ACADEMIA ENGELBERG
Dialogue on Science

Bioenergy

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Biomass Combustion Task

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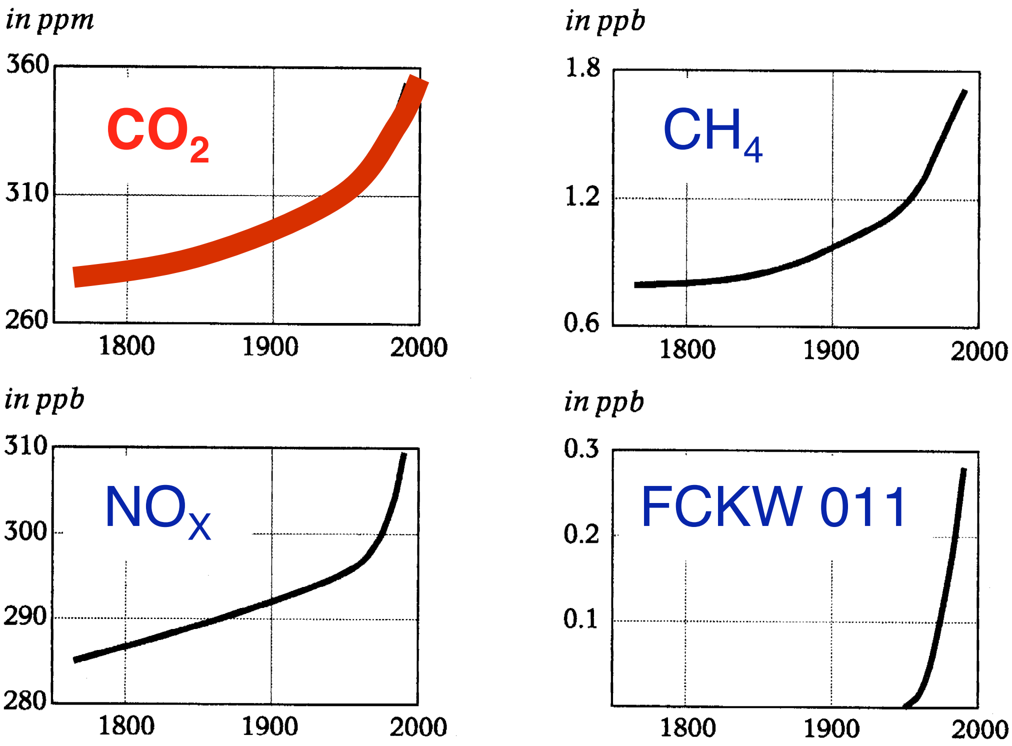
Why Bioenergy ?

Green House Gas Emissions



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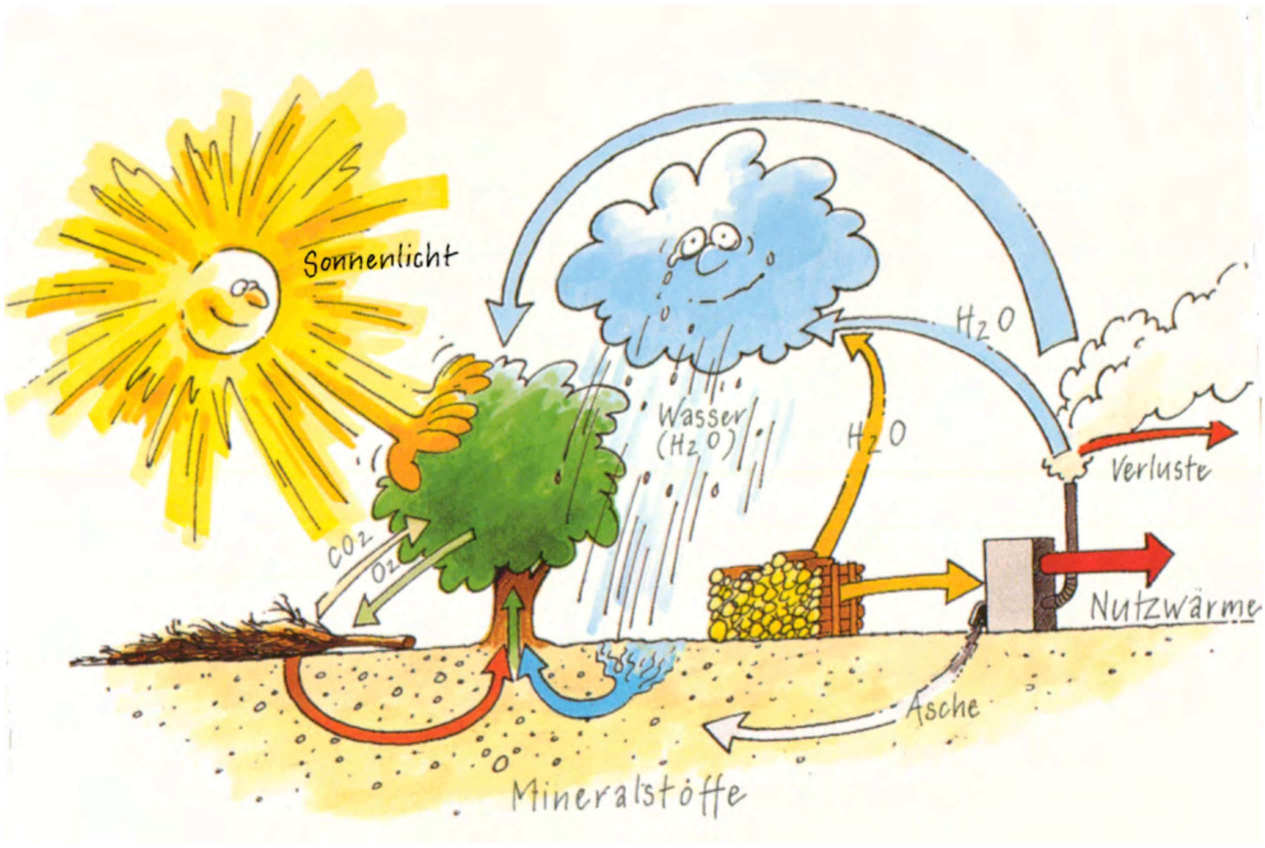

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Rethinking our Energy Future
Smart, sustainable and secure

Bioenergy

Rethinking our Energy Future
Smart, sustainable and secure

Is Bioenergy

1. smart ?
2. sustainable ?
3. secure ?

