Environmental balance: Applications of biomass

Outcomes of the modelling exam on *identifying environmentally beneficial ways of using biomass for energy*

… based on **Green-X**Environment

SD Council Belgium – biomass seminar
Brussels, 3 October 2007

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Content

- Introduction
- Modelling constraints / Key assumptions
- Main outcomes
- Conclusions

Renewable energy sources (RES) have become more and more relevant in the European and global energy markets.

RE technologies help …

- **decreasing import dependency**
- **diversifying sources of production**, and
- ***contribute to a sustainable development***.

This years political developments in Europe …

10 January 2007 … The Commission publishes the **Renewable Energy Road Map** (COM (2006) 848 final) (as part of the ***integrated energy and climate change package "Energy for a changing world")***

9 March 2007 … The Council of the European Union agrees …

→ to increase **RES-share in EU energy mix** up to **20% by 2020**

→ **Binding overall RES target for each Member State**

i.e. → ***National targets*** covering the ***whole energy sector***.

→ Minimum ***10% biofuels*** in each Member State.

Next steps … Preparation of the new policy … *The overall 20% target for RES has to be broken down into **national targets** …*

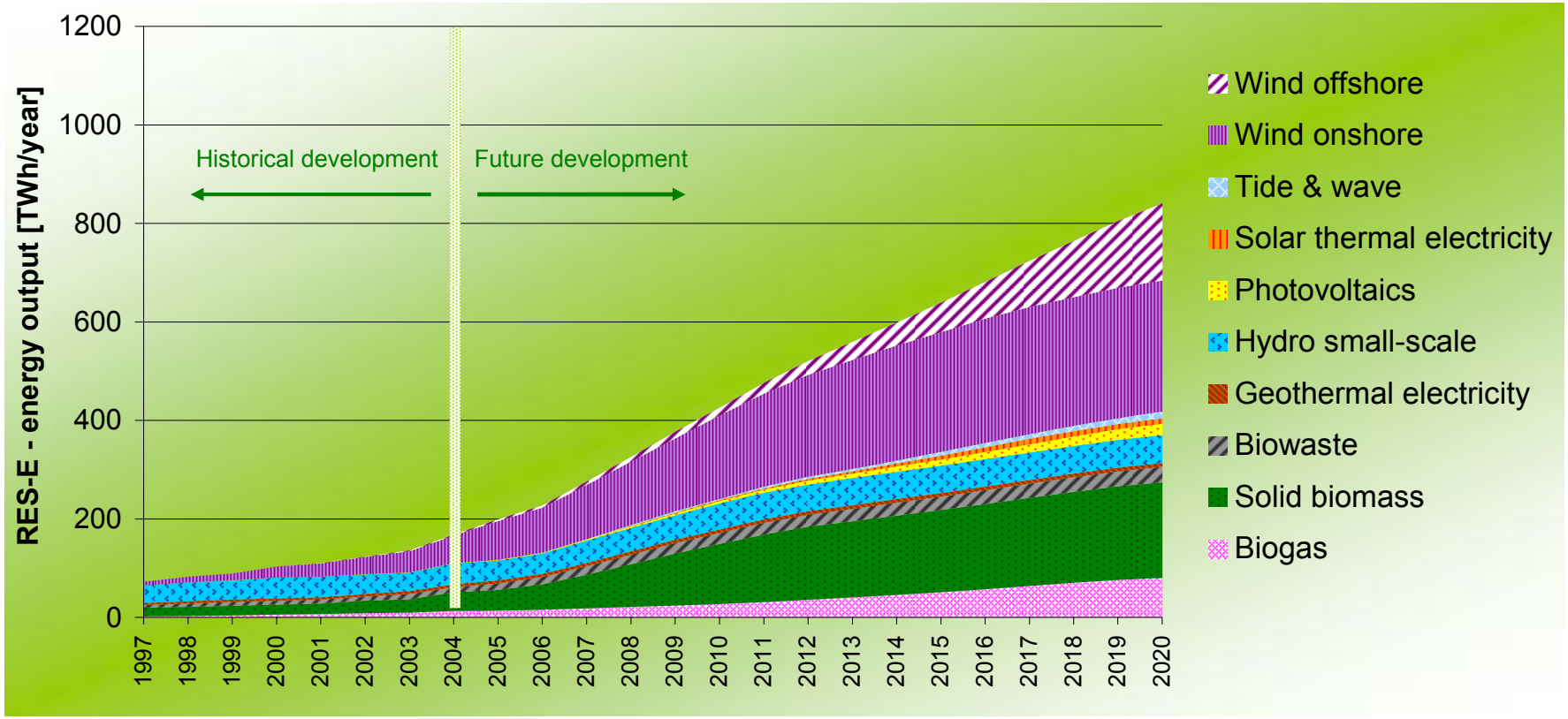
… which emphasises the need for further sound qualitative & quantitative analyses.

Renewable energy sources (RES)

Renewable Energy Roadmap (European Commission, January 2007)

European Union …

20% Renewable Energies by 2020



Green-X balanced scenario

Biomass … currently delivers some 2/3 of RES in total within the EU and will continue to be **one of the most important RES** in the coming years.

Nevertheless,

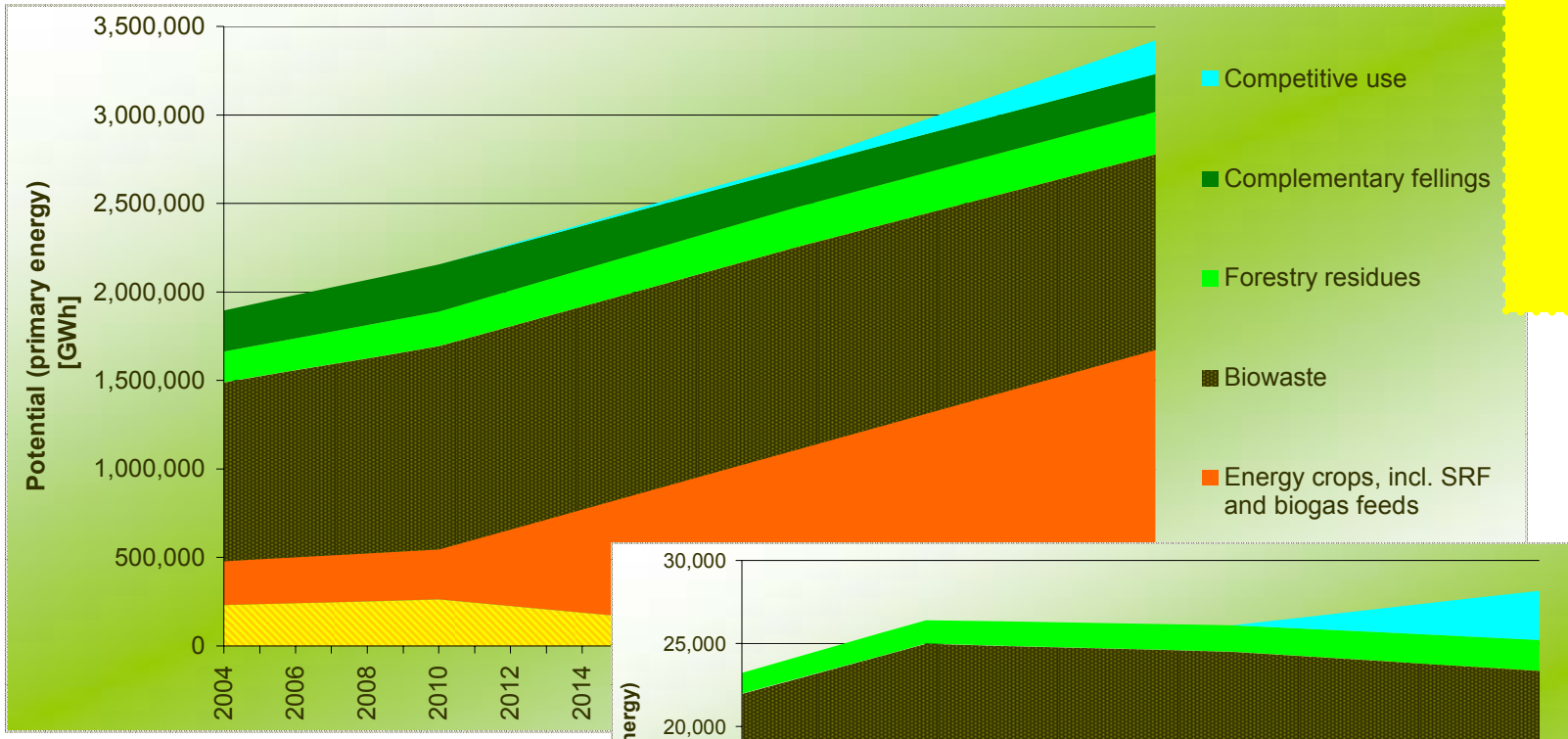
… its **growth is lacking behind what is needed**
→ ***interest in bioenergy increased rapidly*** (biomass action plan)

… there is only a **limited availability of biomass** to produce bioenergy without ***additional environmental pressure***, and without ***reducing Europe's food self sufficiency***
→ (EEA, 2006).

