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Bioenergy Use

Esa Vakkilainen

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Contents

- Renewable energy in Europe
- EU ETS
- Biomass co-combustion
- What is biomass
- IPCC on Bioenergy
- Biomass R&D needs

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Renewable Energy in EU: Progressing towards the 2020 target

Esa Vakkilainen

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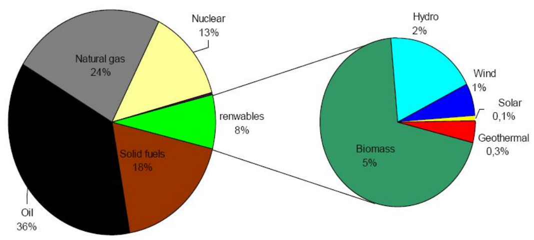
Current EU energy mix



Hans van Steen, DG Energy

EU primary energy consumption

2005	2020	
76 EJ	72 EJ	61$/bbl
	70 EJ	100$/bbl

Jorge Vasconcelos, New Energy Solutions

EU energy imports

2005	2020	
41 EJ	43 EJ	61$/bbl
	40 EJ	100$/bbl

Jorge Vasconcelos, New Energy Solutions

Targets

- EU would reach a share of renewable energy in electricity generation of 21% by 2010
- share of renewable energy replacing petrol and diesel in transport of 5,75% by 2010.
- EU achieves a 20% share of renewable energy by 2020
- EU achieves a 10% share of renewable energy in transport by 2020

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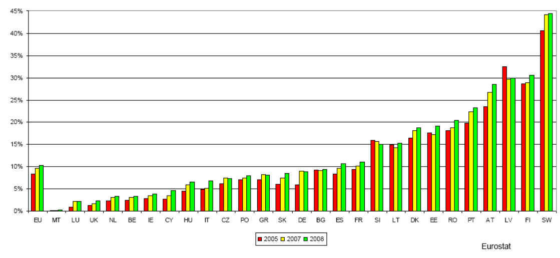
EU renewable energy shares



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Member States' targets

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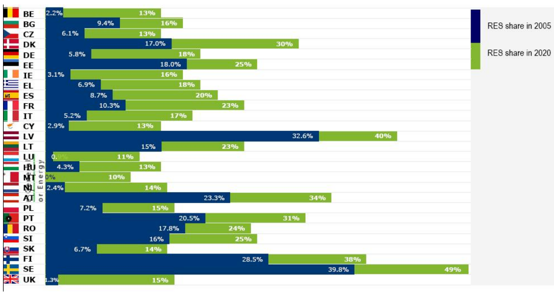

Hans van Steen, DG Energy

Technology Results from the National Renewable Energy Action Plans

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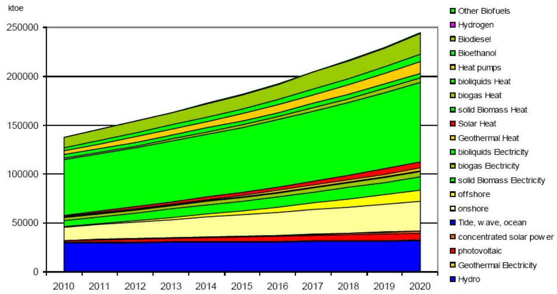

Hans van Steen, DG Energy

Main RES-E support instruments in the EU-27Quota

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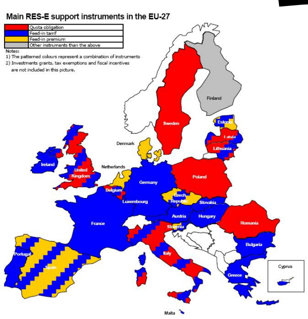

Hans van Steen, DG Energy

Support of renewable heating & transport

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		AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
Heating	Investment grants	x	x	x	x	x	x		x		x	x	x	x	x		x	x	x	x	x	x	x		x	x	x	x
	Tax exemptions	x	x					x				x	x			x	x				x				x			x
	Financial incentives			x			x		x			x											x					
Transport	Quota obligation	x		x	x	x	x	x		x	x	x			x		x	x	x		x	x	x	x		x	x	x
	Tax exemptions	x	x		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x

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Support of renewable electricity

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		AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
Electricity	FIT	x	x	x	x	x	x		x	x		x	x	x	x	x	x	x	x	x			x			x	x	x
	Premium					x		x	x	x											x					x		
	Quota obligation		x													x						x		x	x			x
	Investment grants		x		x	x					x		x	x			x	x	x	x								
	Tax exemptions		x							x	x		x						x		x	x			x		x	x
	Fiscal incentives			x			x		x											x	x	x				x		

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Cost estimations for RES

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- Total investments in renewables are currently at a level of approximately €35 bn/y
- Most analysis predict this has to double to reach our 2020 targets
- Unit cost of renewables, contrary to other forms of energy, are declining; for certain technologies sharply
- Producing (and generating) renewables where most cost-efficient offers significant potential for lowering overall cost (in the range of 10%)

Hans van Steen, DG Energy

Energy system investment needs

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Total investment needs in the electricity and gas sector between 2010-20: over 1 trillion €

- Power generation: ~ 500 bn
  - RES: ~ 310 – 370 bn
- Transmission and distribution: ~ 600 bn
  - Distribution: ~ 400 bn
  - **Transmission: ~ 200 bn**