What is smart ?

Smart for energy = **efficient** !

(and economic, comfortable, ...)

1. Efficient conversion technologies

2. Efficient energy chains from primary resource to useful energy

What is sustainable ?

1. No effects after utilisation, hence renewable in limits of regeneration

2. Aspects of sustainability
   a) for nature: Biodiversity
   b) for society: no competition to food
   c) for health: no pollution

What is secure ?

For Bioenergy:

smart and sustainable = secure !

Hence the target is sustainability for bioenergy utilisation

1. within limits of regeneration
2. without competition to food
3. with conservation of biodiversity
4. with acceptable pollution
5. with maximum energy efficiency
6. for socially acceptable cost

Hence the target is
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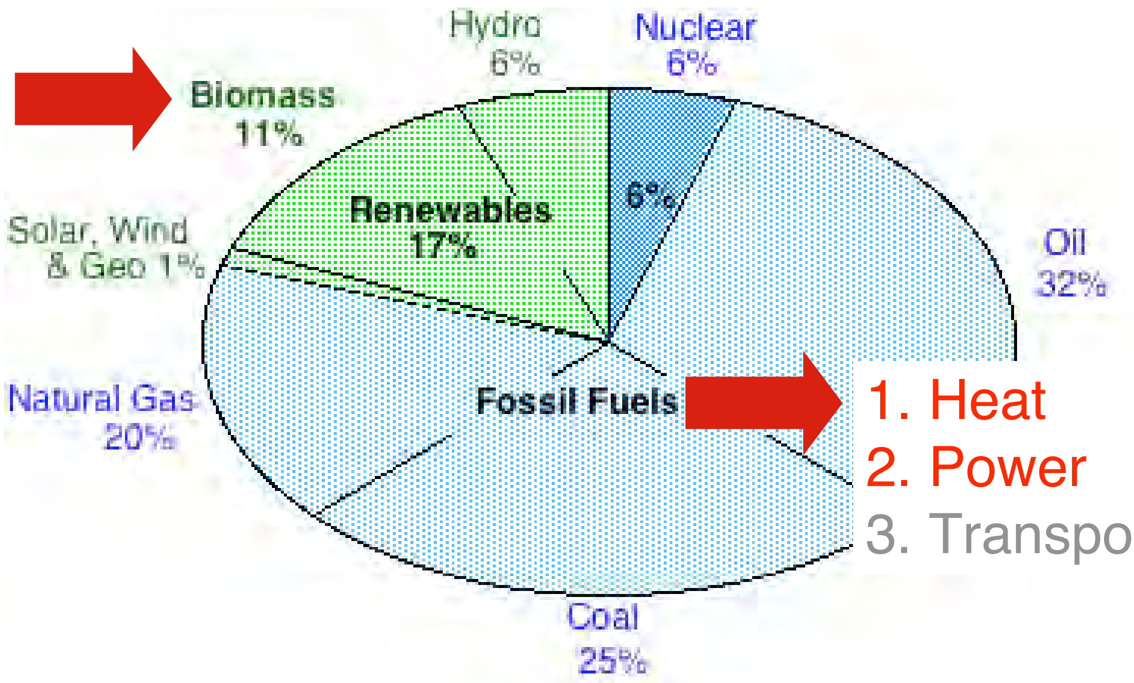

1. Heat
2. Power
3. Transport

Global Energy Consumption
[World Energy Council 1995]

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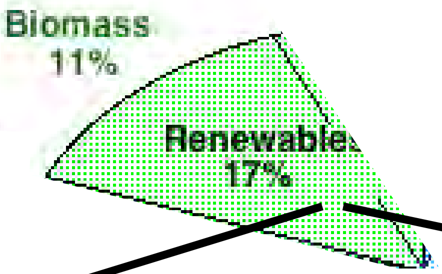
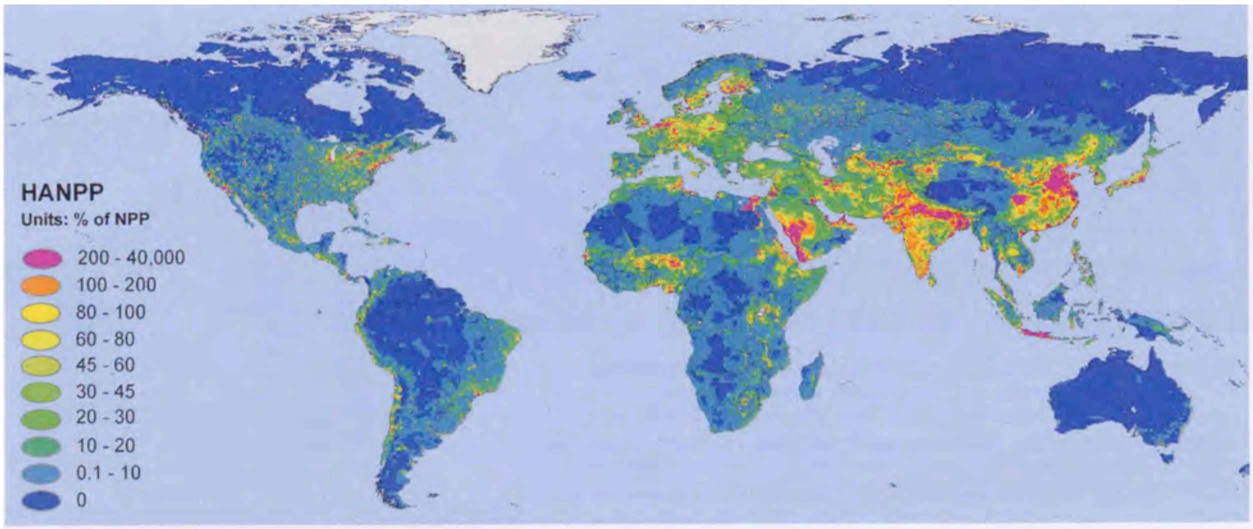


Wood, straw, miscanthus etc.
water content 5% – 55%
lignin > 20%

–> thermal conversion:
combustion, gasification

manure, sewage sludge,
algae, sugar beet, etc.
water content > 60%
no lignin

–> biological conversion,
digestion, fermentation



Der Biomasse-verbrauch des Menschen in Prozent der Nettoprimärpro-duktion (NPP) der Pflanzen: Lila zeigt einen besonders hohen Wert an.