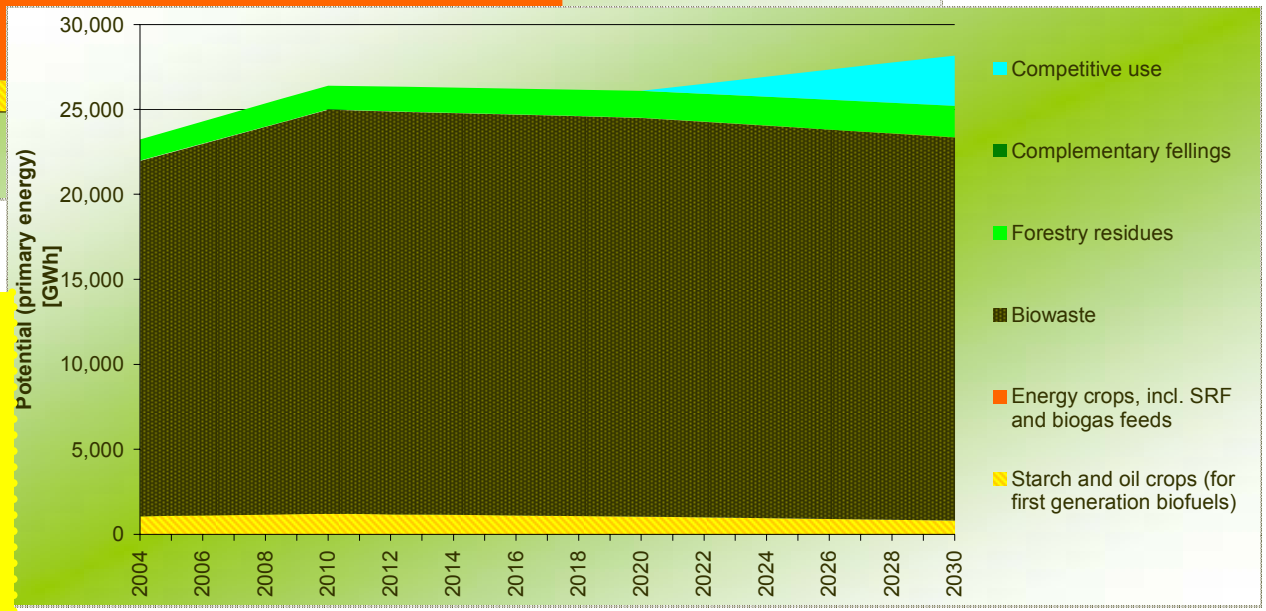
How much bioenergy can Europe produce without harming the environment?
EEA Report No 7/2006: *www.eea.eu.int*

Furthermore,
biomass can be used for **electricity**, **heat** & as **transport** fuel.
→ Explore the ***environmental & economic effects*** of using the environmentally-compatible primary bioenergy potential in the competing end-use sectors

Biomass … Europe's (EU25) environmentally enhanced potential (based on EEA, 2006).



EU-25, 2030: 293 Mtoe … ~16% of gross consumption



Belgium, 2030: 2.4 Mtoe … ~4.5% of gross consumption

This study focuses on:

- Identification of an **environmentally optimised biomass deployment** in the sectors electricity, heat and transport
- Assessment of the **avoided GHG emissions and air pollutant emissions** (direct and LCA)
- Analysis of the **impact on the supply security** ***(import dependency)***
- Derivation of the **additional generation costs** and costs of CO_2 avoidance

Green-XENVIRONMENT

The Green-X model

Simulation model for energy policy instruments in the European energy market

- RES-E, RES-H, RES-T and CHP, conventional power
- Based on the concept of dynamic cost-resource curves
- Allowing forecasts up to 2020 on national / EU-27 level

Reference clients: DG RESEARCH, DG TREN, DG ENV, Sustainable Energy Ireland, German Ministry for Environment, European Environmental Agency, Luxembourg's Energy Agency, IEA, etc.

- Solely bioenergy!
- Transparent linkage of feedstocks, pre-conversion & conversions technologies

Green-X ENVIRONMENT

Major inputs:

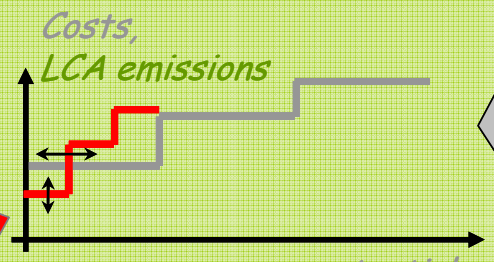
- **GEMIS** (GHG & air pollutant direct & LCA emissions, technology cost)
- **EEA** (2006) (potentials)
- **PRIMES** (demand, conventional reference)

The Green-X Environment approach: Dynamic cost-resource curves

Potentials
- by bioenergy feedstock
- by country

Costs, LCA emissions
- by bioenergy (pre)conversion technology option
- by country

DYNAMIC COST-RESOURCE CURVES
- bioenergy feedstock/technology bands
- by country



- by year

Dynamic aspects
- Costs: **Dynamic cost assessment**
- Potentials: **Dynamic restrictions**
- LCA emissions: **Dynamic adaptation**

(technological change)
(technology diffusion)
(technological progress, changing reference system)

Modelling constraints:

- ***Time horizon:*** 2004 to 2030 – Results are derived on a yearly base
- ***Geographical coverage:*** European Union 25 (as of 2006)
- ***Reference energy system:*** PRIMES modelling – in particular PRIMES "low-carbon energy pathway scenario" ***LCEP*** scenario (PRIMES, 2004) and PRIMES ***baseline*** (2005)
- ***Optimisation of resource allocation on national level*** – An environmentally beneficial use of biomass was seen in line with the fact that the **resources should be used or converted into other energy carriers where available.** → No trade of primary feedstocks was assumed in all modelling cases.
- ***Imports restricted to biofuels*** – The possibility of **importing bioenergy from abroad was restricted to biofuels** within solely certain variants as it is the scope of the study to contribute to an optimal environmentally beneficial allocation of the *domestic* resource base.
- ***Technology selection & combination with feedstocks*** – A **pre-selection** based on expert knowledge has been performed, where first **environmental and secondly economic criteria** was of dominance. The outcome of this selection process forms in total a set of 124 process chains – i.e. from the various feedstock over different pre-conversion paths to the final conversion technologies.

Modelling constraints:

- **Technology selection** - The **pre-selected options**

Electricity:

- Co-firing in non-combined power plants (< 5% straw/10% wood contribution to coal)
- CHP: distinction between sizes 1…20 MWel, fed with biogas, wood and various waste streams.
  - CHP co-firing also includes gas-CHP that is fed with a mix of natural gas and biogas after a series of pre-treatment processes;

Both based on almost all biomass resources – from forestry to energy crops and waste streams.

Heat, non-grid:

- Pellets
- Wood chips

Both mainly based on forestry to selected energy crops and waste streams (based on wood).

Heat, grid-connected:

- Heat plants
- CHP

Both based on various biomass resources – from forestry to energy crops and waste streams.

Transport Fuels:

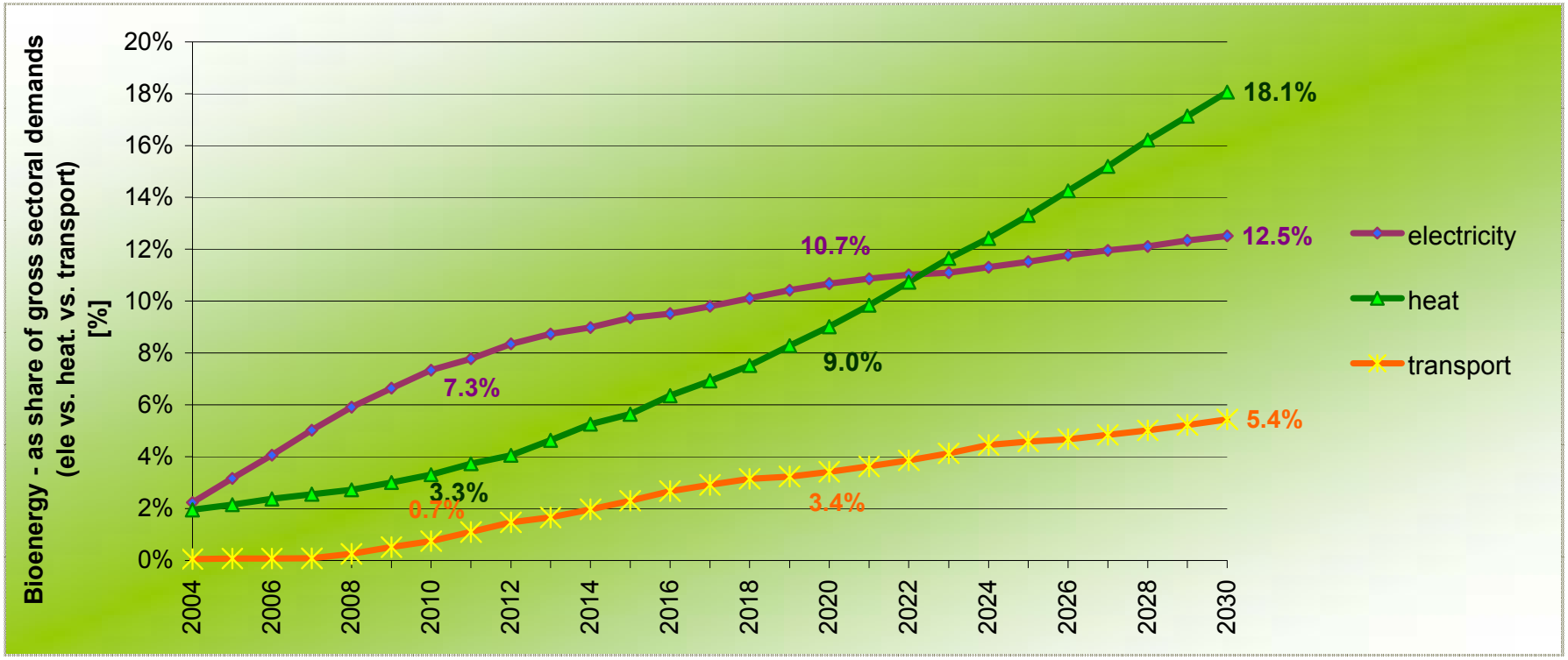
- FAME
- Ethanol
- Ethanol+ (lignocellulosic ethanol from enzyme-enhanced conversion of whole plant)
- BtL (via gasification + Fischer-Tropsch synthesis of lignocellulosic feedstocks)

Investigated cases:

- **Potential exploitation:** *default … **100%*** (variant: 75%) ***exploitation*** of the total biomass potential.
- **Optimisation principle:** *default … **least cost in terms of primary energy***
  Variants … least cost GHG or air pollutant avoidance
- **Sector specific prioritisation:** *default … no prioritisation*
  variants: **prioritisation to the sectors of electricity & heat** or a **separate target for biofuels** (w/o trade, w/o imports)
- **CHP optimisation:** *default … **43% of all generated heat is actually used***, variant: **all generated heat can be used** ("optimised CHP").
- **Exploitation based on "20%-RES-by-2020" - least cost:**
  The **same exploitation of overall biomass use** was modelled as in a recent study for DG Environment (Ragwitz et. al, 2006), **contributing to the "20% RES by 2020" discussion**
- **General settings for the overall energy system:**
  Primary energy prices, sector specific demands are based on ***PRIMES Low-carbon emission pathway*** *(default)* or **PRIMES baseline scenario**.