Jean-Arnold Vinois, DG Security of supply and energy networks

Sectoral and overall growth of renewable energy in the EU7

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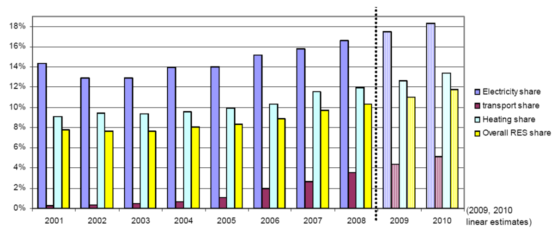

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Status presently (2010)

- Only a few Member States, namely Denmark, Germany, Hungary, Ireland, Lithuania, Poland and Portugal expect to achieve their 2010 targets for renewable energy in electricity generation;
- only Austria, Finland, Germany, Malta, Netherlands, Poland, Romania, Spain and Sweden expect to achieve their targets for renewable energy in transport.
- For the period 2007-2009, funds spent on renewable energy amounted to roughly €9.8bn, (€3.26bn/a), the bulk of which in the form of loans from the European Investment Bank.

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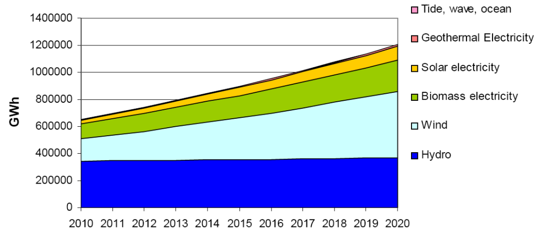
EU development of renewable energy in electricity



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Renewable energy development

- Based on Member States' plans, renewable energy should constitute 37% of Europe's electricity mix by 2020.
- Multiple, flexible, smaller scale distributed forms of electricity generation.
- Following biomass, wind power will account for 27% projected increase (two-thirds onshore, one-third offshore),
- Similarly, the solar energy industry will grow, notably for photovoltaics.
- Policy to shift from investments to consumption
- Conversion of feed in tariffs to feed in premiums

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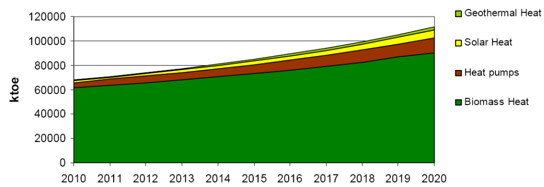
EU development of renewable energy in heating & cooling



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Renewable heating

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- Biomass will remain the dominant technology, with 50% of the growth up to 2020 occurring in energy produced from this source (half of that in heating, a third in transport and the rest in electricity).
- Development and investments in Europe's biomass pellet industry, in biomass boiler technology, co-firing power plant technology and biofuels refining can be expected.
- Regulatory rather than financial solutions at the household level
- District heating networks should be promoted as a matter of priority in all larger agglomerations where local or regional conditions justify it

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EU development of renewable energy in transport

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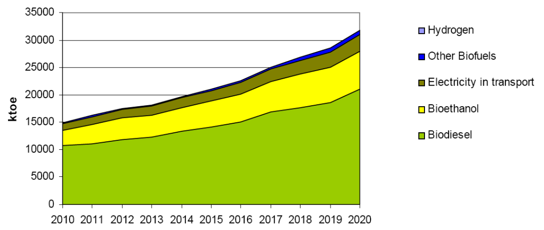

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Results from first 21 National Renewable Energy Action Plans

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RES type	Generation 2010 (TWh)	Generation 2020 (TWh)	Share 2020 (%)	Variation 2010-2020 (%)
Hydro	335.1	358	31.4%	7%
Wind	160.2	464.3	40.7%	186%
Biomass	102.4	200	17.5%	90%
Solar	21	101.8	8.9%	388%
Other	6.5	16.4	1.4%	154%
TOTAL	**625.2**	**1140.5**	**100.0%**	**82%**

Jean-Arnold Vinois, DG Security of supply and energy networks

EU policy notes

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- Second generation biofuels and electric vehicles are expected to make only a small contribution by 2020.
- Need to continue to invest in research for advanced renewable energy technologies.
- Needs to continue to bring down the costs of offshore wind; photovoltaic power; electric cars; and second generation biofuels.
- Renewable electricity investments should be at levels higher than the 62% of all new power investments
- Annual capital investment in renewable energy to rapidly double to €70bn