[Natur+Kosmos 9 2004, 16]

HUNGER NACH PFLANZEN

Forscher der Nasa haben gemessen, dass wir Menschen ein Fünftel der Pflanzen verbrauchen, die jährlich auf unserem Planeten wachsen. Anhand von Satellitenbildern fütterten sie ihre Computer mit Daten zur Biomasse-produktion der Erde und verknüpften sie mit Modellen zum menschlichen Bedarf für Essen, Viehhaltung, Bauwirtschaft, Textil- und Papierindustrie. Es zeigten sich große regionale Unterschiede: Während etwa die Bewohner des Amazonas nur wenige Prozent der regional produzierten Biomasse beanspruchen, sind es in städtischen Gebieten bis zu 30000 Prozent.

Theoretical Potential of Biomass Growth

by Cultivation of high yield Biomass on areas not used for food today

	Yield	Area	Biomass	Heating Value	Energy
	t / ha a	10^9 ha	10^9 t/a	MJ / kg GJ / t	EJ / a
Biomass Potential	**6.0**	**6.6**	**39.6**	**17.7**	**700**
World Energy Consumption					**460**
Potential/WEC					**1.5**
Use Today					**0.12**

[Hoogwijk et al. 2002] University Utrecht

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Baseline = today's situation

– Potential for energy decreases if no hunger is assumed !

– Potential is calculated for today's food culture, which is mostly vegetarian as in Asia and Africa today.

If „western" food culture is assumed for the whole world, the potential for energy crops becomes 0 (ZERO),

however, a huge biomass potential remains from bioresidues as 50% or more of the production are side products

[Hoogwijk et al. 2002] University Utrecht

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Utilisation of bioenery needs Quality assurance
to guarantee ecological and social utilisation

–> no system established yet as e.g. for wood products

[FSC : www.fscoax.org]

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Foreststry wood and agrigultural biomass: Utilisation in a cascade !

Wood use as high quality product first (construction wood etc.)

App. 50% of the mass remain as wood residues, as energy source (wood chips, bark, wood pellets)

After utilisation, urban waste wood is an energy source for large plants with flue gas cleaning

Agricultural biomass is primarily as food

More than 50% of the mass are residues, which potentially can be used as energy source

–> no additional environmental impact

–> no competition to food

Energy crops: Consider side effects !

Potentially in competition to food !

Mono culture does not safe the biodiversity; energy crops are not an alternative to forests, but only an additional option

Cultivation of unused land areas can cause an initial peak of CO_2 and N_2O thus in total increasing the greenhouse effect for decades (according to calculations from 30 years to 200 years) ! The data are highly uncertain, however, this side effect needs to be carefully considered.

Use of water, fertiliziers etc. also needs to be respected.

–> Cultivation of energy crops needs increased attention and careful consideration

Hence the target is sustainability for bioenergy utilisation

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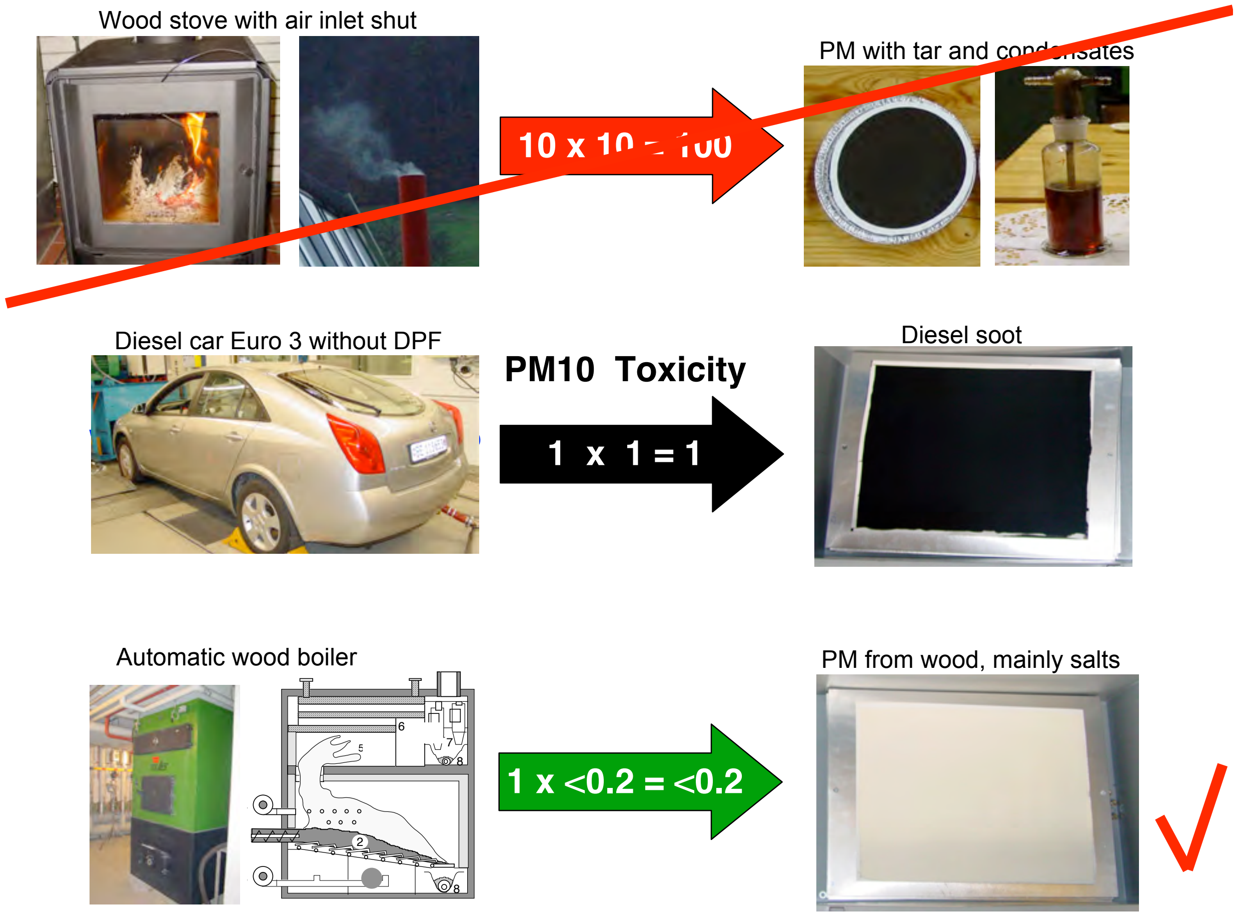
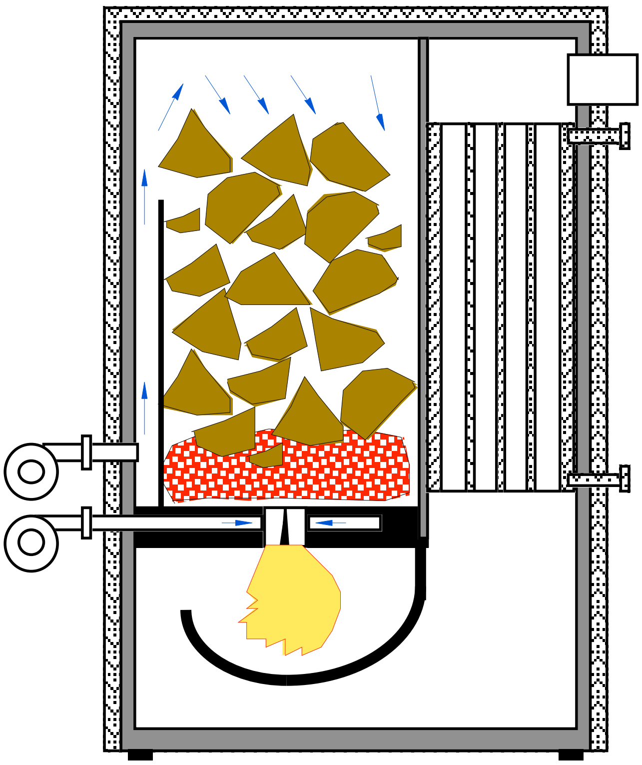
Example 1: Biomass combustion