► About 16 % of the EU's primary energy consumption in 2030 can be met by biomass

Pure least cost: … 12.5% biomass electricity … 18.1% biomass heat … 5.4% biofuels
(15.9% in terms of primary energy)

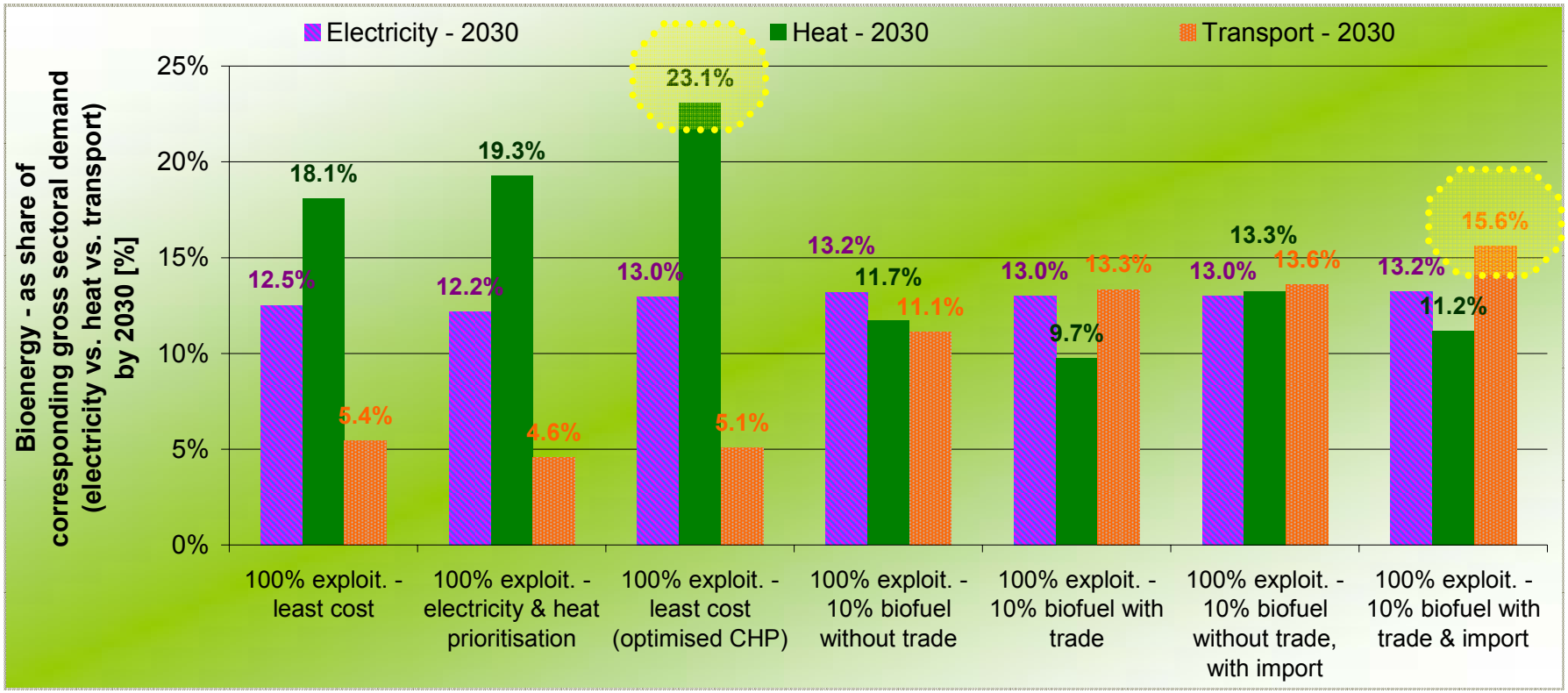


… based on Primes LCEP (2004)

(Primes baseline (2005)) *(12.6%)* *(14.8%)* *(7.2%)*
(15.3% in terms of primary energy)

► About 16 % of the EU's primary energy consumption in 2030 can be met by biomass

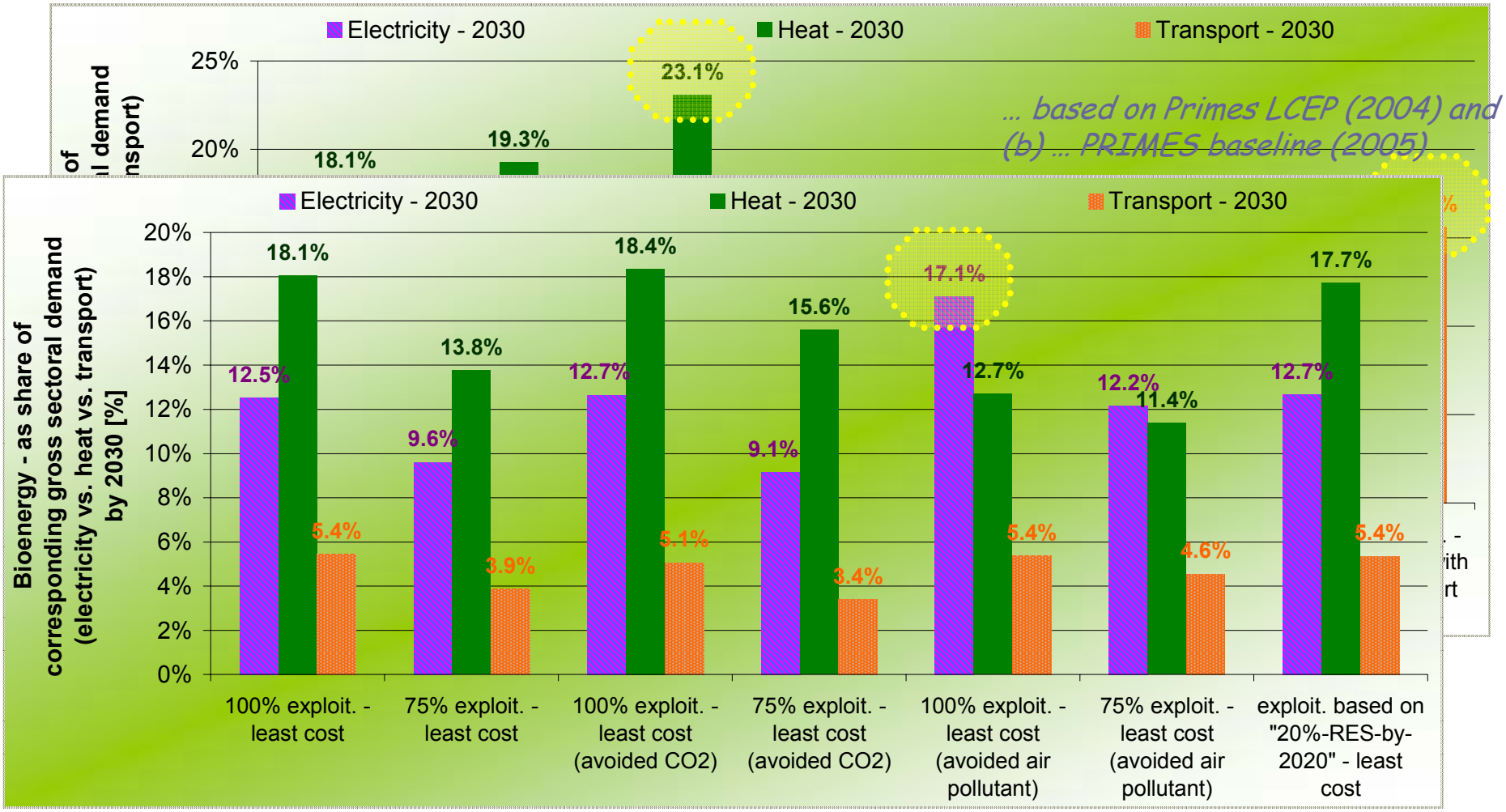
… up to 14.3% biomass electricity … up to 23% biomass heat … up to 15.6% biofuels



… based on Primes LCEP (2004)

► About 16 % of the EU's primary energy consumption in 2030 can be met by biomass

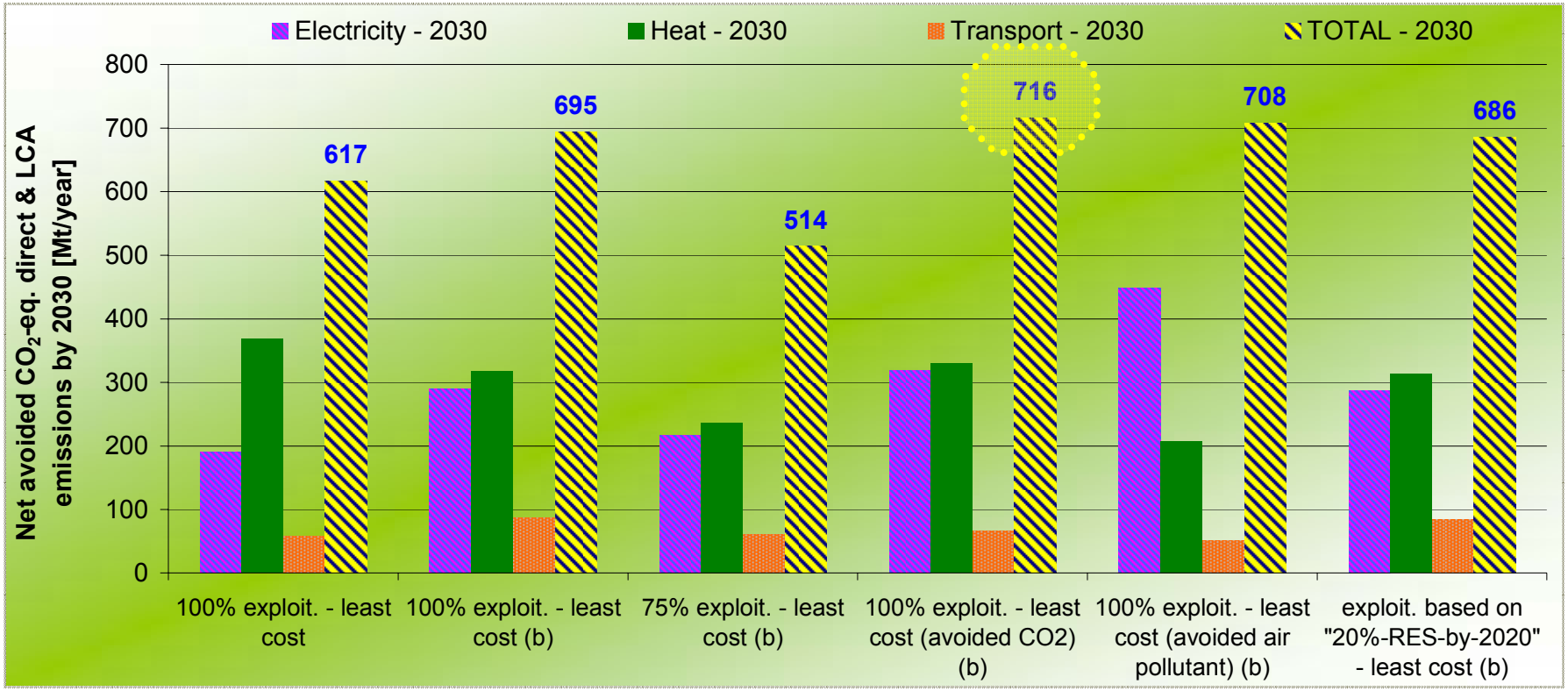
… up to 17.1% biomass electricity … up to 20% biomass heat … up to 15.5% biofuels