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Cost of renewable bioenergy

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RES-E sub-category	Plant specification	Investment costs	O&M costs	Efficiency (electricity)	Efficiency (heat)	Lifetime (average)	Typical plant size
		[€/kW$_{e}$]	[€/(kW$_{el}$*year)]	[1]	[1]	[years]	[MW$_{el}$]
Biogas	Agricultural biogas plant	2550 - 4290	115 - 140	0.28 - 0.34	-	25	0.1 - 0.5
	Agricultural biogas plant - CHP	2765 - 4525	120 - 145	0.27 - 0.33	0.55 - 0.59	25	0.1 - 0.5
	Landfill gas plant	1350 - 1950	50 - 80	0.32 - 0.36	-	25	0.75 - 8
	Landfill gas plant - CHP	1500 - 2100	55 - 85	0.31 - 0.35	0.5 - 0.54	25	0.75 - 8
	Sewage gas plant	2300 - 3400	115 - 165	0.28 - 0.32	-	25	0.1 - 0.6
	Sewage gas plant - CHP	2400 - 3550	125 - 175	0.26 - 0.3	0.54 - 0.58	25	0.1 - 0.6
Biomass	Biomass plant	2225 - 2995	84 - 146	0.26 - 0.3	-	30	1 – 25
	Cofiring	450 - 650	65 - 95	0.37	-	30	-
	Biomass plant - CHP	2600 - 4375	86 - 176	0.22 - 0.27	0.63 - 0.66	30	1 – 25
	Cofiring – CHP	450 - 650	85 - 125	0.2	0.6	30	-
Biowaste	Waste incineration plant	5500 - 7125	145 - 249	0.18 - 0.22	-	30	2 – 50
	Waste incineration plant - CHP	5800 - 7425	172 - 258	0.14 - 0.16	0.64 - 0.66	30	2 – 50

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Ecofys 2011

Cost of hydro, tidal and wave

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RES-E sub-category	Plant specification	Investment costs	O&M costs	Efficiency (electricity)	Efficiency (heat)	Lifetime (average)	Typical plant size
		[€/kW$_{e}$]	[€/(kW$_{el}$*year)]	[1]	[1]	[years]	[MW$_{el}$]
Hydro large-scale	Large-scale unit	850 - 3650	35	-	-	50	250
	Medium-scale unit	1125 - 4875	35	-	-	50	75
	Small-scale unit	1450 - 5750	35	-	-	50	20
	Upgrading	600 - 3600	35	-	-	50	-
Hydro small-scale	Large-scale unit	975 - 1600	40	-	-	50	9.5
	Medium-scale unit	1275 - 5025	40	-	-	50	2
	Small-scale unit	1550 - 6050	40	-	-	50	0.25
	Upgrading	900 - 3700	40	-	-	50	-
Tidal stream energy	Tidal (stream) power plant - shoreline	5650	145	-	-	25	0.5
	Tidal (stream) power plant - nearshore	6825	150	-	-	25	1
	Tidal (stream) power plant - offshore	8000	160	-	-	25	2
Wave energy	Wave power plant - shoreline	4750	140	-	-	25	0.5
	Wave power plant - nearshore	6125	145	-	-	25	1
	Wave power plant - offshore	7500	155	-	-	25	2

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Ecofys 2011

Cost of geothermal, solar and wind

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RES-E sub-category	Plant specification	Investment costs	O&M costs	Efficiency (electricity)	Efficiency (heat)	Lifetime (average)	Typical plant size
		[€/kW$_{e}$]	[€/(kW$_{el}$*year)]	[1]	[1]	[years]	[MW$_{el}$]
Geothermal Eletricity	Geothermal power plant	2575 - 6750	113 - 185	0.11 - 0.14	-	30	5 – 50
Photovoltaics	PV plant	2950 - 4750	30 - 42	-	-	25	0.005 - 0.05
Solar thermal electricity	Concentrating solar power plant	3600 - 5025	150 - 200	0.33 - 0.38	-	30	2 – 50
Wind onshore	Wind power plant	1125 - 1525	35 - 45	-	-	25	2
Wind offshore	Wind power plant - nearshore	2450 - 2850	90	-	-	25	5
	Wind power plant - offshore: 5…30km	2750 - 3150	100	-	-	25	5
	Wind power plant - offshore: 30…50km	3100 - 3350	110	-	-	25	5
	Wind power plant - offshore: 50km…	3350 - 3500	120	-	-	25	5

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Ecofys 2011

New RES-H plant cost

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RES-H sub-category	Plant specification	Investment costs	O&M costs	Efficiency (heat)[1]	Lifetime (average)	Typical plant size
		[€/kW$_{heat}$][2]	[€/(kW$_{heat}$*yr)][2]	[1]	[years]	[MW$_{heat}$][2]
Grid-connected heating systems						
Biomass - district heat	Large-scale unit	350 - 380	16 - 17	0.89	30	10
	Medium-scale unit	390 - 420	17 - 19	0.87	30	5
	Small-scale unit	475 - 550	20 - 22	0.85	30	0.5 - 1
Geothermal - district heat	Large-scale unit	800	50	0.9	30	10
	Medium-scale unit	1200 - 1500	55	0.88	30	5
	Small-scale unit	2000 - 2200	57 - 60	0.87	30	0.5 - 1
Non-grid heating systems						
Biomass - non-grid heat	log wood	255 - 340	6 - 10	0.75 - 0.85*	20	0.015 - 0.04
	wood chips	340 - 610	6 - 10	0.78 - 0.85*	20	0.02 - 0.3
	Pellets	390 - 530	6 - 10	0.85 - 0.9*	20	0.01 - 0.25
Heat pumps	ground coupled	900 - 1100	5.5 - 7.5	3 - 4[1]	20	0.015 - 0.03
	earth water	650 - 1050	10.5 - 18	3.5 - 4.5[1]	20	0.015 - 0.03
Solar thermal heating & hot water supply	Large-scale unit	400 - 420[2]	5 - 7[2]	-	20	100 - 200
	Medium-scale unit	540 - 560[2]	7 - 9[2]	-	20	50
	Small-scale unit	900 - 930[2]	13 - 15[2]	-	20	5 - 10