$\mathbf{CH_{1.4}O_{0.7}}$ + O_2	→	$CO_2 + 0.7\ H_2O$
	→	CO, C_XH_Y, C_{org},C_{el} (soot)
+ N	→	NO_X
+ Ash (K, Ca, ...)	→	KCl, CaO,... (salts)

Particles PM10

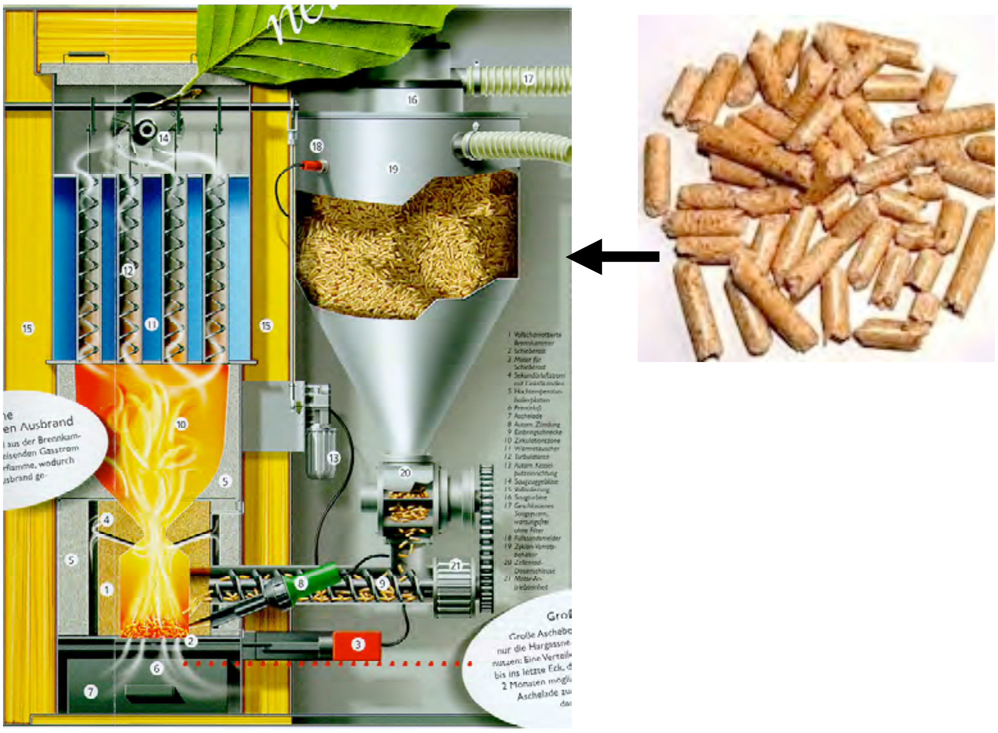


2-stage combustion to reduce organic PM



Eta = 80% hence 1 MJ wood replaces 1 MJ oil or gas

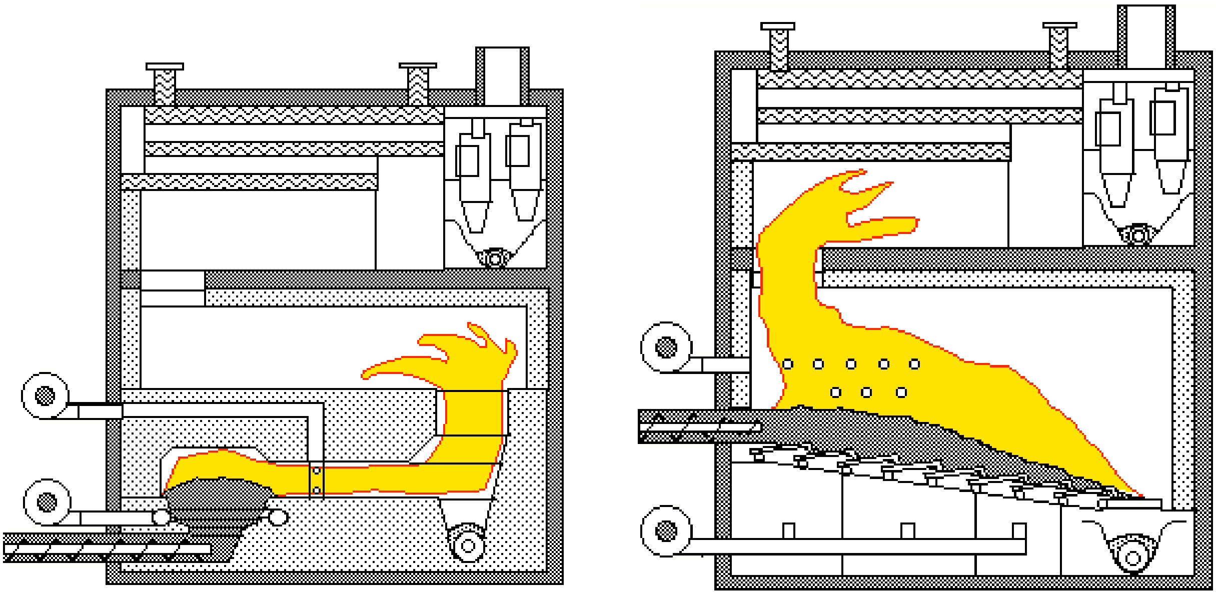
Wood pellets instead of log wood



Eta = 80% hence 1 MJ wood replaces 1 MJ oil or gas

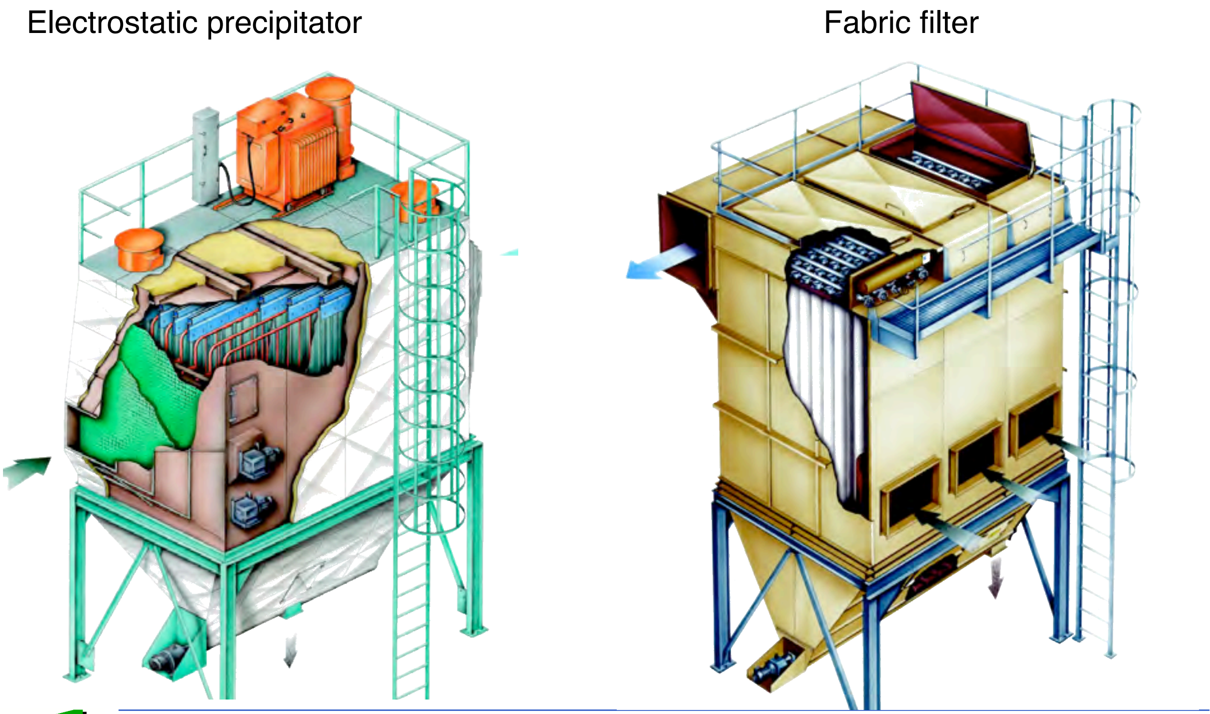
Automatic wood chip boilers

Eta = 80% hence 1 MJ wood replaces 1 MJ oil or gas