► Bioenergy as an important contribution to meeting EU GHG reduction targets

Full exploitation of sustainable biomass potentials: … avoidance of up to 716 Mt of CO_2 emissions (net life cycle emissions - LCA)

In case of other policy objectives: … about 617 (to 708) Mt CO_2 savings



(12 to 14% of EU's 1990 GHG emissions)

… based on Primes LCEP (2004) and (b) … PRIMES baseline (2005)

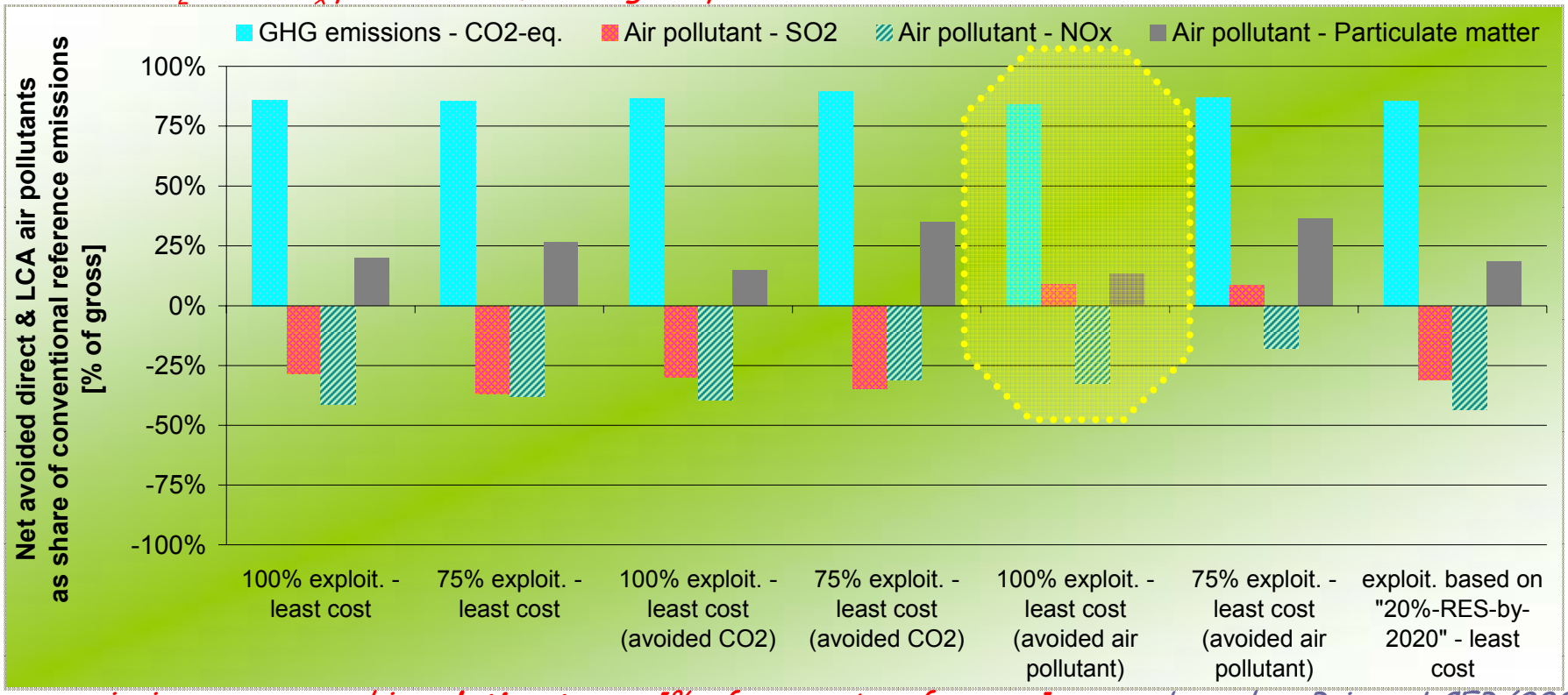
► LCA emissions from air pollutants like SO_2 and NO_x may increase

*Most of the investigated bioenergy cases → increase of the LCA emissions of **SO_2** and **NO_x** by up to 44% (compared to the conventional reference system)*

*… only a marginal change of **particulate matter** emissions.*

Exception: Explicit priority to air pollutant reduction

→ less SO_2 and NO_x particulates, but higher particulate emissions



*… emissions expressed in **relative terms** [% of convent. reference]*

… based on Primes LCEP (2004)

► LCA emissions from air pollutants like SO_2 and NO_x may increase

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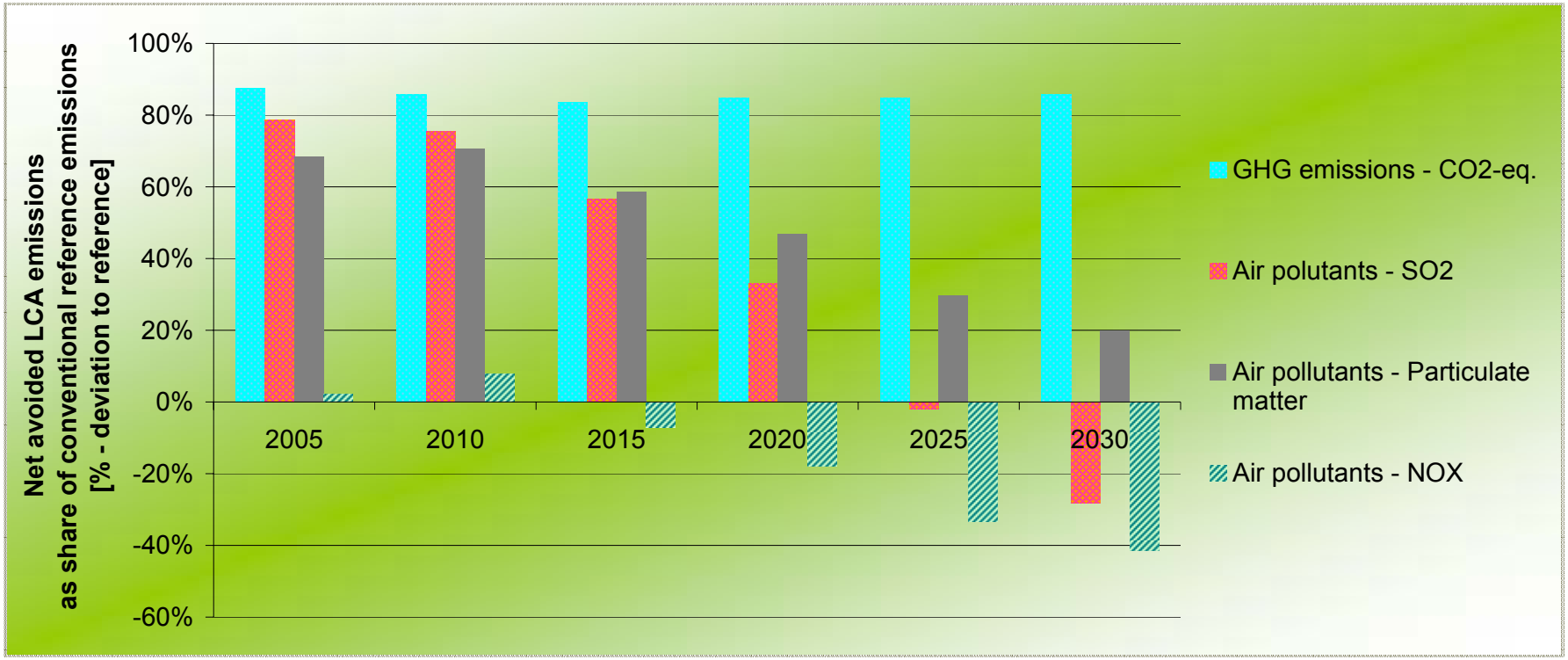
Reasons? … A closer look on the dynamic development

Pure least cost (in terms of primary energy)



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► LCA emissions from air pollutants like SO_2 and NO_x may increase

