rapeseed oil, organic	3,3	3,8	544	14,0	**0,1**
	sunflower oil	2,5	3,8	225	59,5	0,5
	sunflower oil, organic	3,3	3,8	623	37,5	0,3
	RME	4,8	5,5	193	42,4	**0,7**
	RME, organic	6,4	5,5	554	-37,1	0,0
	sunflower-ME	4,8	5,5	216	9,6	0,4
	sunflower-ME, organic	6,4	7,3	617	-12,6	0,2
	BtL-triticale	**10,5**	**8,5**	603	-4,0	**0,7**
	BtL-triticale, organic	**12,4**	**10,2**	801	**-73,8**	0,2
OTTO-CAR	**fossil gasoline, with tax**	**7,9**	9,1	**6**	**230,4**	**0,3**
	dito, without tax	**2,4**	3,7			
	Bio-EtOH, wheat	**13,7**	**14,3**	161	**121,6**	**0,9**
	Bio-EtOH, wheat organic	**15,3**	**16,1**	371	75,2	0,6
	Bio-EtOH, sugarbeets	**13,8**	**14,6**	161	**128,8**	**1,0**
	BtL-SRF poplar	9,0	7,6	1.554	**-69,0**	0,2
	BtL-miscanthus	9,1	7,7	277	**-66,0**	0,2
	BtL-wood residues	**7,1**	4,9	219	20,7	0,2
	biogas-cattle+pig manure	**1,9**	1,6	239	49,5	0,3
	biogas-manure+maize	4,8	4,5	205	62,5	0,4
	biogas-manure+maize org.	6,1	5,9	302	51,4	0,3

Biofuels with credits for upstream **couple products** (electricity, materials); **excl. taxes!**

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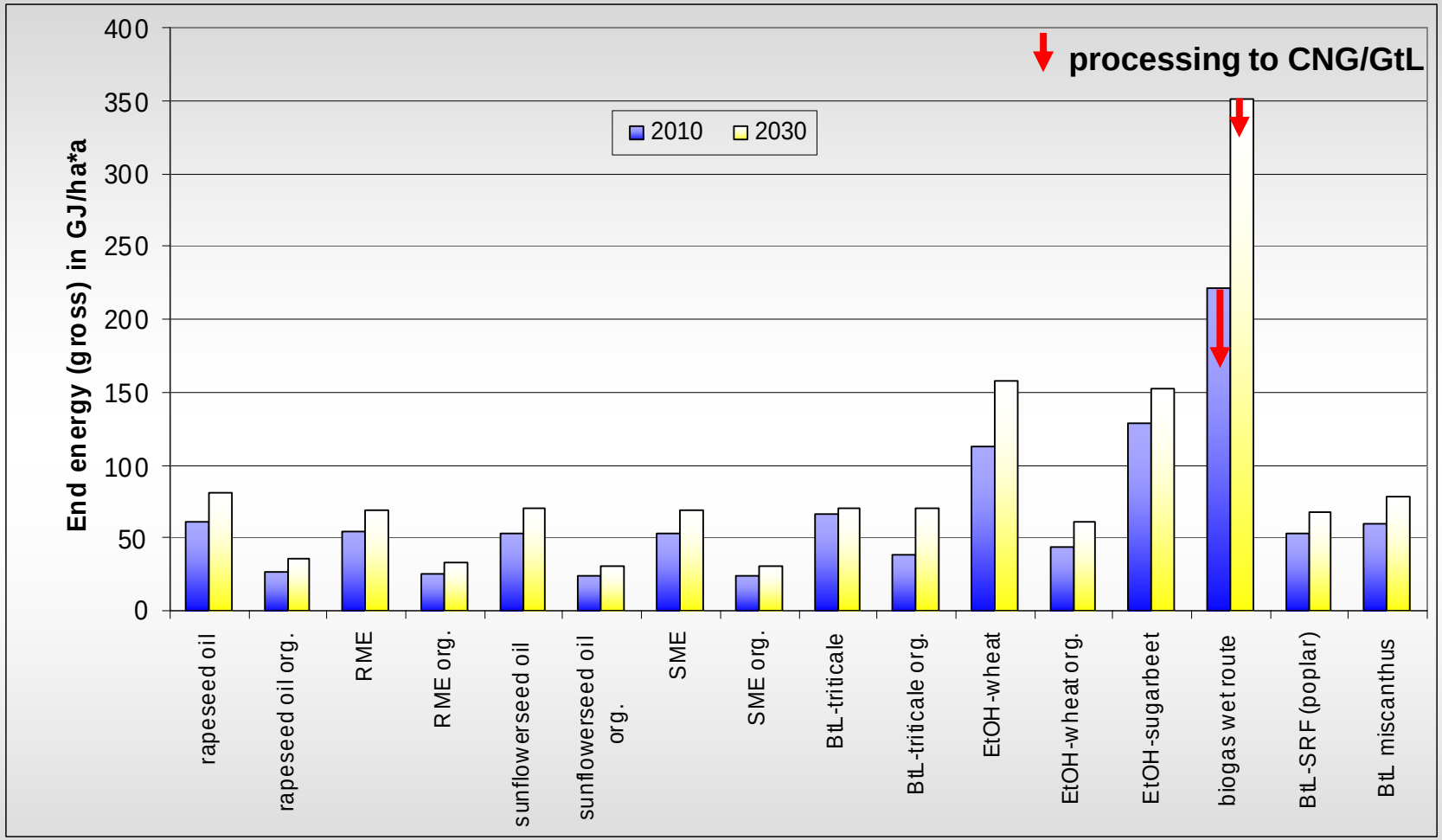
Bioenergy Yields

Sustainable biomass



RME = rapeseed oil methylester; org = organic farming; SME = sunflower seed oil methylester; SRF = short rotation forestry; BtL = Biomass-to-Liquid

(data for German situation, and future learning curves)

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Project Tasks (2)

- **Potentials and Scenarios for sustainable biomass energy production and use**

used to

- **Analyze trade-offs between scenarios**
- **Policy recommendations for biomass energy in Germany**

Scenario Storylines

- Reference (REF): business-as-usual
- Environment (ENV): reduced demand by efficiency; more non-biomass renewables; environmental restrictions for biomass, +10% area for nature protection (2010)
- Biomass (BIO): less restrictions than ENV; + 5% nature protection area til 2030; maximum sustainable biomass supply
- Sustainable Dev. (SD): mix of ENV + BIO

Scenario Drivers

- In ENV, BIO and SD: 30% organic farming for food until 2030
- Dynamics: population, food consumption, yields, ex- and imports
- Land use for settlements & transport
- Land use for nature protection; biodiversity in forestry; soil protection (straw)
- No bioenergy ex- or imports (yet)