Eta = 80% hence 1 MJ wood replaces 1 MJ oil or gas

Particle separation to reduce PM



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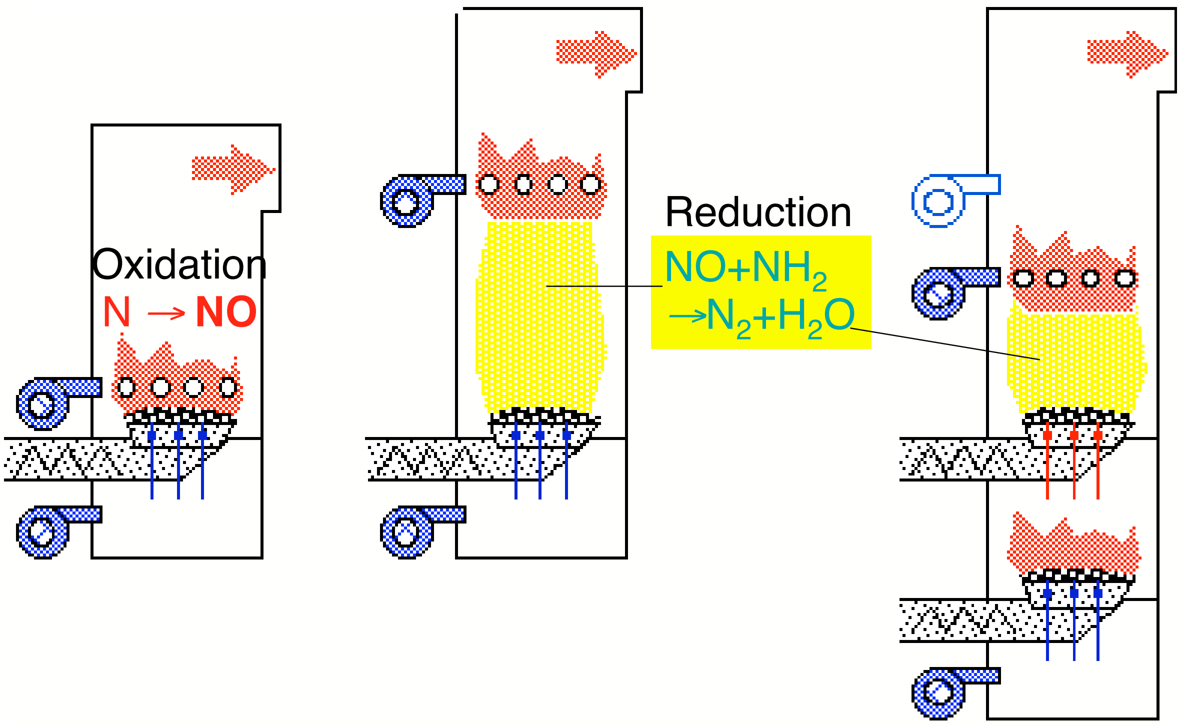
Measures for NO_X reduction



[T. Nussbaumer, Energy & Fuels, Vol. 17, No 6, 2003, 1510–1521]

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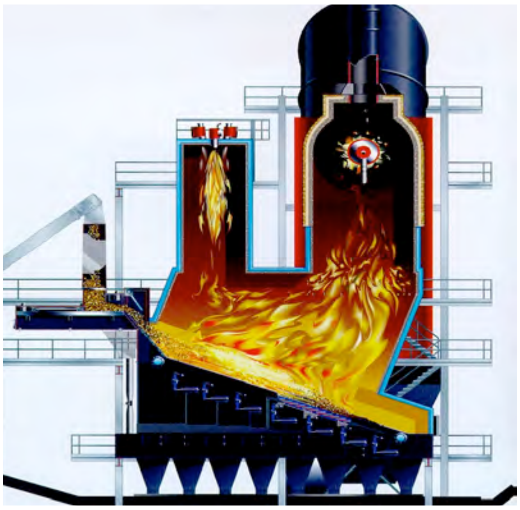
Example 2: Power production in steam plants



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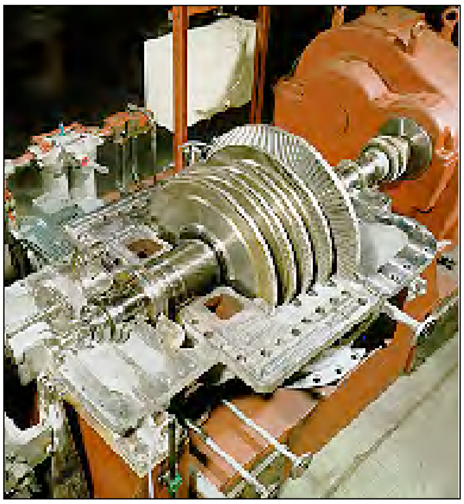