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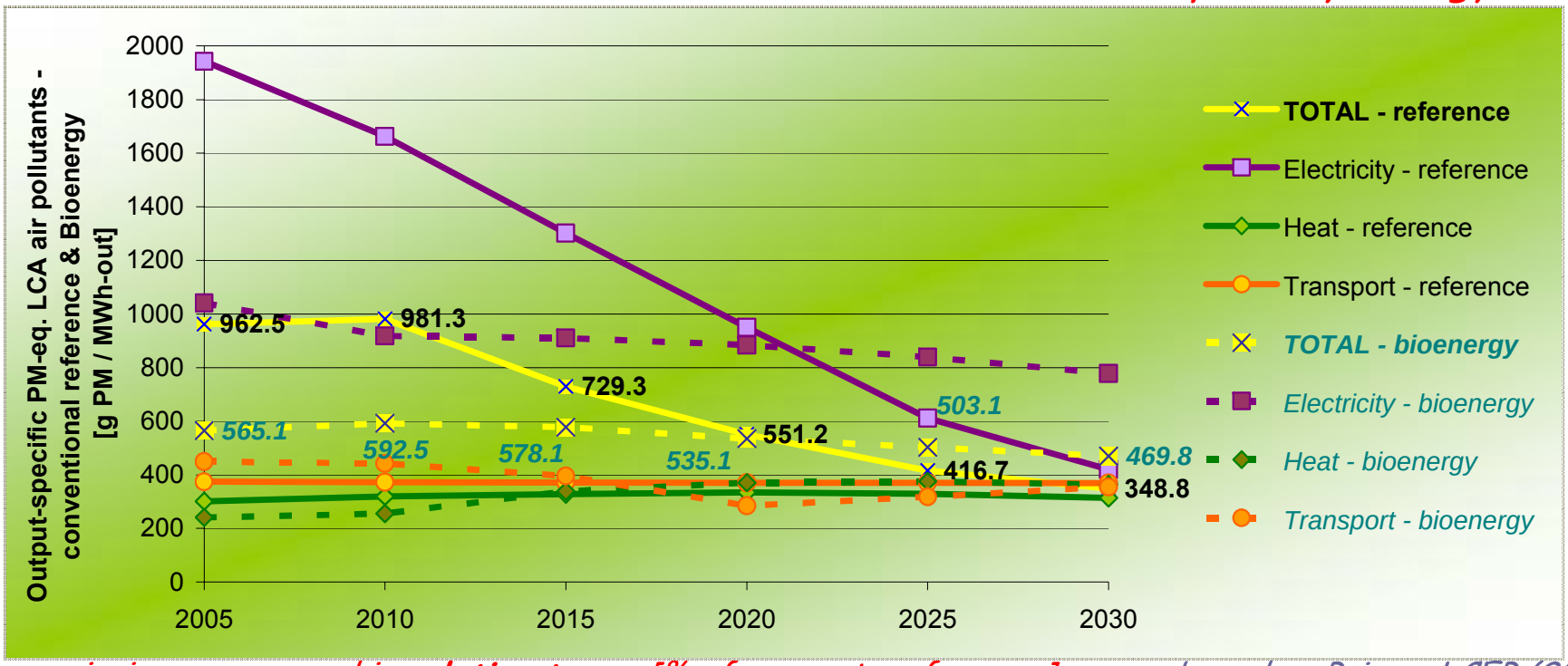
Reasons? … A closer look on the dynamic development of the conventional reference system

Pure least cost (in terms of primary energy)

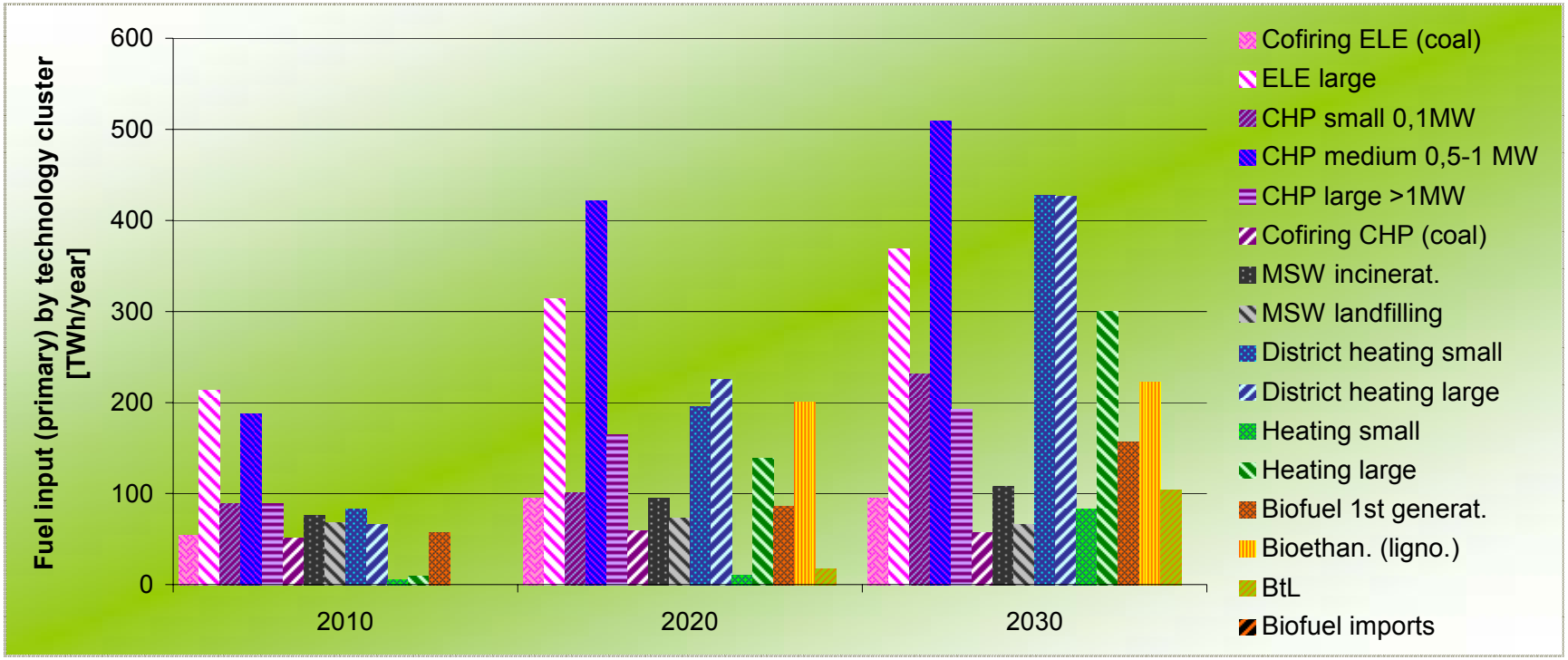


*… emissions expressed in **relative terms** [% of convent. reference]*

… based on Primes LCEP (2004)

► A broad technology mix occurs

As stated for the different energy sectors,
*also **at technology level***
a broad set of technologies is needed
to achieve an enhanced bioenergy deployment.

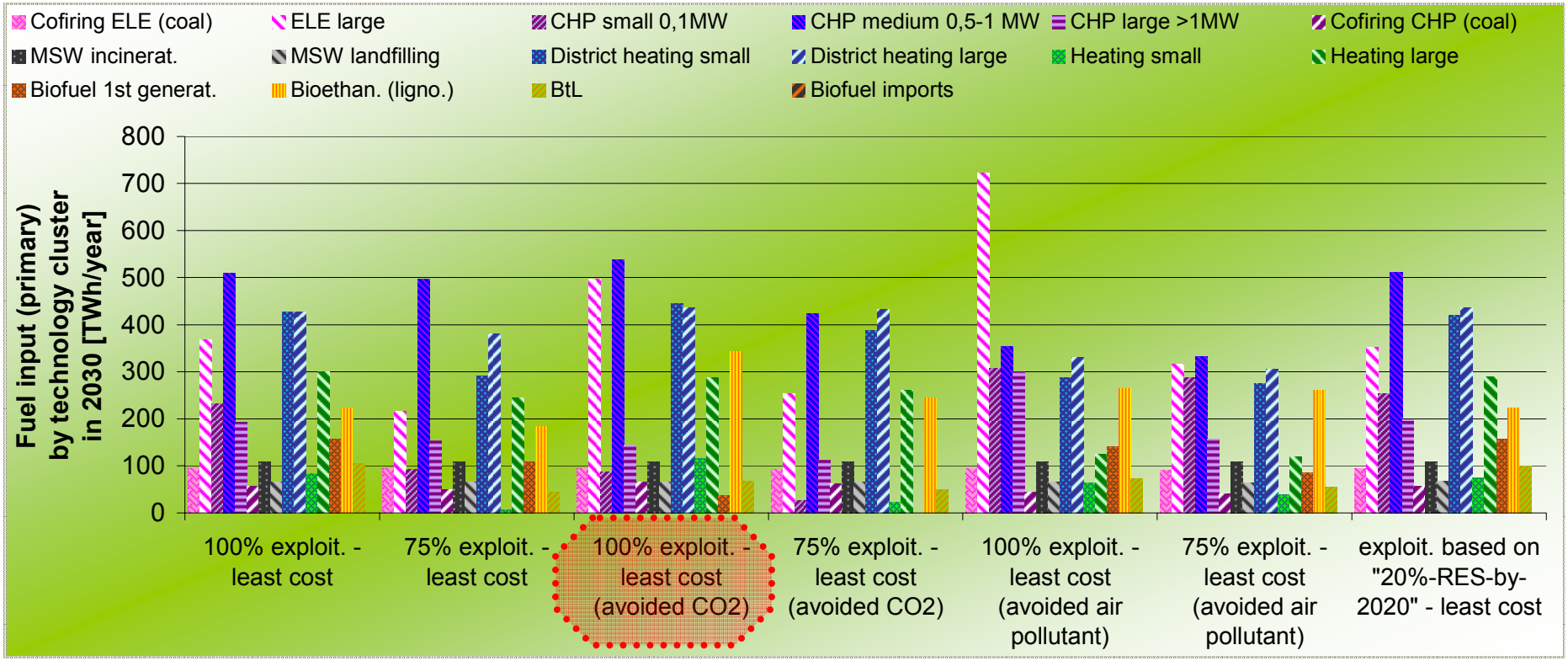


Fuel input
by technology cluster

Pure least cost (in terms of primary energy)
... based on Primes LCEP (2004)

► A broad technology mix occurs

*Striving for **"least cost GHG reduction"**: Large-scale power plant and 2nd generation biofuels based on ligno-cellulosic bioethanol benefit, whilst large-scale CHP and 1st generation biofuels deploy less.*