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Cost of biofuel refineries

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RES-T sub-category	Fuel input	Investment costs	O&M costs	Efficiency (transport)	Efficiency (electricity)	Lifetime (average)	Typical plant size
		[€/kW_{trans}]	[€/(kW_{trans}*year)]	[1]	[1]	[years]	[MW_{trans}]
Biodiesel plant (FAME)	rape and sunflower seed	210 - 860	10.5 - 45	0.66	-	20	5 - 25
Bio ethanol plant (EtOH)	energy crops (i.e. sorghum and corn from maize, triticale, wheat)	640 - 2200	32 - 110	0.57 - 0.65	-	20	5 - 25
Advanced bio ethanol plant (EtOH+)	energy crops (i.e. sorghum and whole plants of maize, triticale, wheat)	1130 - 1510[1]	57 -76[1]	0.58 - 0.65[1]	0.05 - 0.12[1]	20	5 - 25
BtL (from gasifier)	energy crops (i.e. SRC, miscanthus, red canary grass, switchgrass, giant red), selected waste streams (e.g. straw) and forestry	750 - 5600[1]	38 - 280[1]	0.36 - 0.43[1]	0.02 - 0.09[1]	20	50 - 750

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EU ETS

Esa Vakkilainen

EU ETS

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- As from 2013, full auctioning for electricity sector:
- More than half of all allowances will be auctioned
- Potentially some transitional free allocation to electricity producers in up to 10 new Member States
- Auctioning Regulation adopted and published in November 2010
- Rules agreed unanimously by Member States

Jos Delbeke, Director General, DG Climate Action

EU ETS - Auctioning

- Simplest auction format: single round, multiple bids, uniform clearing price –auctioning spot rather than futures
- Access also for intermediaries –widest possible participation
- Bidders established in the EU, except for ETS operators (aviation)
- Or Bidder's representative established in the EU
- Provisions to mitigate risk of market abuse
- Single auction monitor

Jos Delbeke, Director General, DG Climate Action

EU ETS – use of revenues from auctioning

- Member States should use at least 50% of revenues for climate and energy related purposes
- 100% earmarking for the revenues from auctioning „aviation allowances"

Jos Delbeke, Director General, DG Climate Action

EU ETS – Carbon market oversight

- Carbon market has developed well in terms of liquidity, participation of intermediaries and transparency
- COM has launched a comprehensive study to look at existing levels of market oversight and implications of introducing new measures
- Options under consideration:
  - Full coverage of the European carbon market by financial markets legislation (e.g. by classifying allowances as financial instruments)
  - A tailor-made regime for emission allowances building on the financial markets rules

Jos Delbeke, Director General, DG Climate Action

EU ETS – Benchmarking

- Decision voted 15 December 2010
- Main principle: one product –one benchmark
- No modification based on which fuel is used, which technology is used, which inputs are used
- ~50 benchmarks cover ~75% industrial emissions in the EU ETS
- Starting point for benchmark values: average performance of 10% most efficient installations in (sub)sector
- Next steps: Member States have to submit list with allocation per installations by 30 September 2011, to be checked by Commission

Jos Delbeke, Director General, DG Climate Action

EU ETS – NER 300 Evaluation

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- Eligibility: Technology categories and sub-categories, capacity thresholds, innovation (RES)
- Due diligence: Financial and technical, aim to ensure that any Project receiving a funding commitment under NER 300 has a good prospect of proceeding to project completion and entry into operation
- Ranking: Based on cost per unit performance, CCS projects together, RES projects in sub-categories
- CCS Group: 8 highest ranked projects meeting portfolio requirements (representation of technology categories, storage options)
- RES Group: Highest ranked project in each sub-category

Jos Delbeke, Director General, DG Climate Action

EU Non ETS

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- Annual binding greenhouse gas emission targets for Member States for the period 2013–2020
- Emissions of all: CO_2, CH_4, N_2O, HFCs, PFCs and SF_6
- All sectors except: ETS, LULUCF, International maritime shipping, Aviation
- More than 50% of the EU's greenhouse gas emissions
- Typically "small emitters" as a result of our daily activities: transport, heating in buildings, services & SME's, agriculture (CH_4, N_2O), waste (CH_4), F-gases
- MS with high GDP/capita shall reduce emissions
- MS with low GDP/capita may increase emissions
- But no reduction of more than 20% and no increase of more than 20%.

Jos Delbeke, Director General, DG Climate Action

EU Non ETS - ESD 2020 targets

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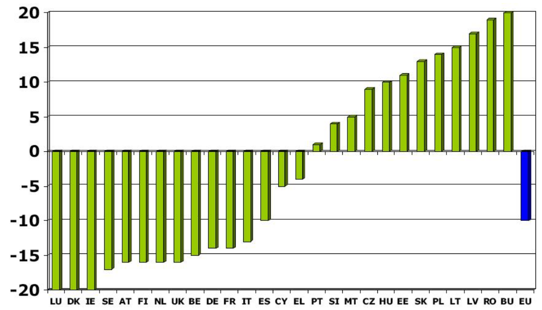

Jos Delbeke, Director General, DG Climate Action

Increasing wind and solar will decrease electricity prices

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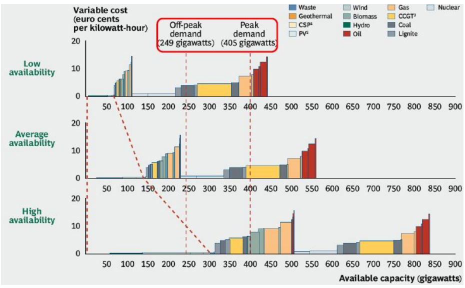