Eta$_e$ = 20% hence 1 MJ wood replaces 0.5 MJ coal

Example 3: Power production by cofiring of biomass in coal fired power stations

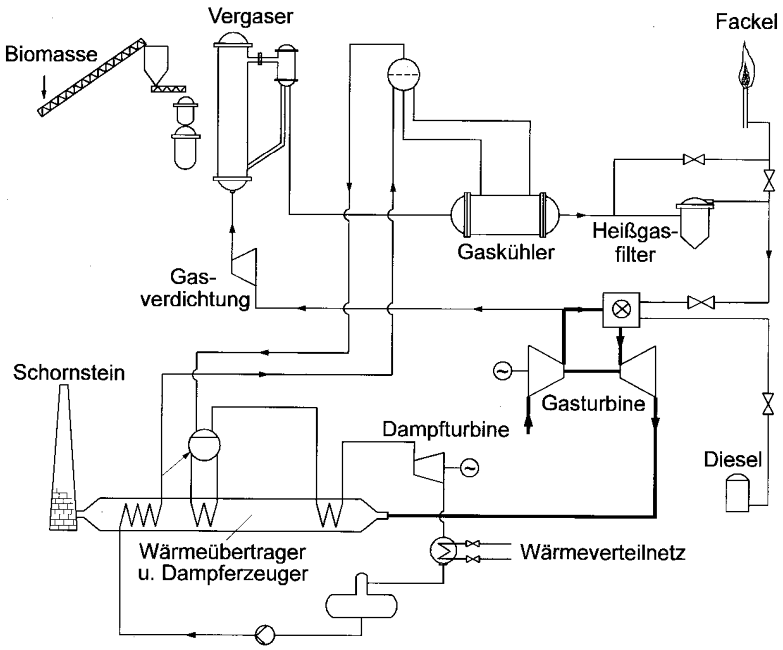
Example from the Netherlands

P = 635 MWe, Eta$_e$ = 40%

Urban waste wood replaces coal

1 MJ wood replaces 1 MJ coal

Example 4: Dedicated power production with Integrated Gasification Combined Cycle (IGCC)



$Eta_e > 40\%$ for 100 MWe

1 MJ Biomass replaces 1 MJ coal or 0.8 MJ natural gas

Example 5: Biofuels from solid biomass

Synthesis of Biofuels, e.g.