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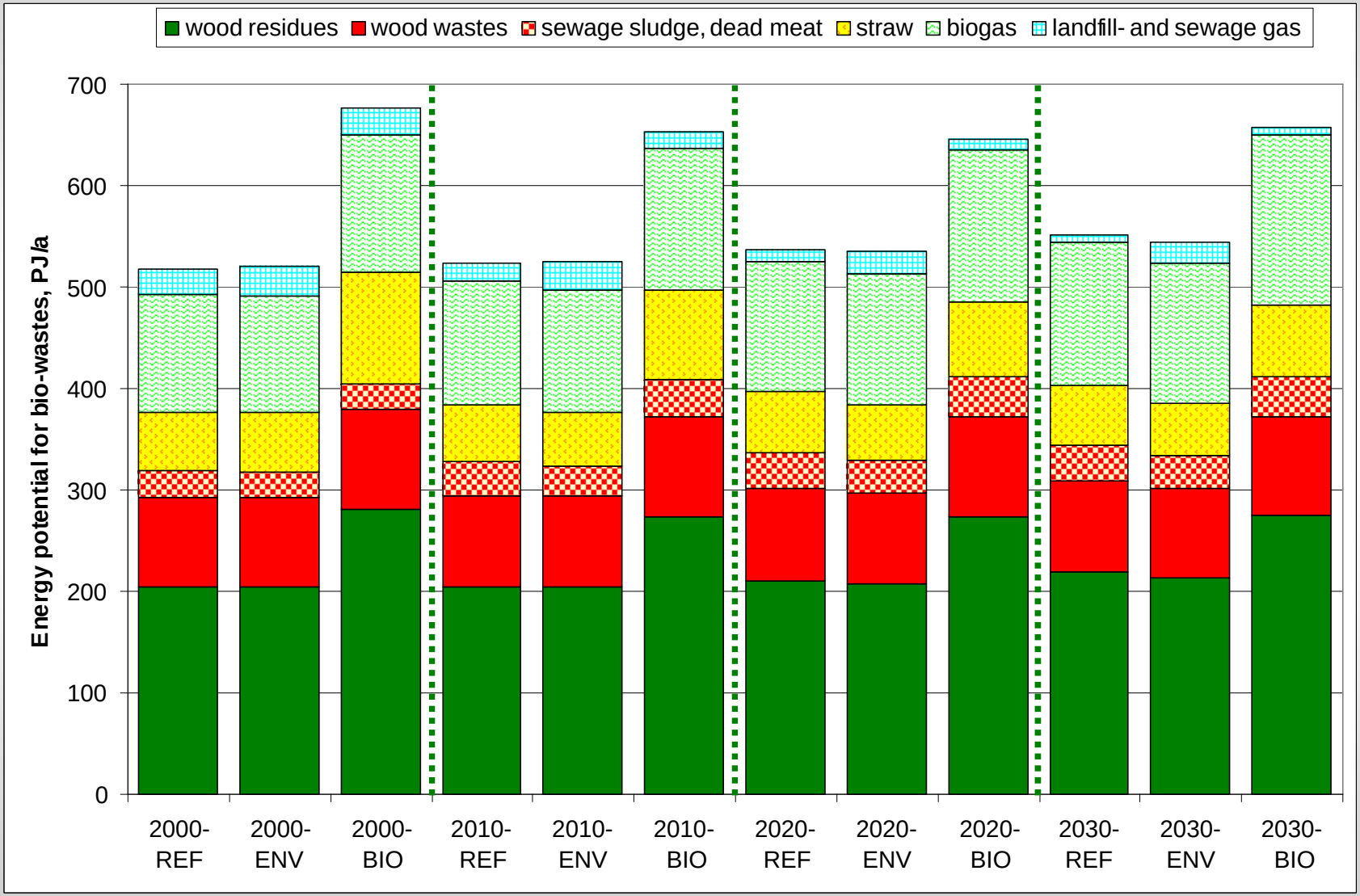
Potential Bio-Wastes

Sustainable biomass



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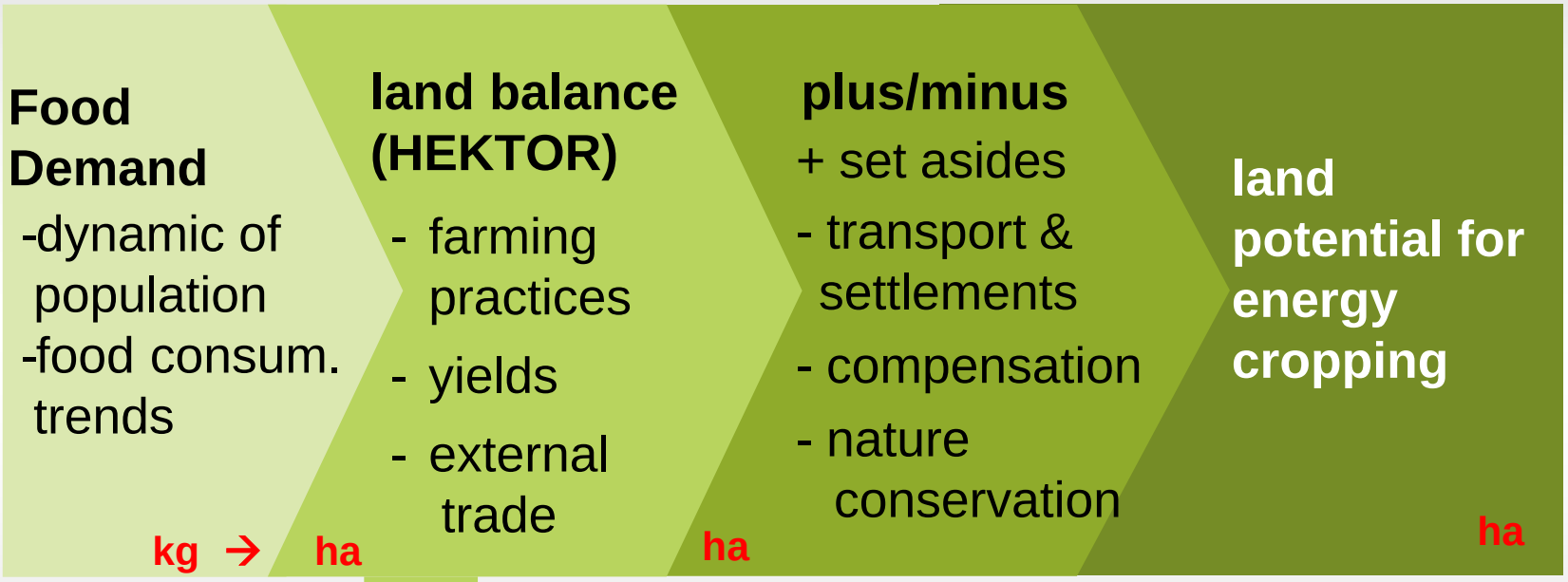
Land Potential