Boston Consultants, 2010

Huge additonal investment needs required to reach renewable energy targets in 2020

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EU sees challenges to reach renewable targets for 2020

- So far, only 18% of avisaged target of 21% in renewable power production reached
- Seven countries expected to meet their 2010 non-binding targets, and most countries are behind schedule
- EU slighty concerned about 2020 targets, but updated NREAP plans indicate that countries are on track

Huge annual capital investment needs in renewable sector

- Doubling of yearly investment capital from €35bn up to €70bn required to fullfil targets
- Investment primarily sourced by private sector through subsidy schemes
- "We need smart, cost–effective financing", says Energy Commissioner

Lack of cooperation and convergence of support schemes

- "Statistical transfer" of surplus capacity to other states – trading of renewable cedits
- "Joint projects" by bilateral financing
- "Joint support schemes" where states harmonize all their support schemes

41 UPM 2011

Individual progress on renewable power production targets for 2010

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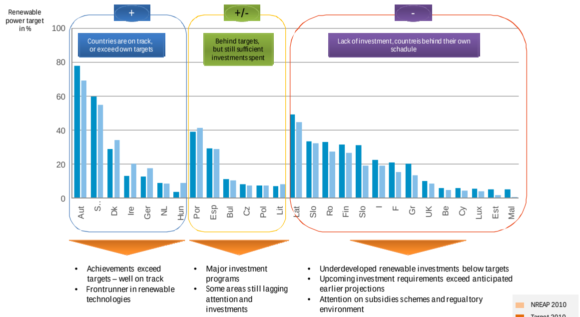

NREAP = National renewable Energy Action Plan

EC Feb 2011, Press 42

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Biomass co-combustion

Esa Vakkilainen

Biomass physical properties I

- Biomass is a hydrocarbon, as all other fuels. Chemical constitution varies little depending on origin and type.
- Most biomass fuels are rather moist in fresh form (40 – 50 % moisture) and has a heating value of about 10 MJ/kg
- Fresh biomass cannot be stored long in a chopped fresh form
  - Biological activity and degradation starts within weeks
  - If stored in large volumes it self ignites.
  - Biomass either have to be in form of logs or be dried to be stored
  - To reduce volume it can be either pelletized or briquetted
- All biomass in a naturally dried form (~30% moisture) has a heating value of about 17 MJ/kg. This varies very little whether it is in pellets form, logs or woodchips and originally straw, wood, bark or dried cowshit.
- All biomass dry substance has a heating value of about 21 MJ/kg

Lars Strömberg , Vattenfall, 2011, 45

Biomass physical properties II

- Pelletization is a way to reduce volume and make the biomass easier to handle and store.
  - Pellets are made of milled and dried biomass (~15%), as are briquettes.
  - Pellets have a higher density
- Torrefaction is a heat treating technology to further increase the handling properties (250 - 280C, moisture below a few %)
  - Density is further increased
  - Milling properties is much better
  - Pellets are hydrophobic
- All treatment of biomass have a certain cost
- Torrefaction can reduce volume to make transported fuels competitive, even if processing cost is higher than for other biomass

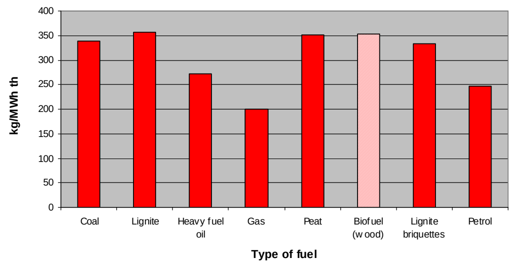
Lars Strömberg , Vattenfall, 2011, 46

Biomass physical properties III

- Co – combustion is limited primarily due to cost reasons.
  - Biomass is three times more expensive that coal
- Technical reasons to limit percentage of biomass are due to
  - Biomass is bulkier than coal – space limitations
  - Biomass is very difficult to handle in chips or natural form
  - Ash properties give corrosion problems
- All biomass have more alkali and halogen content in the ash than coal
  - Alkali gives low temperature melting ash
  - Chlorine gives hydrochloric acid corrosion
- Superheater temperature is limited to about 500 C with present techniques in boilers, giving low efficiency
- Torrefaction or drying or pelletization does not alter ash properties at all.

Lars Strömberg , Vattenfall, 2011, 47

CO_2 release from combustion of different fuels



Lars Strömberg , Vattenfall, Feb 2011, 48

Biomass co-combustion cost calculations

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- The new ZEP cost report is base for all calculations
  - All costs for the plants are same
  - All calculation base data are same, as wacc, depreciation time and cost definitions
  - Methodology is the same
- Biomass is assumed to be either
  - Local fresh biomass chips at 15 €/MWh
  - Transported pellets/briquettes/torrefied pellets at 25 €/MWh
- CCS is either newbuilt oxyfuel or new or retrofitted post combustion technology.