Biodiesel via Fischer-Tropsch* or
Natural gas via methanation**

$*CO + H_2 \rightarrow C_nH_{2n/+1/+2} + H_2O$

$**CO + 2 H_2 \rightarrow CH_4$

$Eta_f = 50\%$ for 1 GW

1 MJ Biomass replaces 0.5 MJ natural gas or Diesel

Example 6: Biofuel from solid biomass

Europe:
Sugar beet
Maize

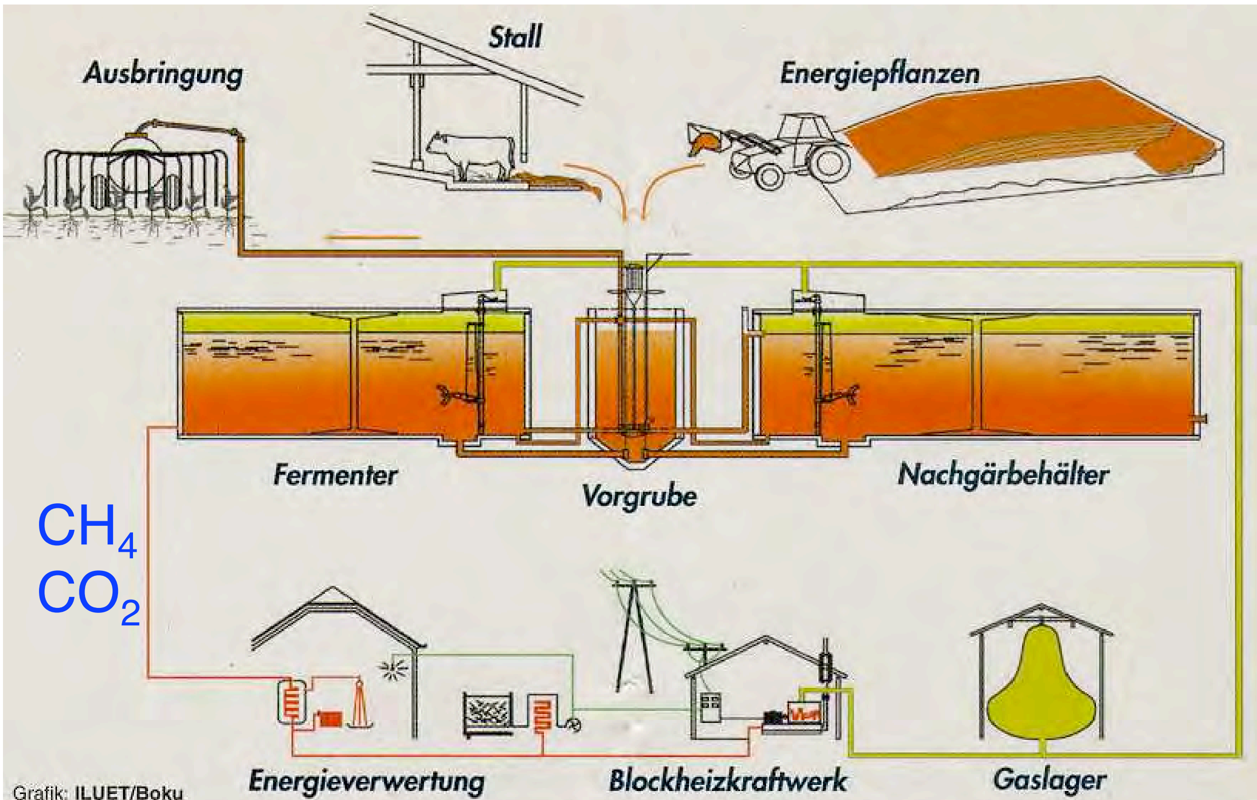
Brasil:
Sugar cane

→ Ethanol production

Energy Yield (Europe) = 2.2 $\frac{\text{MJ Energy output}}{\text{MJ Total energy input}}$

1 MJ Biomass replaces < 0.5 MJ natural gas or Diesel

Example 6: Anaerobic digestion



1 MJ biomass replaces 0.5 MJ natural gas

Hence the target is sustainability for bioenergy utilisation

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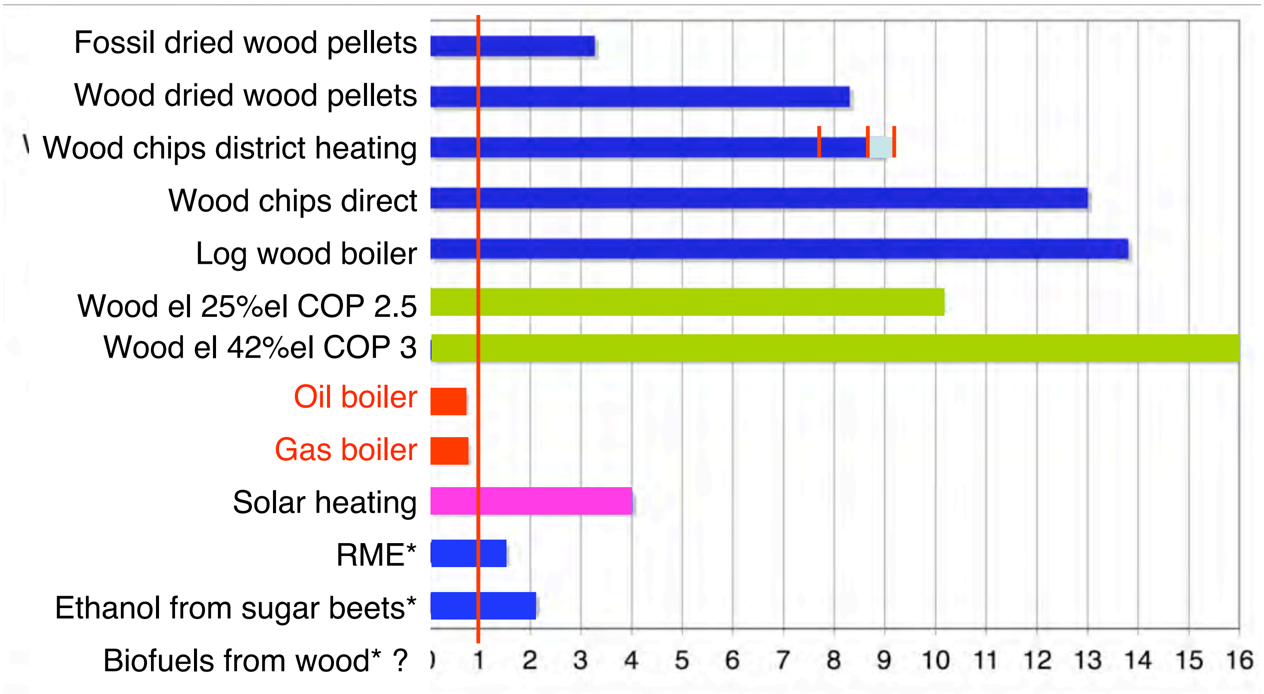
$$\text{Energy Yield} = \frac{\text{Useful energy (*secondary energy)}}{\text{non renewable primary energy}}$$