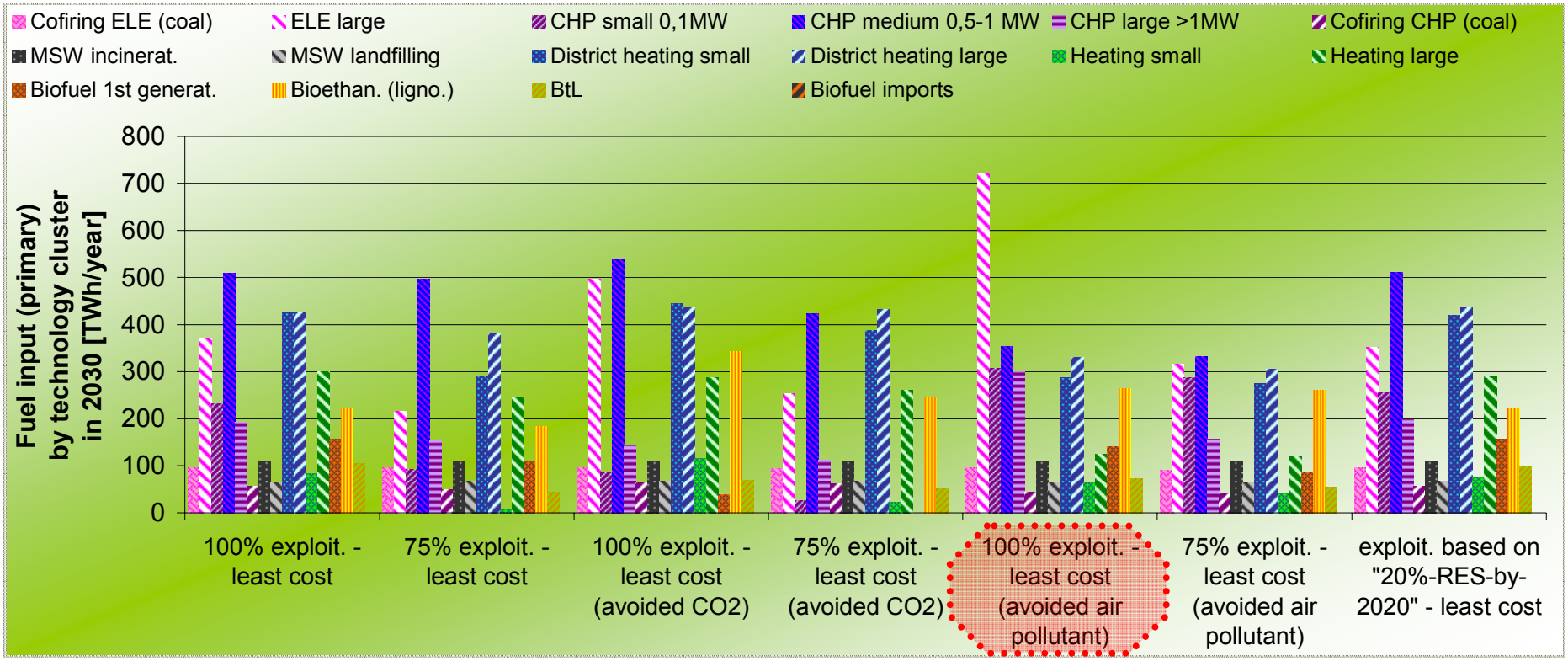


Fuel input
by technology cluster in 2030

Pure least cost (in terms of primary energy)
... based on Primes LCEP (2004)

► A broad technology mix occurs

*Focusing on **"least cost air pollutant avoidance"**: a shift towards large-scale plant – i.e. pure power plant as well as CHP. In terms of overall penetration the biofuel sector stays unaffected, but more ligno cellulosic bioethanol and less 1st generation biofuels and BtL.*



Fuel input
by technology cluster in 2030

Pure least cost (in terms of primary energy)
... based on Primes LCEP (2004)

► Increased bioenergy deployment brings large benefits to EU security of supply

The increased biomass deployment leads to a reduction in fossil fuel demand of up to 2691 TWh per year in 2030. In 2030 up to 47 billion € can be saved on fossil fuels (which possibly affects a country's trade balance).

Supply security - avoided fossil fuels	**Avoided fossil fuels in energetic terms - by sector**						
	[Unit]	2005	2010	2015	2020	2025	2030
Electricity	TWh/a	264	628	799	890	960	1,073
Heat (grid-connected)	TWh/a	137	213	346	538	782	1,016
Decentralised heat	TWh/a	10	13	58	125	195	325
Transport	TWh/a	3	35	111	172	232	277
TOTAL	TWh/a	**415**	**889**	**1,315**	**1,725**	**2,168**	**2,691**

Supply security - avoided fossil fuels	**Avoided fossil fuels in monetary terms - by sector**						
	[Unit]	2005	2010	2015	2020	2025	2030
Electricity	M€/a	2,313	6,044	8,718	11,055	13,605	15,959
Heat (grid-connected)	M€/a	1,632	2,761	5,067	8,727	13,782	19,086
Decentralised heat	M€/a	128	176	876	2,008	3,383	5,908
Transport	M€/a	43	520	1,815	3,073	4,486	5,771
TOTAL	M€/a	**4,116**	**9,501**	**16,476**	**24,863**	**35,256**	**46,724**

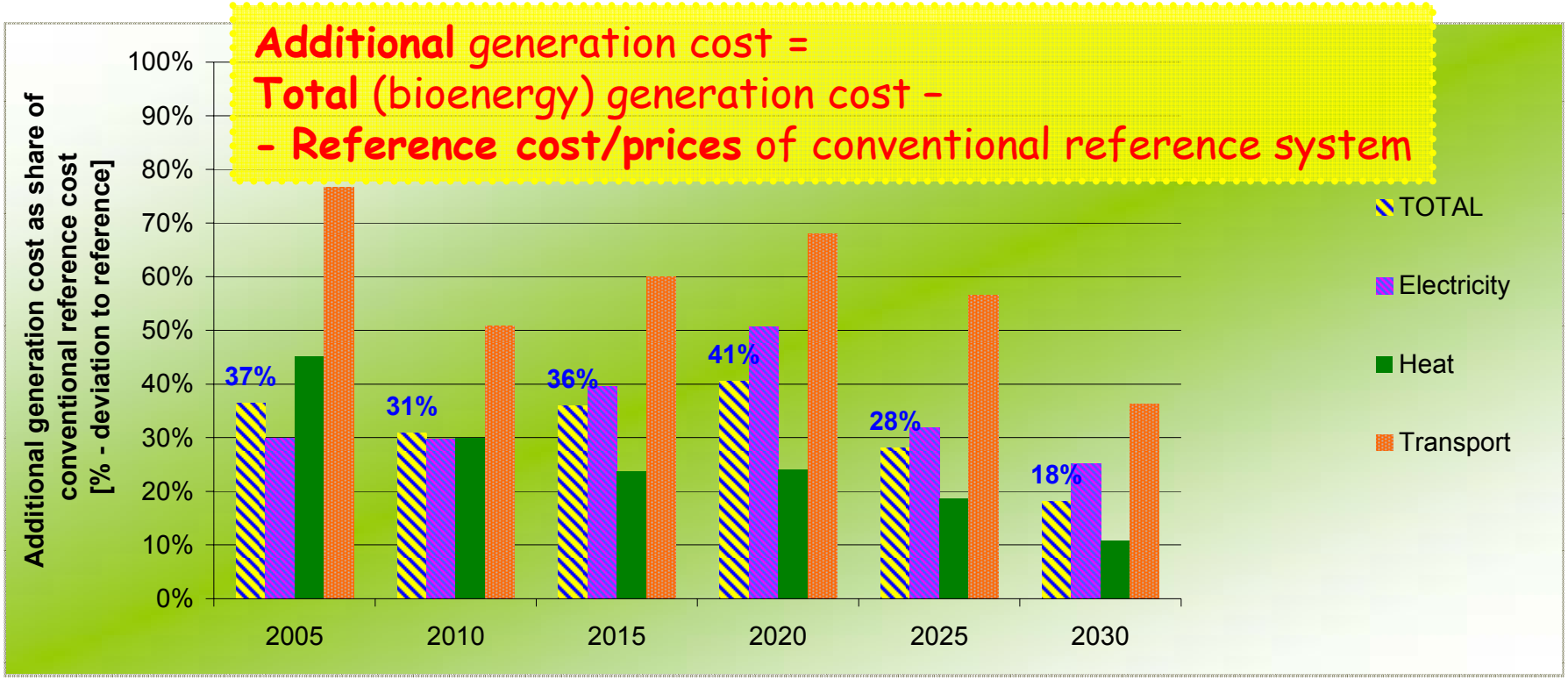
Pure least cost (in terms of primary energy)
… based on Primes LCEP (2004)

*… avoided fossil fuels expressed in **monetary terms** [M€/year]*

► Additional generation costs will be moderate

Maximum level of the additional generation costs in the year 2020 with about 40% (to 70%) above conventional reference costs if the biomass potential is fully exploited.

By 2030: about 18% (to 51%) additional cost

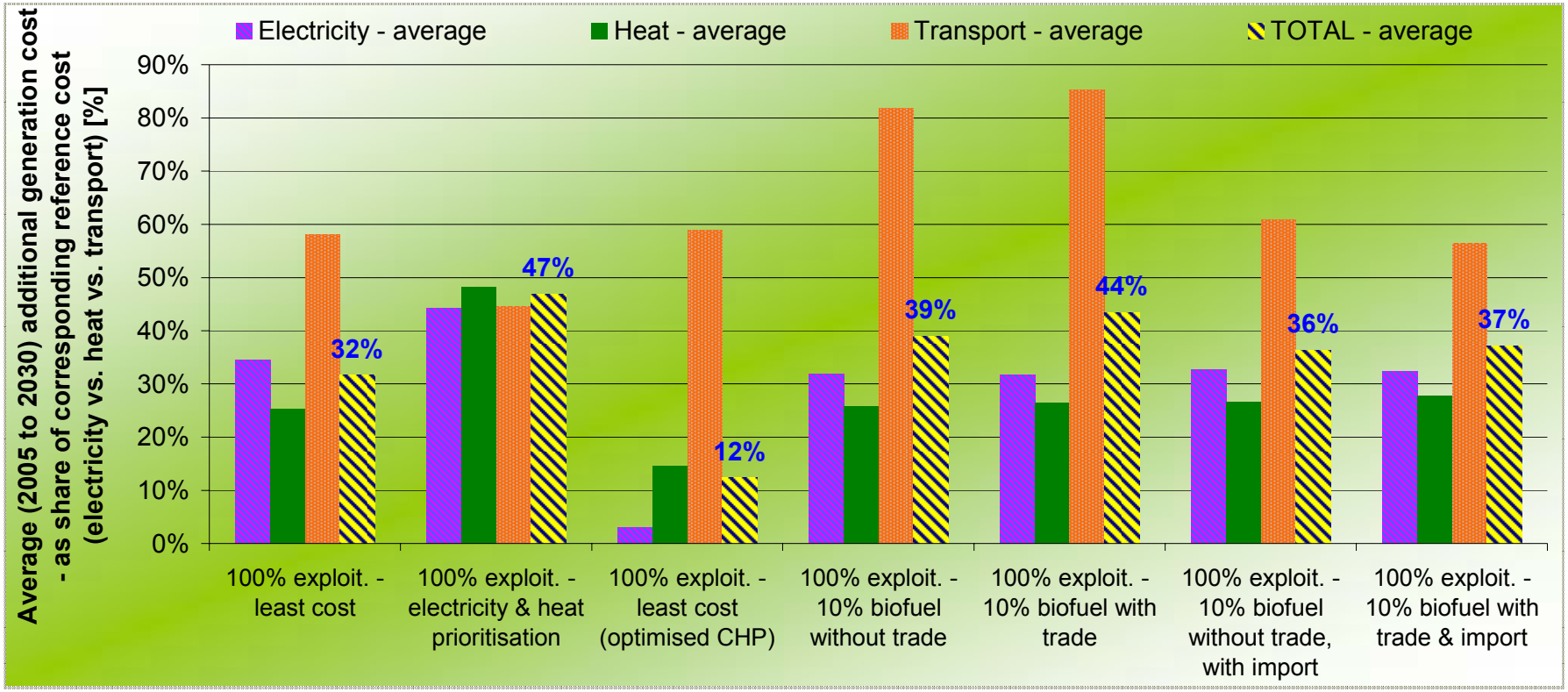


Pure least cost (in terms of primary energy)
... based on Primes LCEP (2004)

Dynamic development
of additional generation cost

► Additional generation costs will be moderate

Additional generation cost on average (2005 to 2030) in case of full bioenergy exploitation: 32% pure least cost, 47% for prioritisation of electricity and heat, 12% in case of optimised CHP, 36 to 44% for the case of a prioritisation of biofuels.