Model-based analysis of land potential from agriculture

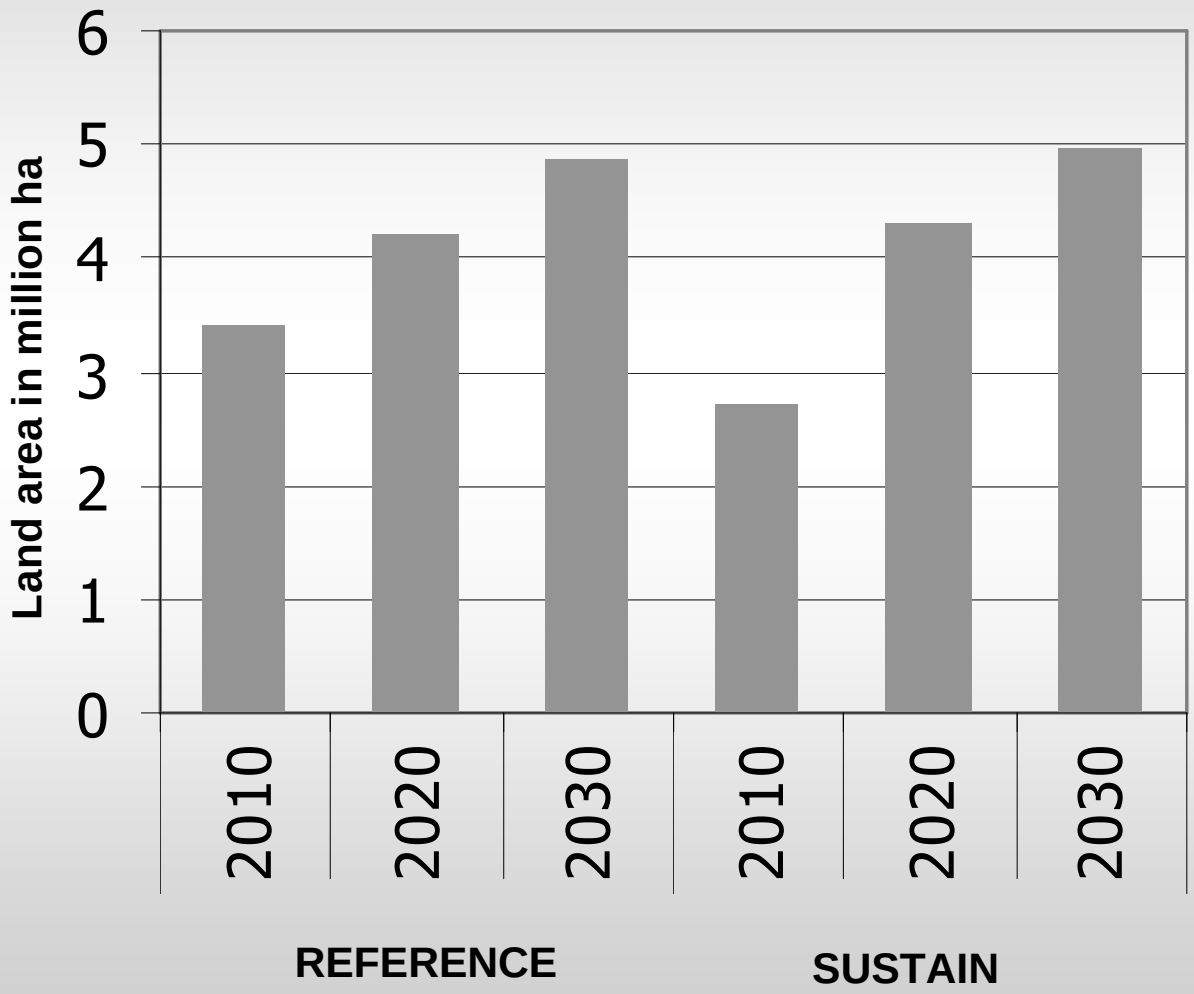


potential of by-products:

manure, straw, leafs from sugar beets + potatoes

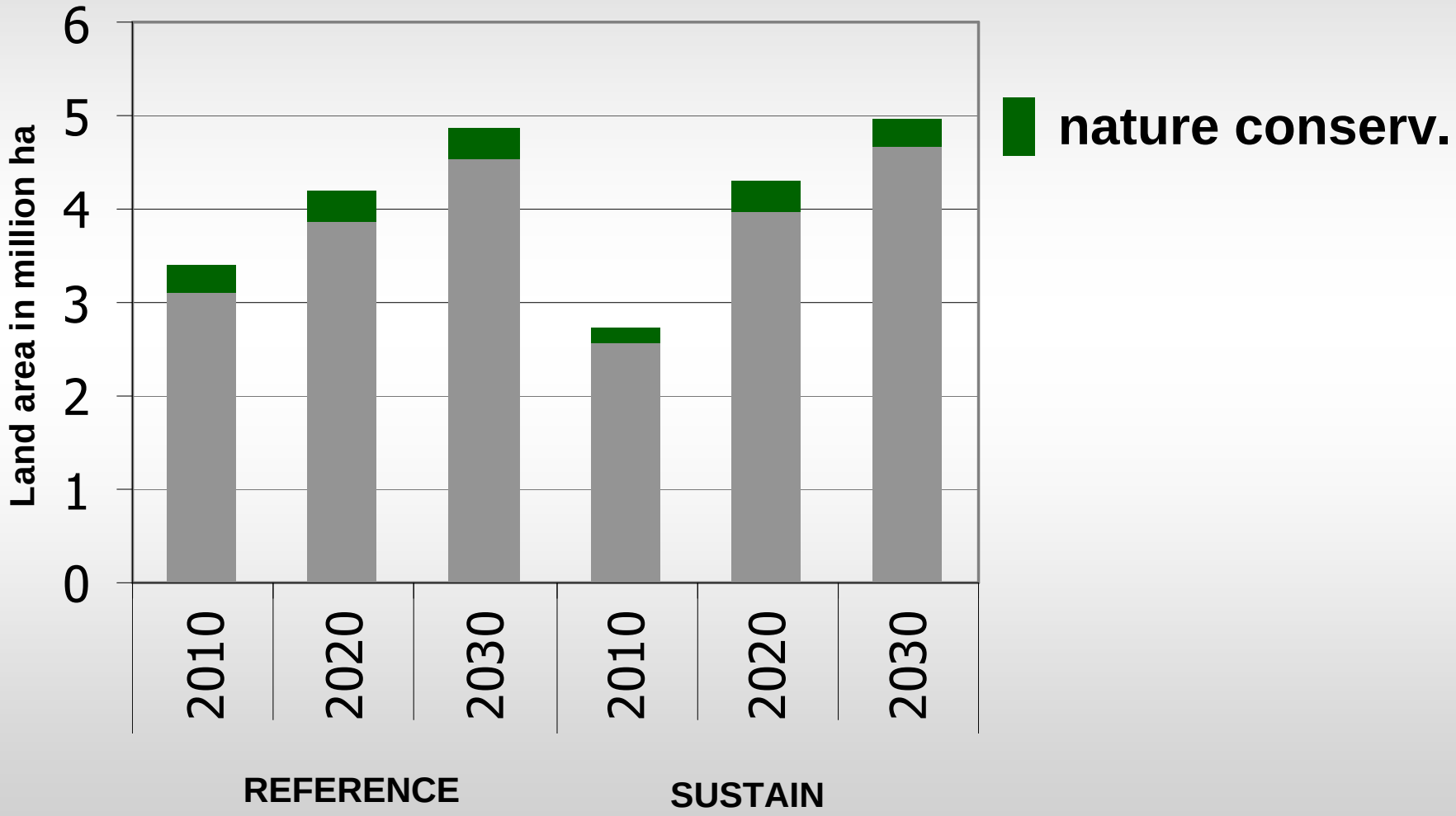
Land „set free“

Gross balance, excluding competing uses



Net Land Potential

Net balance, including competing use:



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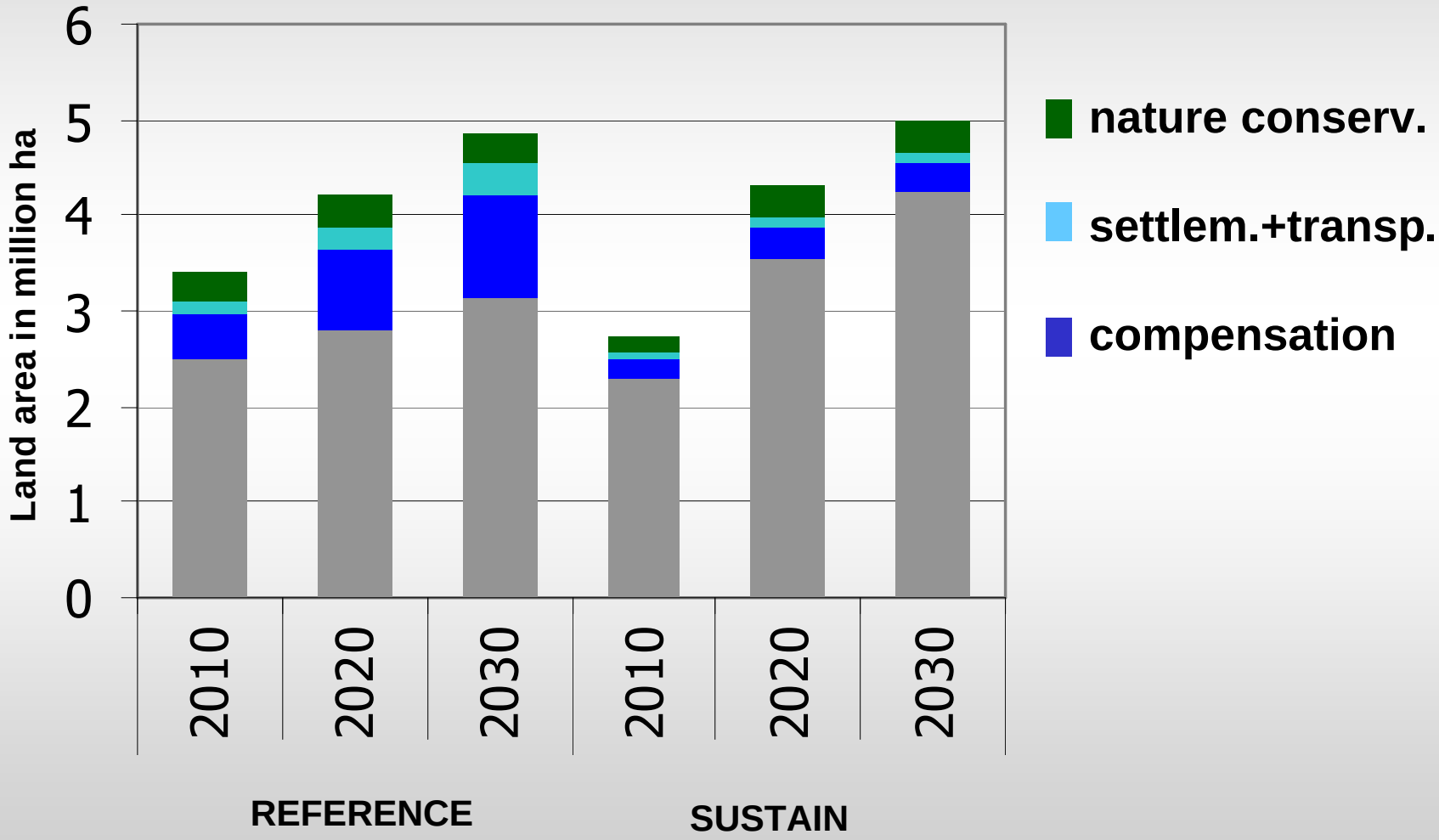
Net Land Potential

Sustainable biomass

Net balance, including competing use:



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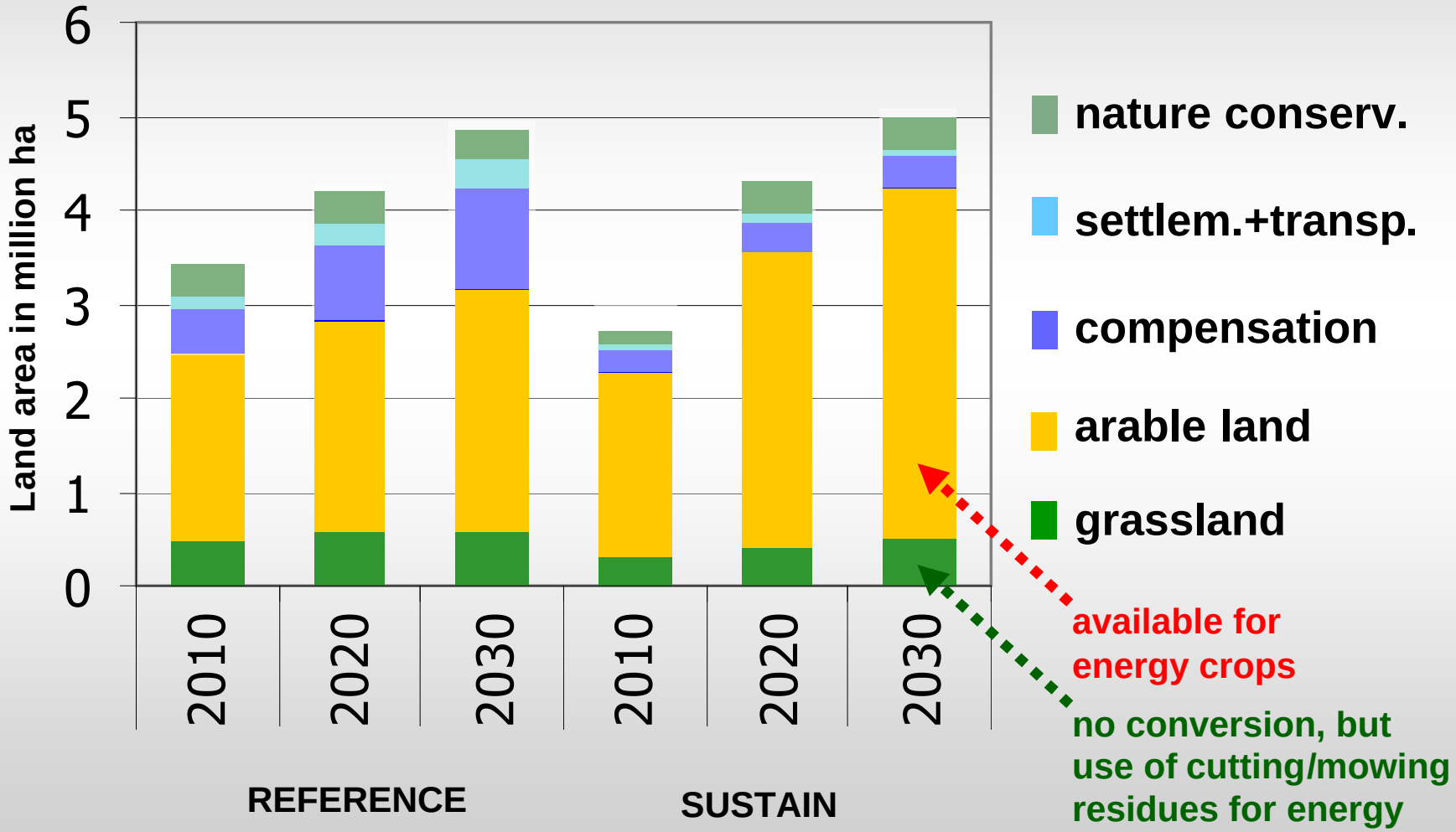
Net Land Potential