Lars Strömberg, Vattenfall, Feb 2011, 49

Allowable cost for biomass to exchange lignite or hardcoal

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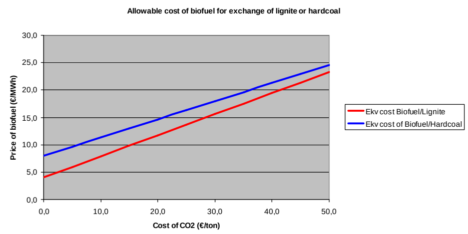
- ETS cost for CO_2 35 €/ton.
- Biomass cost 25 €/MWh.
- Biomass mix 10 %.



Lars Strömberg, Vattenfall, Feb 2011, 50

Cost of electricity for PF plants

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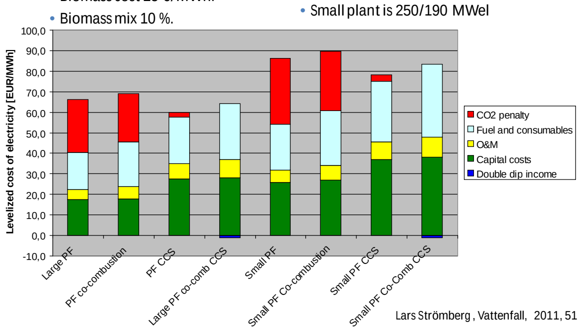
- ETS cost for CO_2 35 €/ton.
- Biomass cost 25 €/MWh.
- Biomass mix 10 %.
- Large plant is 900/720 MWel.
- Small plant is 250/190 MWel



Lars Strömberg, Vattenfall, 2011, 51

Cost of electricity for PF plants

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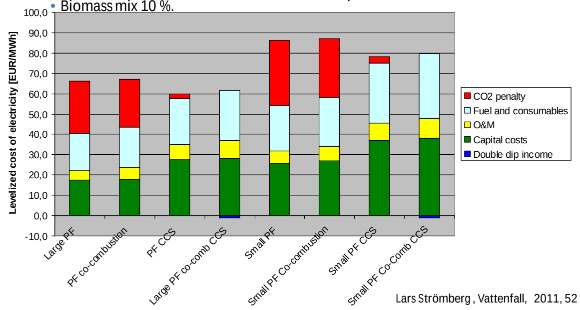
- ETS cost for CO_2 35 €/ton.
- Biomass cost 15 €/MWh.
- Biomass mix 10 %.
- Large plant is 900/720 MWel.
- Small plant is 250/190 MWel



Lars Strömberg, Vattenfall, 2011, 52

Cost of electricity for small PF plants

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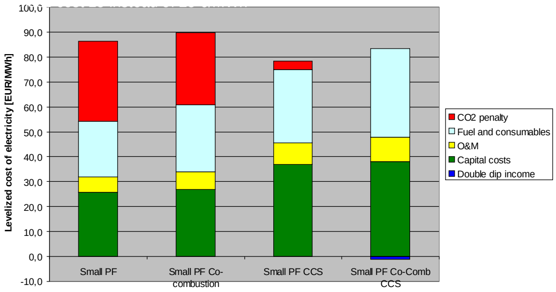
- ETS cost for CO_2 35 €/ton.
- Biomass cost 25 €/MWh.
- Double dip income sam
- Biomass mix 10 %.



Lars Strömberg , Vattenfall, 2011, 53

Cost of electricity for small PF plants

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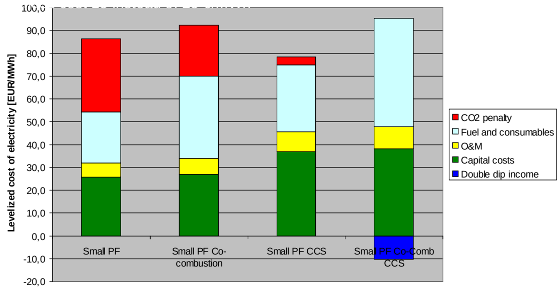
- ETS cost for CO_2 35 €/ton.
- Biomass cost 25 €/MWh.
- Double dip income same as CO_2 cost
- Biomass mix 30 %.



Lars Strömberg , Vattenfall, 2011, 54

Cost of electricity for small PF plants

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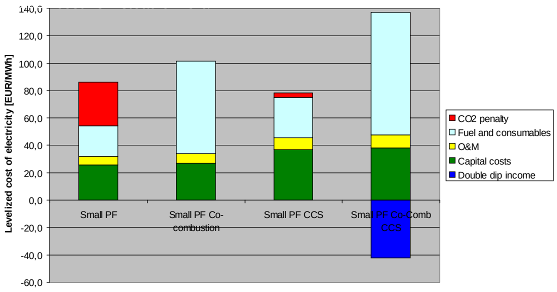
- ETS cost for CO_2 35 €/ton.
- Biomass cost 25 €/MWh.
- Double dip income same as CO_2 cost
- Biomass mix 100 %.



Lars Strömberg , Vattenfall, 2011, 55

Cost of electricity for small PF plants

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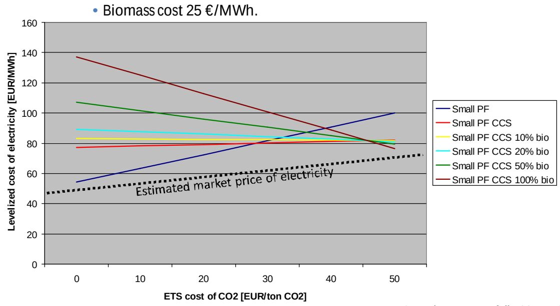
- Double dip income same as CO_2 cost
- Biomass cost 25 €/MWh.