Average (2005 to 2030) additional generation cost

... based on Primes LCEP (2004)

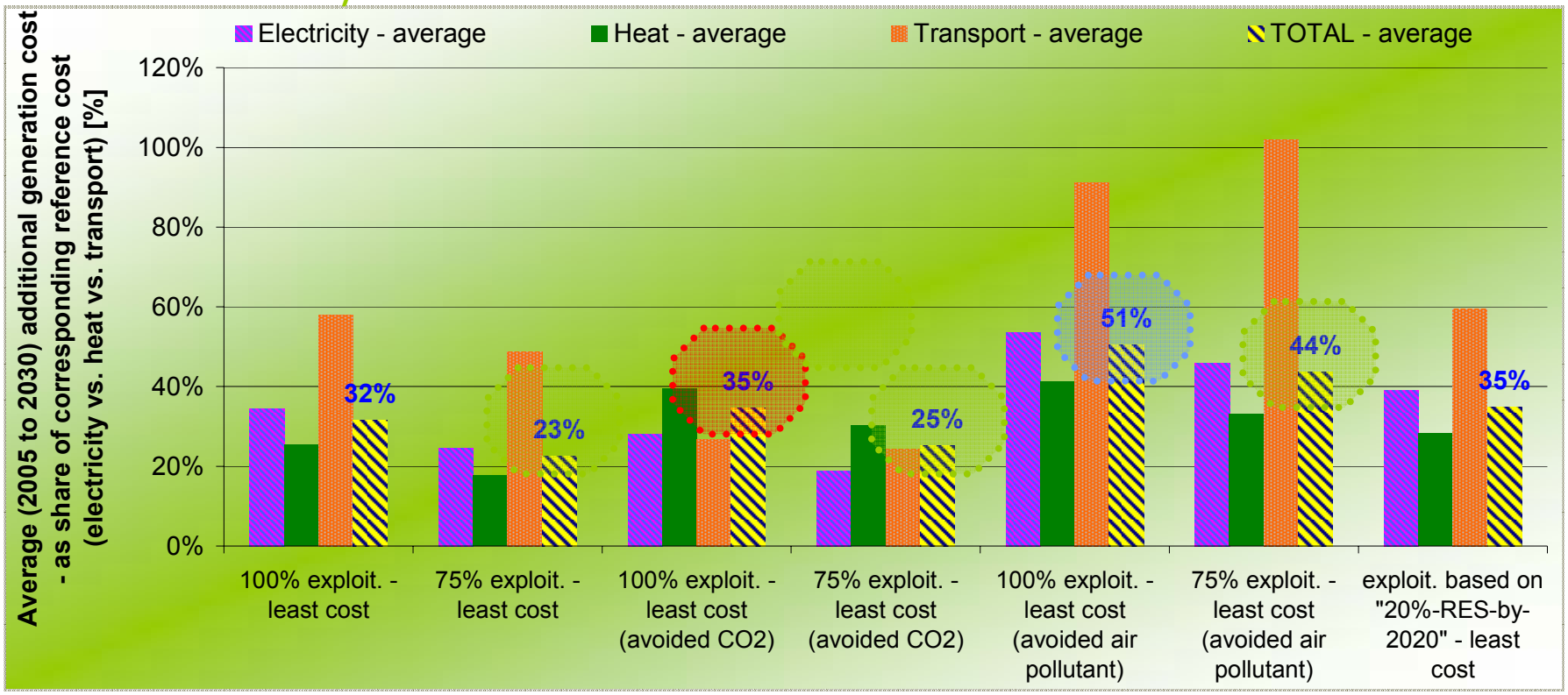
► Additional generation costs will be moderate

Additional generation cost on average (2005 to 2030) in case of full bioenergy exploitation:

32 to 35% pure least cost (in terms of primary energy or CO_2!),

51% in case of avoided air pollutants,

… in case of 75% exploitation: 23 to 44% additional cost!



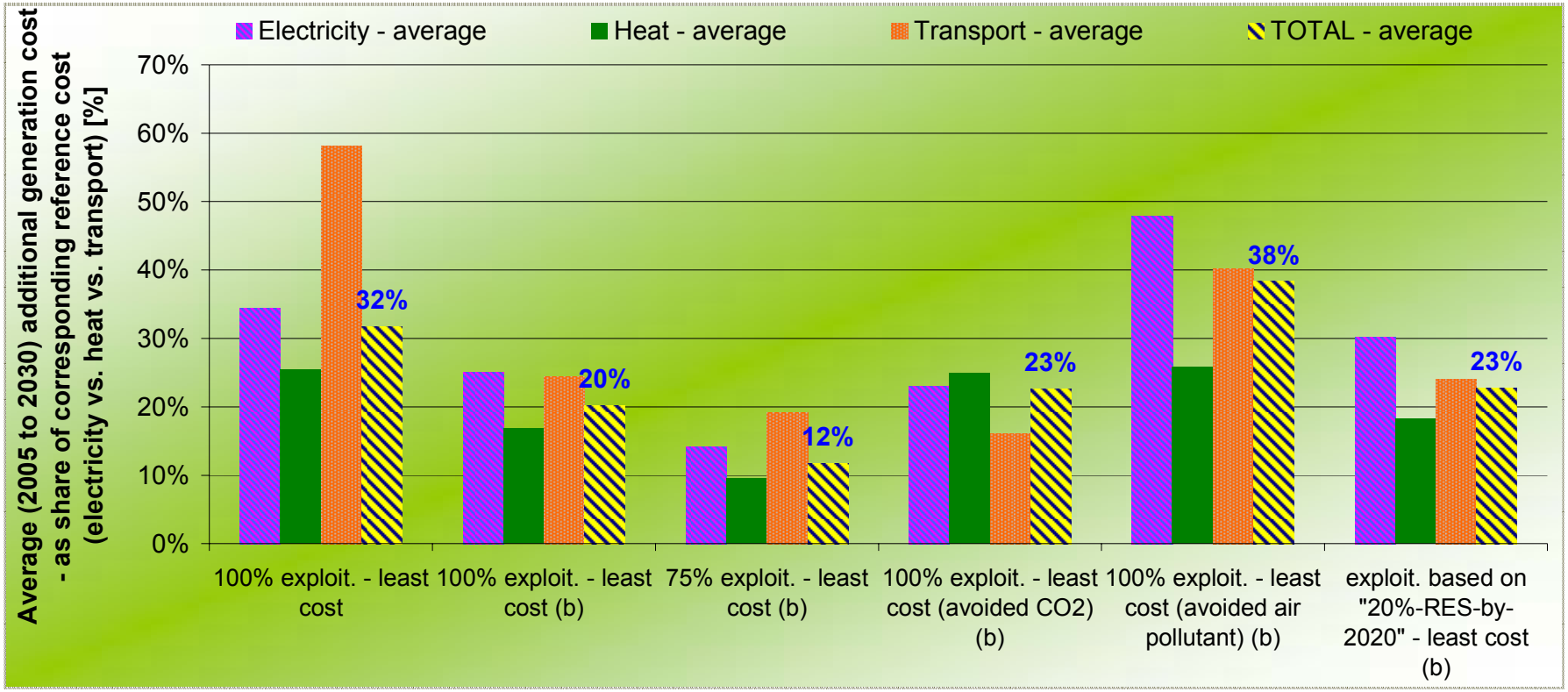
… based on Primes LCEP (2004)

Average (2005 to 2030) additional generation cost

► Additional generation costs will be moderate

"Switching to PRIMES baseline (as 2005)" (i.e. higher oil and reference prices especially in case of biofuels)

→ lower additional generation cost (at about 2/3 of corresponding levels)