Sustainable biomass

Net balance, including competing use:



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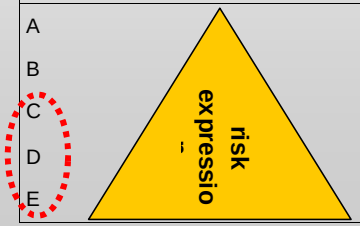
QualitativeAssessment

Sustainable biomass

Risk for nature/landscape	wheat	triticale	rape	sunflower	maize	sugarbeets
erosion	A	A	B	C	D	E
damage from compression	A	A	A	A	C	E
eutrophication	A	A	B	B	C	B
biocide impacts	A	A	C	A	C	A
ground water contamination	A	A	B	B	C	B
surface water contamination	A	A	B	C	C	C
loss of habitats/biodiversity	B	B	A	A	B	B
quantified aspectes	**relative valuation**					
CO_2 equivalent emissions	-	-	+	+/-	-	+/-
SO_2 equivalten emissions	-	-	+	+/-	-	+
land use	-	-	+/-	+	-	+/-
relative valuation						
nature + environment total	**1**	**1**	**2**	**2**	**2-3**	**3**

categories for nature/landscape	symbols for environmental aspects	total valuation
A B C D E	- = low +/- = moderate + = high (relative within lines)	1 = favorable 2 = medium 3 = unfavorable



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Core Standards

- Conservation of natural ecosystems, e.g., no clearing of old-growth forests for cultivation of energy crops
- 10% of land for nature conservation (biotope networks & corridors)
- Genetic + structural diversity within energy crop plantations
- Recirculation of nutrients; low/no fertilizer and pesticides
- Low irrigation in semi-dry and dry regions, no soil erosion.

Biodiv "Standards"

- **multi-year "crops" (SRC/perennials) in principle more favorable for nature conservation than annual crops → priority !**
- **residues from "nature management" need extraction anyway → positive impacts**
- **SRC/perennials help soil and erosion protection, also reduce N input**
- **"wet route" annual crops offer minimum (external) input and maximum output, less biocides/fertilizers, no tilling → priority !**

Biodiv "Standards"

- **short-rotation forestry/coppice help soil and erosion protection, also reduce N input**
- **for nature conservation + biodiv., SRF + perennials better than annual crops**
- **"wet route" (2 culture) crops: minimum (external) input + max. output, no biocides/fertilizers, no tilling → priority !**
- **residues from "nature management" need extraction anyway → positive impact**

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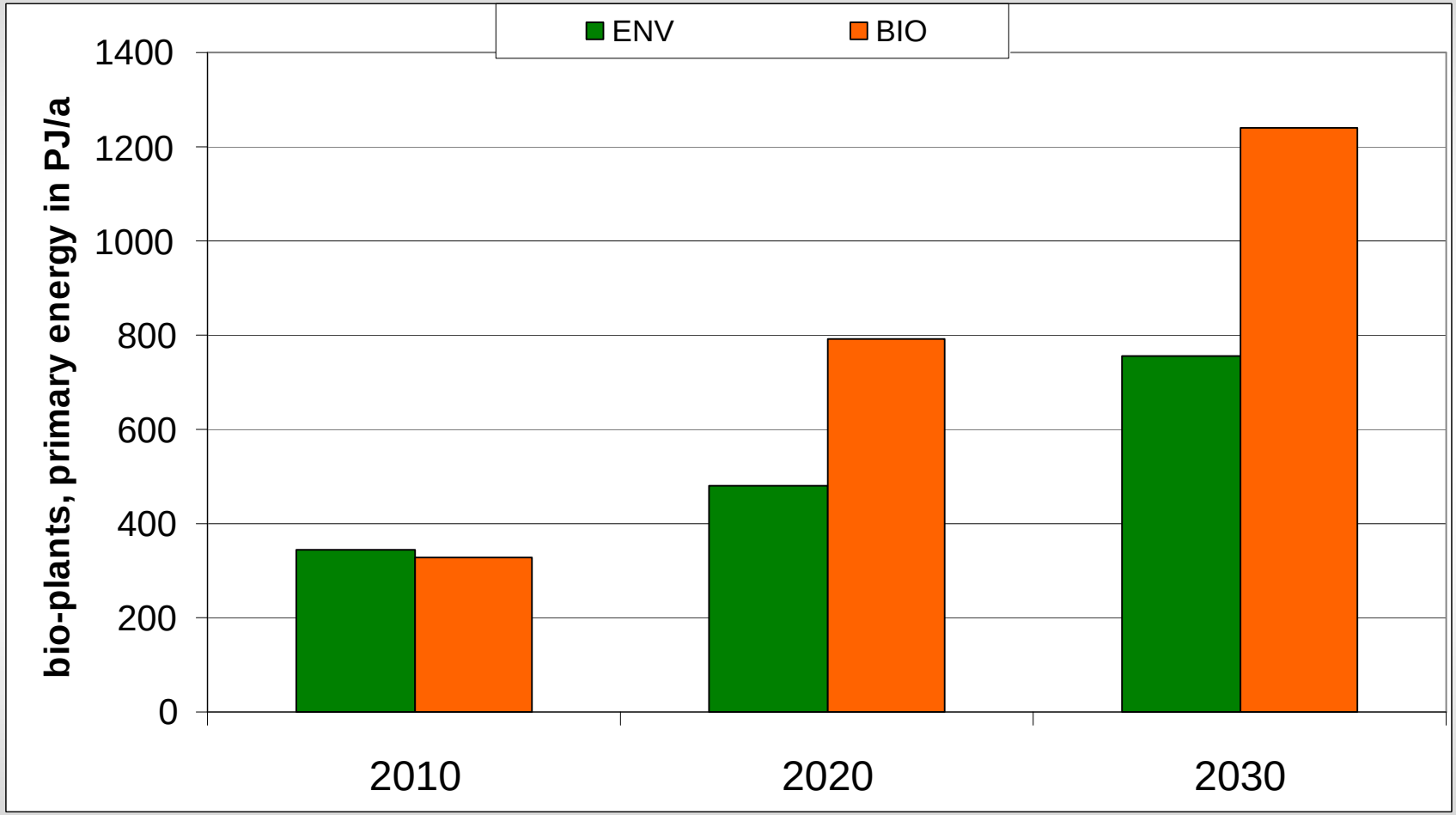
Potential Bio-Crops