Lars Strömberg , Vattenfall, 2011, 56

Biomass co-combustion conclusions

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- Biomass co – combustion has a cost problem
  - Large volumes gives a need for refined biomass – pellets or similar
  - Small plants are more expensive than large (A large pulp mill equals 500 – 1000 MW power including all biomass used in the mill)
- CCS can give an actual reduction of CO_2 in atmosphere
  - Co – combustion with coal can keep efficiency up, but biomass costs must be halved to make this profitable including additional plant costs
  - Even if biomass is supported by getting paid to remove CO_2 from atmosphere with ETS price we are far from profitability with CCS
- CCS for biomass is more expensive than for coal
  - Efficiency is lower
  - Loss of energy is paid for by a three times more expensive fuel
  - Even a 100% biomass plant will not be profitable unless the ETS price exceeds about 50 €/MWh
- Large biomass plants with advanced steam data will never be profitable
- Medium sized plants designed for biomass will be a better choice

Lars Strömberg , Vattenfall, 2011, 57

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What is biomass

Esa Vakkilainen

Biomass to sustainable biomass

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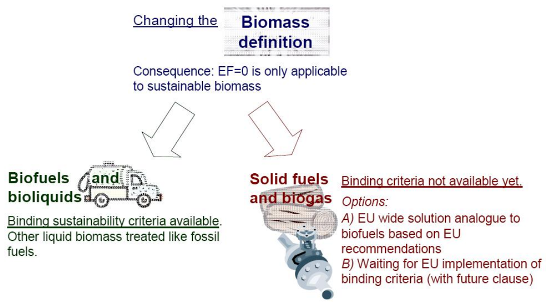


ZOD Definition

Following DG ENER presentation to TWG 19.1.11

"Biomass" *means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal wastes*

MSs noted not complete/inclusive of bioliquids and biofuels, and in favour of change.

TWG M&R Regulation 2011 61

FOD Definition

"biomass" *means biomass, bioliquids and biofuels within the meaning of Directive 2009/28/EC including sustainability criteria for biofuels and bioliquids*

Adds:

- ***"bioliquids"*** *means liquid fuel for energy purposes other than for transport, including electricity and heating and cooling, produced from biomass*
- ***"biofuels"*** *means liquid or gaseous fuel for transport produced from biomass*

TWG M&R Regulation 2011 62

Implications for EU ETS

Only emissions from biomass [2009/28/EC definition], sustainable bioliquids and sustainable biofuels will be zero-rated

Non-sustainable bioliquids/biofuels will be treated as fossil carbon (not zero-rated)

"fossil carbon" means inorganic and organic carbon not stemming from biomass

TWG M&R Regulation 2011 63

Directive 2009/28/EC

Framework for promotion of energy from renewable sources

Mandatory national targets for overall share of energy from renewable sources

20% share energy; 10% in each MS transport by 2020

MS responsibility

Article 17- Sustainability criteria for biofuels/bioliquids

Article 18 – Verification of compliance with sustainability criteria: economic operators required to show Art. 17 points a-c are met

Fuel Quality Directive 2009/30/EC

TWG M&R Regulation 2011 64

ETS Interests

Only relevant in relation to definition of biomass [M&RR Definition] and zero-rating

Not for implementation or enforcement of 2009/28/EC or 2009/30/EC, or

- COM 2010/C 160/01 (default values)
- COM 2010/C 160/02 (practical implementation/counting rules)

Sustainability requirements for biomass [2009/28/EC Definition] yet to be confirmed

GHG savings – not relevant to ETS zero-rating

Minimal additional regulatory/verification burden

TWG M&R Regulation 2011 65

IPCC Biomass

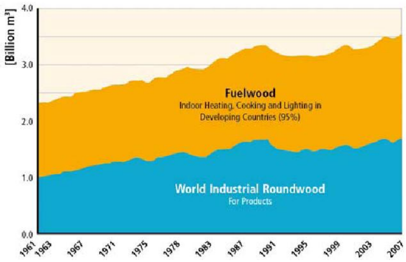
Esa Vakkilainen

Status of biomass

- Use of biomass residues and wastes and advanced conversion systems are able to deliver 80 to 90% emission reductions compared to the fossil energy baseline.
- Biomass is a primary source of food, fodder and fibre and as a renewable energy (RE) source provided about 10.2% (50.3 EJ) of global total primary energy supply (TPES) in 2008.
- From the expert review of available scientific literature, potential deployment levels of biomass for energy by 2050 could be in the range of 100 to 300 EJ.
- Bioenergy has complex societal and environmental interactions, including climate change feedback, biomass production and land use.
- Costs vary by world regions, feedstock types, feedstock supply costs for conversion processes, the scale of bioenergy production and production time during the year.