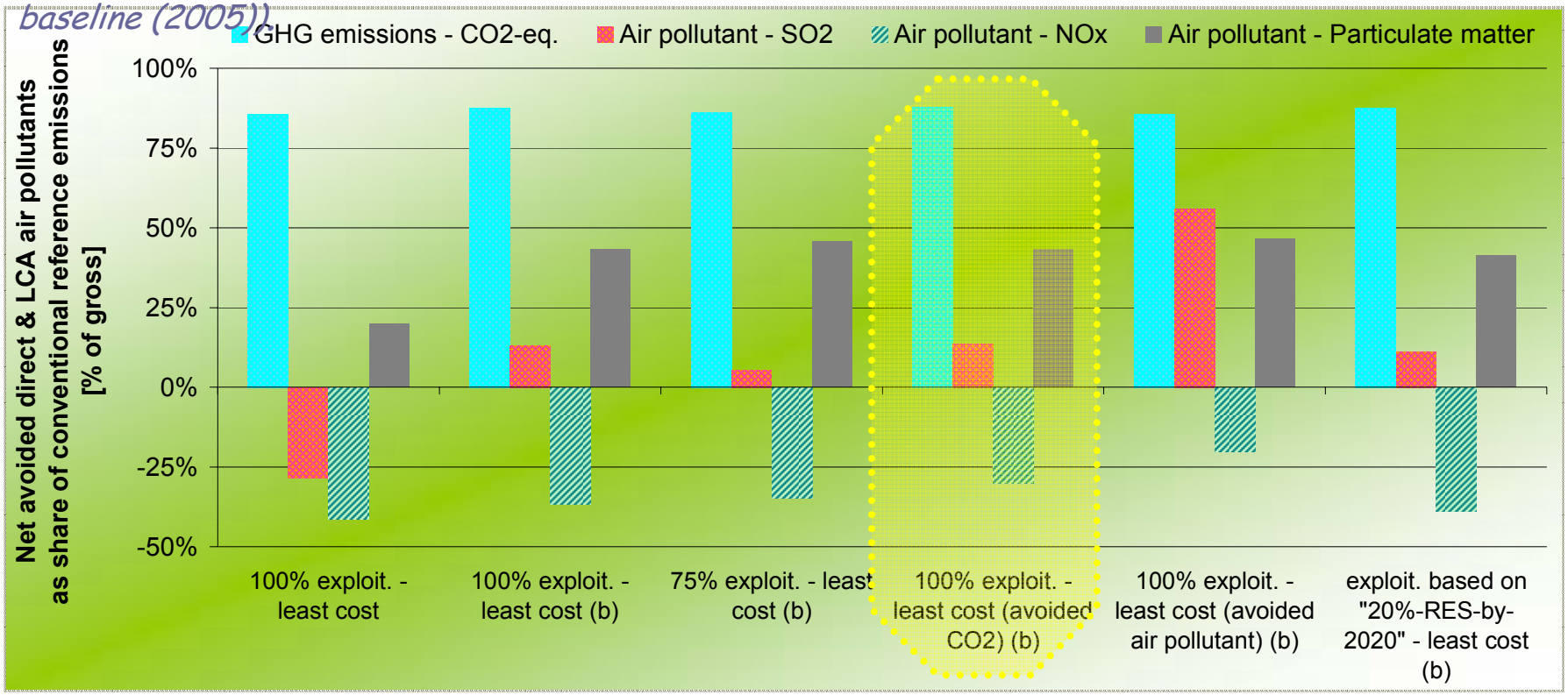


Average (2005 to 2030) additional generation cost

… based on Primes LCEP (2004) and (b) … PRIMES baseline (2005)

► Scenarios based on a least cost GHG reduction lead to maximisation of further benefits

A least cost biomass allocation with respect to the avoided amount of CO_2 lead to additional beneficial situations like high reduction of other air pollutants and high level of avoided fossil fuels at reasonable cost (especially in case of PRIMES baseline (2005))

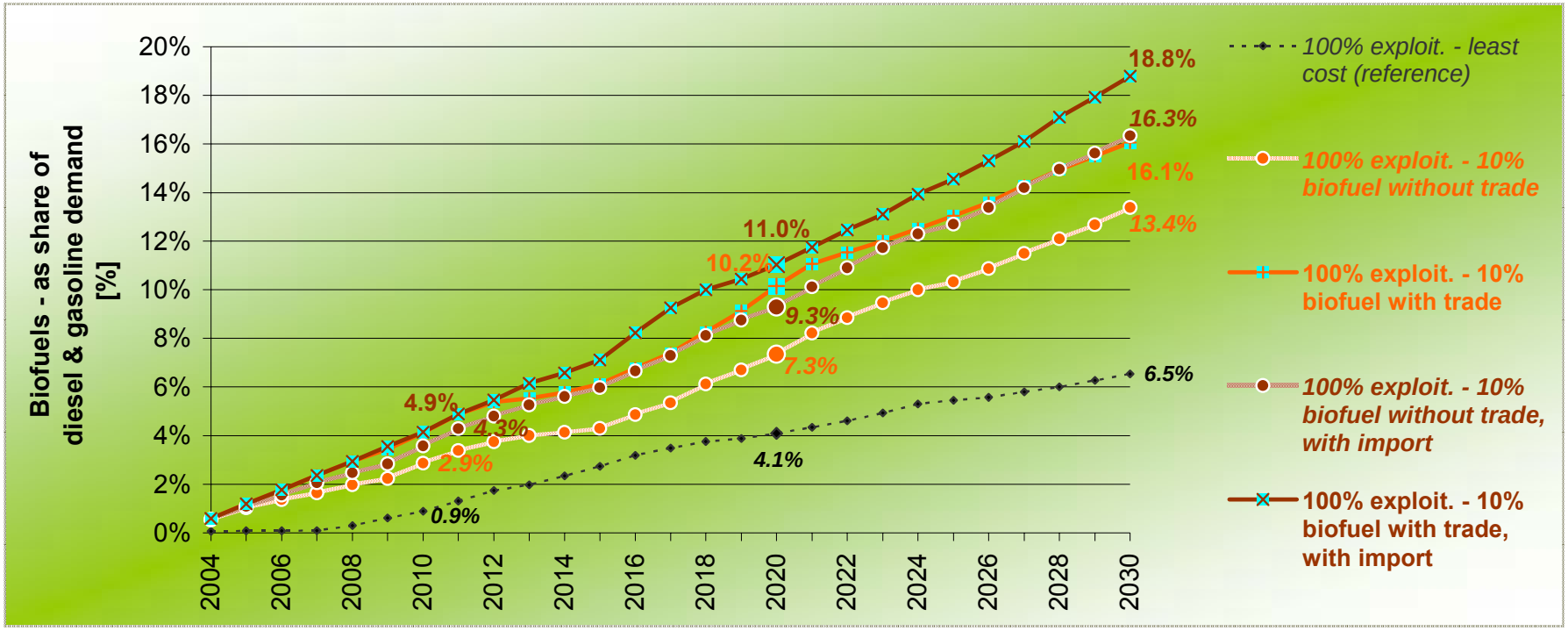


... based on Primes LCEP (2004) and (b) ... PRIMES baseline (2005)

► 10% biofuels by 2020 are feasible

The fulfillment of this policy target is feasible even under the applied restrictions of considering solely environmentally beneficial bioenergy technologies and corresponding feedstocks.

Necessity: Intra European trade … beneficial: Imports from abroad



Biofuel shares *… overview: scenarios on "10% biofuels by 2020"*

… based on Primes LCEP (2004)

► Country-specifics are worth to consider

Country-specific results differ largely among countries as well as investigated cases.

→ *Any policy approach in order to stimulate deployment has to consider the national circumstances with regard to resource conditions and the overall energy market deficits in an appropriate manner.*

	Deployment [%]	**Net LCA emission avoidance - expressed as share of reference emisions** [% - deviation to reference]				**Additional generation cost** [% - of reference cost]
		CO_2-eq.	SO_2	NO_X	PM	
Spain						
Electricity	6%	72%	27%	-69%	-8%	-7%
Heat	22%	95%	-38%	5%	64%	-14%
Transport	10%	43%	48%	-25%	38%	19%
TOTAL	**15%**	**77%**	**-17%**	**-18%**	**46%**	**-5%**
Poland						
Electricity	42%	79%	35%	-89%	-7%	-5%
Heat	23%	94%	-327%	-8%	58%	-11%
Transport	12%	89%	82%	-14%	86%	3%
TOTAL	**38%**	**85%**	**-50%**	**-56%**	**13%**	**-6%**

Pure least cost (in terms of primary energy)
... based on Primes LCEP (2004)

*Example: **Spain** versus **Poland***

► Cross-sectoral least cost indicates the way forward …

*The derived cross-sectoral **least cost-approach represents an artificial instrument**, which does not aim to reflect an energy policy instrument suitable for practical implementation under real-world conditions.*

*It does allow assessing "optimal" targets for the contribution of biomass within each considered end-use sector – i.e. bioelectricity, bioheat and biofuels – according to well defined criteria such as **GHG avoidance** or **primary deployment**.*

► … but actual deployment requires effective & efficient energy policies

*An enhanced deployment of bioenergy as sketched in the conducted model exam requires strong deployment strategies **(combined with environmental regulations (labeling?))** in order to become reality.*

→ *The conducted cross-sectoral least cost approach represents an important **step forward to apply an appropriate holistic energy policy framework** accompanied by strong market incentives within each energy sector.*

► … but actual deployment requires effective & efficient energy policies

Recommendations for implementing effective & efficient renewable electricity/energy policies

→ www.optres.fhg.de

… concise "recommendations report" & comprehensive final report on "Assessment and optimisation of renewable energy support schemes in the European electricity market"

→ www.green-x.at … information on **Green-X** – i.e. our simulation model for energy policy instruments in the European (renewable) energy market

→ www.futures-e.org … ongoing EU research project in this topical area

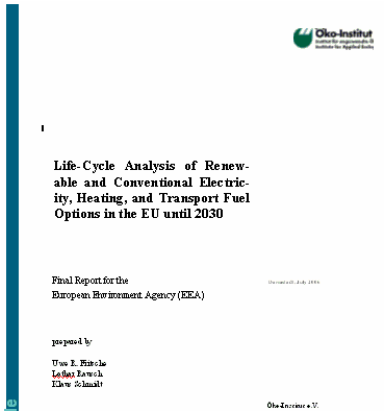
futures-e

► the way forward in our exam

The corresponding final (technical?) EEA-report will be published soon!

Background information

1) How much bioenergy can Europe produce without harming the environment?, EEA Report No 7/2006: www.eea.eu.int
2) Life-Cycle Analysis of Renewable and Conventional Electric-ity, Heating, and Transport Fuel Options in the EU until 2030 , ETC/ACC Technical Paper, 2007/03, Uwe R. Fritsche, Lothar Rausch, Klaus Schmidt, Öko-Institut: request by e-mail: hans.eerens@mnp.nl
3) Database LCA: www.gemis.de
4) GREEN-X model outcome:
   Assistance with identifying environmentally beneficial ways of using biomass for energy, EU-25, EEA Report forthcoming (autumn 2007), Gustav Resch, Thomas Faber, Mario Ragwitz, Felipe Toro: www.eea.eu.int
5) Background report agricultural sector (summer 2007)
   Estimating the environmentally compatible bio-energy potential from agriculture EEA Report No xx/2007: www.eea.eu.int
6) Background report forest sector Environmentally enhanced bio-energy potential from European forests Marcus Lindner, Jeannette Meyer, Thies Eggers, Alexander Moiseyev European Forest Institute, Joensuu, Finland 23 September 2005. request by e-mail: hans.eerens@mnp.nl



Thanks for your attention!

In case of questions / remarks …

► *Email: resch@eeg.tuwien.ac.at*