Sustainable biomass



Data for model mix; in scenarios, the mix varies

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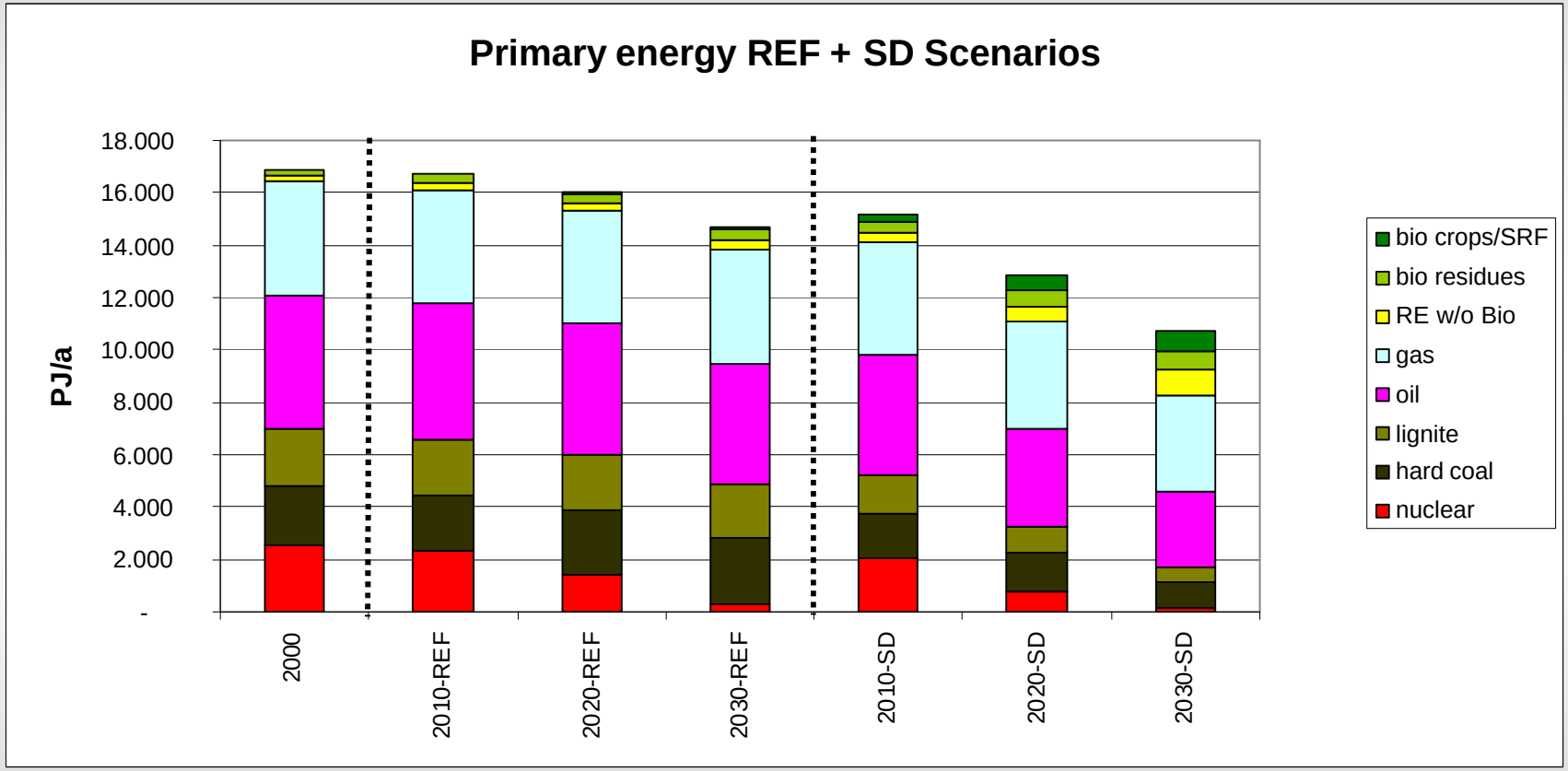
Biomass Results