Oil, Gas: [Kessler et al. 2000] Solar: [Sterkele 2001]
RME: [Studer & W. 1991] Ethanol: [Hartmann & K. 2002]

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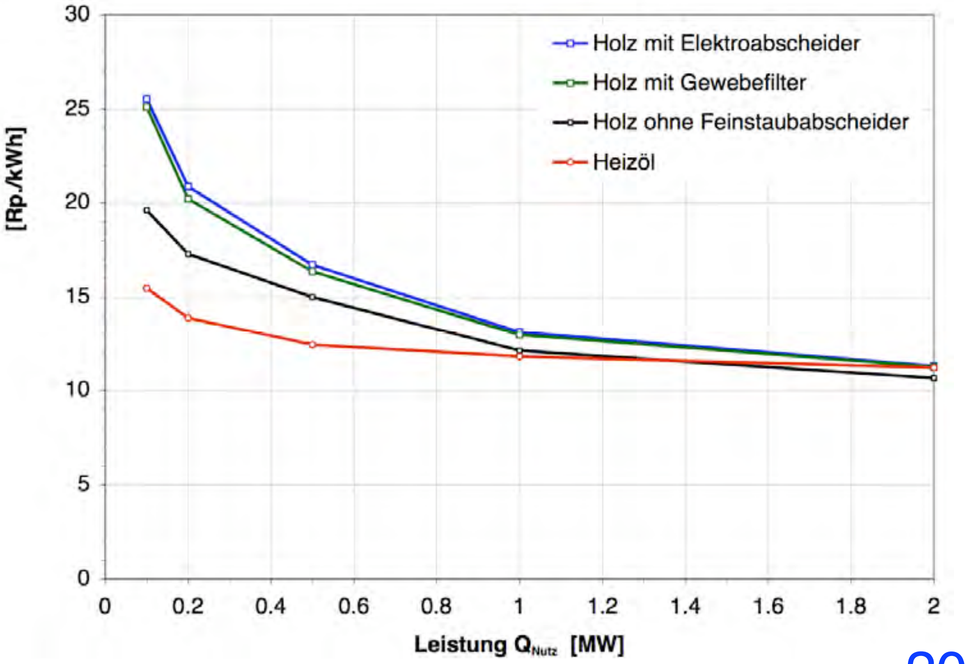
Economy Example 1: Heat production cost from wood in comparison to light fuel oil

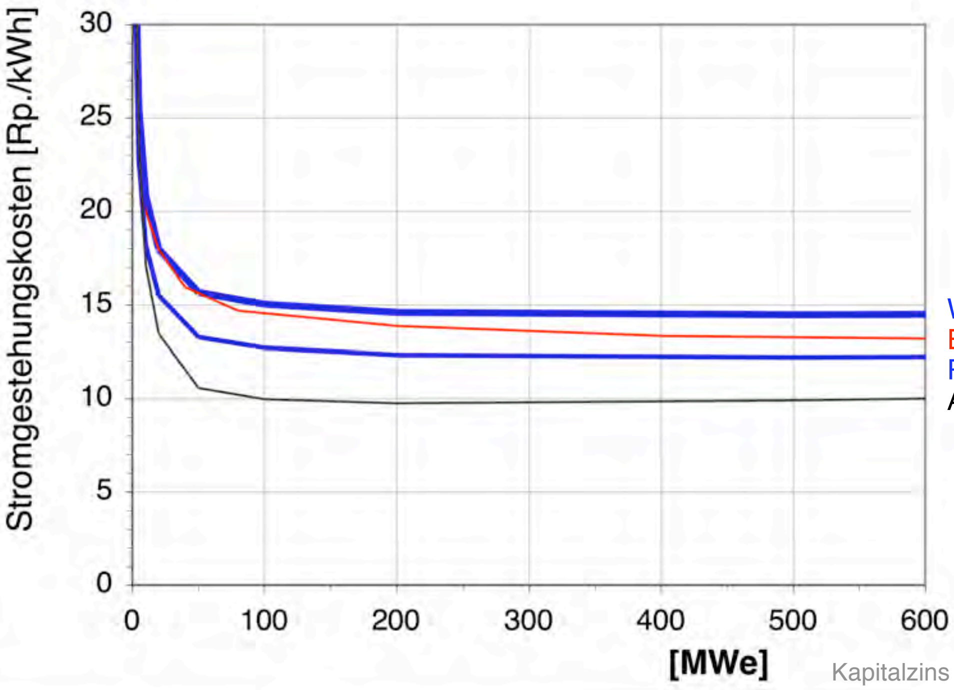


2000 h/a

Für Brennstoffpreise von 5 Rp./kWh für Holz und 8 Rp./kWh für Heizöl sowie einen Kapitalzins von 5% p.a.. Exklusive Wärmenetz

[Nussbaumer 2006]

Economy Example 2: Power production cost from wood in IGCC plant incomparison to natural gas



Waldholz 5 Rp./kWh
Erdgas 7 Rp./kWh
Restholz 4 Rp./kWh
Altholz 2 Rp./kWh

Kapitalzins 2.5% p.a.
Kalkulationsdauer Technik 30 Jahre

[Nussbaumer 2005]

Conclusion

1. Bioenergy is smart, sustainable and secure, but only in the limits of regeneration and only in efficient plants with pollutant reduction.

2. It can contribute to more than 20% but less than 50% of total today's WEC (most probably 25%-30%).

3. Power and heat from biomass achieve a higher substitution potential than biofuels at lower cost.

Acknowledgements

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Literature

available as pdf at www.verenum.ch
or on demand via
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