Sustainable biomass



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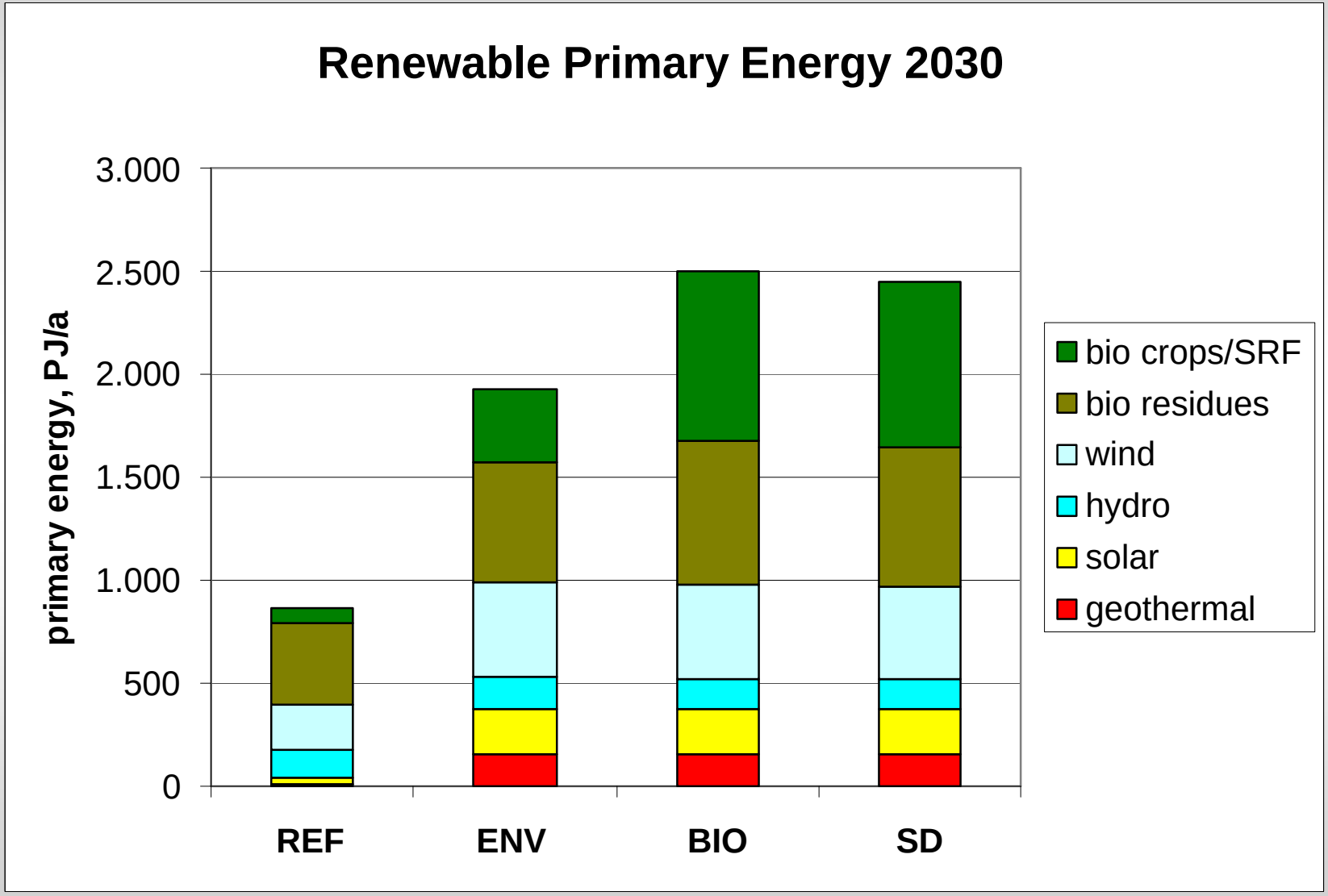
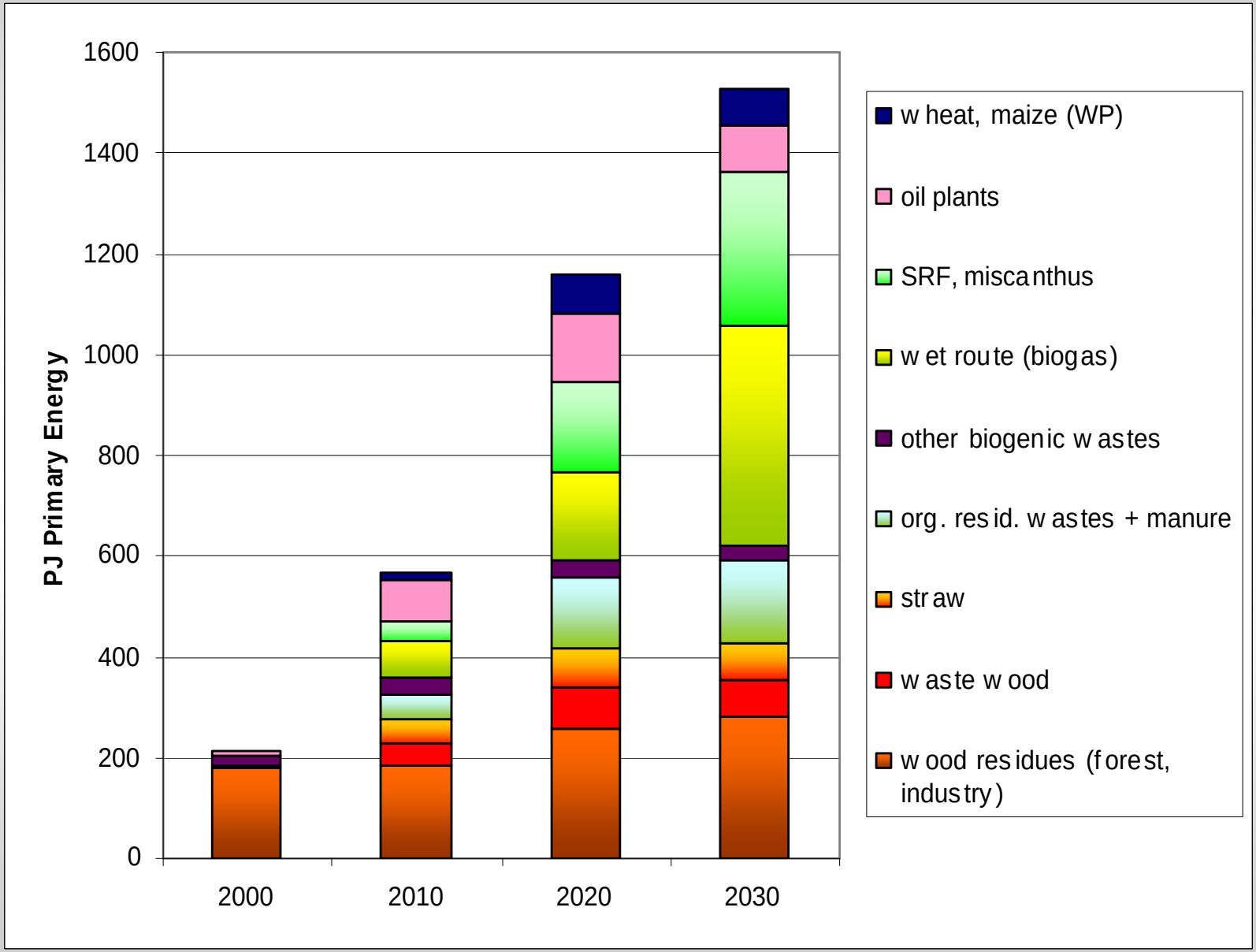
Biomass Results



Sustainable Biomass in D



Source: ÖKO (2004); WP = whole plant, SRF = short-rotation forestry

Biomass Policy

- Cogeneration is key, needs support (heat grids)
- Co-firing cost-effective with CO_2 trading
- Additional RT&D program for small/medium gasifier (BIG-ICE + BIG-STIG/BIG-CC)
- "wet route" + SRF offer synergies (nature, biodiv, jobs), market intro needed !
- Biofuels: BtL promising, domestic potential restricted; enzym. bioethanol ? biogas ?

Ongoing Activities

- **update of data in 2005-2006, biogas/nature protection synergies, more on biofuels…**
- **BioRegio: implementing bioenergy in six regions in DE; tool for regional economic benefits, feedback to national level**
- **EU Bio-Trade: potentials and inner-EU trade options**
- **EEA: sustainable biomass EU-28 – input to EU BAP**
- **GEF/STAP Biofuels Workshop**
- **IEA Biofuels + Bioenergy Task 40**

More Information

Brochure, full report, appendix, and all data:

www.oeko.de/service/bio

Model + database(freely available):

www.gemis.de

Languages: German, English, Czech
(Spanish in summer 2005, French in 2006)

GlobalEnergy

data in EJ/a	primary energy	renewables	biomass	biomass share of primary energy
Africa	21.5	10.8	10.5	49%
Latin America	18.8	5.3	3.3	18%
Asia	48.2	16.1	15.0	31%
China	48.4	10.0	9.0	19%
Near East	16.3	0.1	0.0	0%
CIS + CEE	43.7	1.7	0.6	1%
OECD	223.3	12.7	6.8	3%
World	**420.3**	**56.7**	**45.2**	**11%**

Source: CIP (2004), based on IEA (2003)

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GlobalB iomass

Sustainable biomass

Potential (EJ/a)	North America	Latin America, Caribbean	Asia	Africa	Europe	CIS + Near East	Total
- wood	12.8	5.9	7.7	5.4	4	5.8	41.6
- grasses & straw	2.2	1.7	9.9	0.9	1.6	0.9	17.2
- manure	0.8	1.8	2.7	1.2	0.7	0.4	7.6
Sum of biogenic wastes/residues	**15.8**	**9.4**	**20.3**	**7.5**	**6.3**	**7.1**	**66.4**
Energy crops	**4.1**	**12.1**	**1.1**	**13.9**	**2.6**	**3.6**	**37.4**
Grand total	**19.9**	**21.5**	**21.4**	**21.4**	**8.9**	**10.7**	**103.8**
Share of energy crops	21%	56%	5%	65%	29%	34%	36%

Source: IE (2003); technical potentials *without* ecological restrictions

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SustainablePotential (1)

	potential land		WBGU-„guard rail“		
Region	**[mio.ha]**	**[%]**	**[mio.ha]**	**[%]**	**[EJ/a]**
Europe	22	4.5	22	4.5	2.5
Asia + Australia	37	0.7	26	0.5	3
Africa	111	3.8	111	3.8	12.7
Latin America	323	16	165	8	18.8
North America	101	5.9	67	3.6	7.7
World	**595**	**4.6**	**391**	**3**	**44.7**

Source: WBGU (2003)

SustainablePotential (2)

Author(s)	Time Frame of estimates	Raw biomass potential (EJ/a)			Liquid biofuels after conversion (EJ/a)
		Crops	Biomass waste	**Total**	
IPCC TAR: Mitigation (2001)	2050	440	N/A	**440**	154
	2100	310		**310**	109
IIASA 2001	2050, Low	240	130	**370**	130
	2050, High	320	130	**450**	158
	2050	A/NR	A/NR	**150**	53
Yamamoto et al. 2001	2050	110	72	**182**	64
	2100	22	114	**136**	48
Moreira 2002	2100	1301	N/A	**1301**	455
Lightfoot/Greene 2002	2100	268	N/A	**268**	94
Hoogwijk et al 2003	2050, Low	0	33	**33**	12
	2050, High	1054	76	**1130**	396

Source: Moreira (2004)

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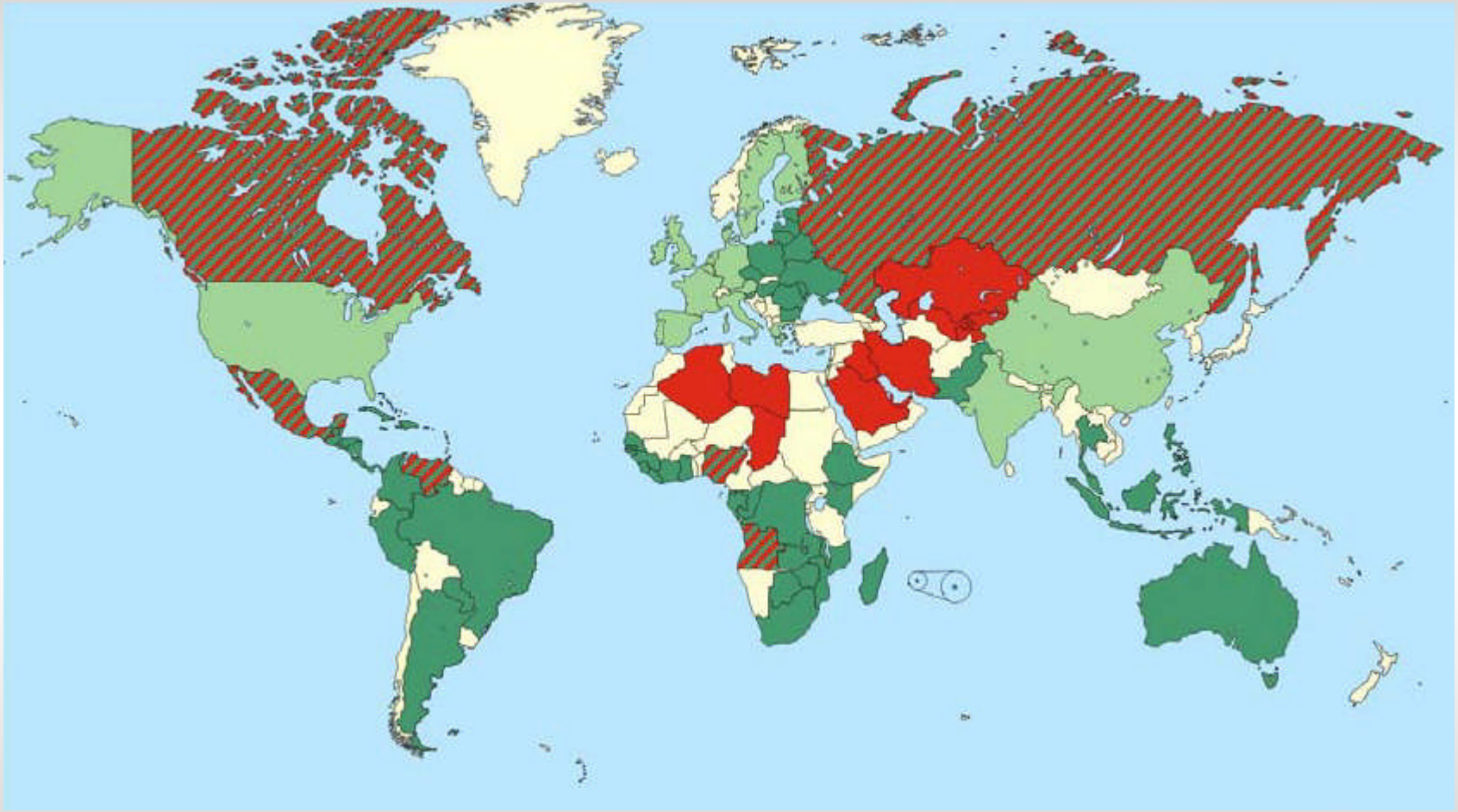
GlobalPattern 2030

Sustainable biomass



= oil-export = oil & bio domestic = bio-export = bio domestic

Source: IEA (2005)

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Local Potentials

Sustainable biomass

Advancing Bioenergy for Sustainable Development
Guideline for Policymakers and Investors
Volumes I, II, and III

April 2005

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Interim Summary

- **short-term options for DC biofuel exports: BioEtOH (sugarcane), plant oil/FAME**
- **Plant oil/FAME larger species variety, more decentral production + processing, easier use of by-products; exports possible for more DC than BioEtOH, + higher direct employment**
- **Competing use: feedstock for chemicals**
- **Biofuel exports only if economically viable supply potentials + infrastructure (processing, transport)**
- **longer-term: BtL routes also for DC**

Results

Biofuel exports from DC *only if*

- **food security is given**

and

- **biofuel production leads to higher environmental and socio-economic benefits than alternative land uses.**

For 2nd condition, no adequate analyses for DC is available; operational/quantifiable concepts for „sustainability “ in DC missing.

Way Forward

- **Resources for local/national stakeholders to assess cost, environmental, and social sustainability of bioenergy → IEA, MDB, bilateral donors**
- **Research crops varieties + cultivation for**
  - **closed material flows („wet routes“),**
  - **climate/soil conditions in DC**
  - **erosion reduction + carbon sequestration**
- **Initiate good practise in cooperation with research institutions in developing countries; include bioenergy business**