IPCC, Biomass, 2011 68

Biomass usage for fuelwood equals industrial usage



IPCC, Biomass, 2011

Biomass usage is mostly inefficient

Type	Approximate Primary Energy (EJ/yr)	Approximate Average Efficiency (%)	Approximate Secondary Energy (EJ/yr)
Traditional Biomass			
Accounted for in IEA energy statistics	30.7	10–20	3–6
Estimated for informal sectors (e.g., charcoal)	6–12		0.6–2.4
Total Traditional Biomass	***37–43***		***3.6–8.4***
Modern Bioenergy			
Electricity and CHP from biomass, MSW, and biogas	4.0	32	1.3
Heat in residential, public/commercial buildings from solid biomass and biogas	4.2	80	3.4
Road transport fuels (ethanol and biodiesel)	3.1	60	1.9
Total Modern Bioenergy	***11.3***	***58***	***6.6***

IPCC, Biomass, 2011

Modern biomass usage

- Uses convenient solids, liquids and gases as secondary energy carriers to generate heat, electricity, combined heat and power (CHP) and transport fuels for various sectors
- Process industry, municipalities, districts and cooperatives generate for their own use, but also for sale to national and international markets.
- Biomass derived gases, primarily methane from anaerobic digestion of agricultural residues and waste treatment streams, are used to generate electricity, heat or CHP for multiple sectors.
- The most important contribution is based on solids, such as chips, pellets, recovered wood previously used etc.
- High energy efficiency biomass conversion is found typically in the industry sector (with a total consumption of ~7.7 EJ/yr) associated with the pulp and paper industry, forest products, food and chemicals.
- Examples are fibre products (e.g., paper), energy, wood products, and charcoal

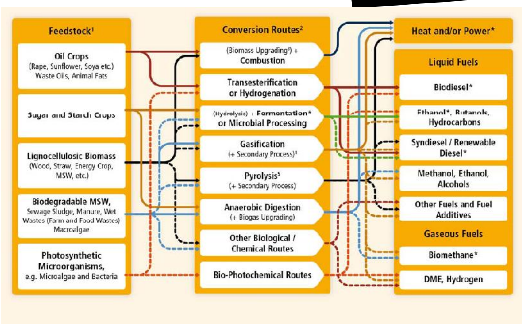
IPCC, Biomass, 2011

Status of biomass usage

- In 2006, China led all countries and used 9 EJ of biomass for energy, followed by India (6 EJ), the USA (2.3 EJ) and Brazil (2 EJ) (GBEP, 2008).
- Bioenergy provides a relatively small but growing share of TPES (1 to 4 % in 2006) in the largest industrialized countries (grouped as the G8 countries: the USA, Canada, Germany, France, Japan, Italy, the UK and Russia).
- The use of solid biomass for electricity production is particularly important in pulp and paper plants and in sugar mills.
- By contrast, in 2006, bioenergy provided 5 to 27% of TPES in the largest developing countries (China, India, Mexico, Brazil and South Africa), mainly through the use of traditional forms, and more than 80% of TPES in the poorest countries.
- The bioenergy share in India, China and Mexico is decreasing, mostly as traditional biomass is substituted by kerosene and liquefied petroleum gas within large cities.
- However, consumption in absolute terms continues to grow.
- This trend is also true for most African countries

IPCC, Biomass, 2011

Biomass conversion routes



IPCC, Biomass, 2011 73

Bioenergy production effects

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- Bioenergy production interacts with food, fodder and fibre production as well as with conventional forest products.
- Bioenergy demand constitutes a benefit to conventional plant production in agriculture and forestry by offering new markets for biomass flows that earlier were considered to be waste products.
- It can also provide opportunities for cultivating new types of crops and integrating bioenergy production with food and forestry production to improve overall resource management.
- However, biomass for energy production can intensify competition for land, water and other production factors, and can result in overexploitation and degradation of resources.

IPCC, Biomass, 2011 74

Bioenergy production potential

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- The magnitude of the biomass resource potential depends on the priority given to bioenergy products versus other products obtained from the land
  - Food
  - Fodder
  - Fibre
  - conventional forest products such as sawn wood and paper
  - and on biomass from agriculture and forestry.
- Growth depends on
  - natural conditions (climate, soils, topography),
  - agronomic and forestry practices
  - how societies understand and prioritize nature conservation and soil/water/biodiversity protection
  - how production systems are shaped to reflect these priorities

IPCC, Biomass, 2011 75

Bioenergy production potential

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- **Theoretical potential** refers to the biomass supply as limited only by biophysical conditions
- **Technical potential** considers the limitations of the biomass production practices assumed to be employed and also takes into account concurrent demand for food, fodder, fibre, forest products and area requirements for human infrastructure. Restrictions connected to nature conservation and soil/water/biodiversity preservation can also be considered.
- **Sustainable potential** is sometimes used as synonym
- **Market potential** refers to the part of the technical potential that can be produced given a specified requirement for the level of economic profit in production.
- Market potential not only depends on the cost of production but also on the price of the biomass feedstock, which is determined by a range of factors such as the characteristics of biomass conversion technologies, the price of competing energy technologies and the prevailing policy regime

IPCC, Biomass, 2011 76

Key climate change associations

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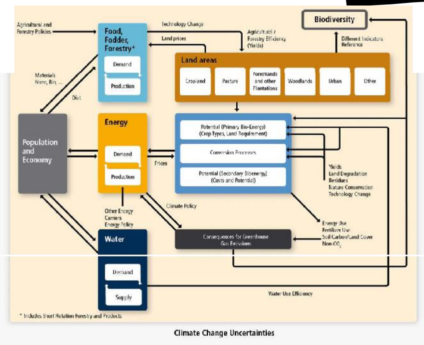

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Suitability of land to woody feedstock

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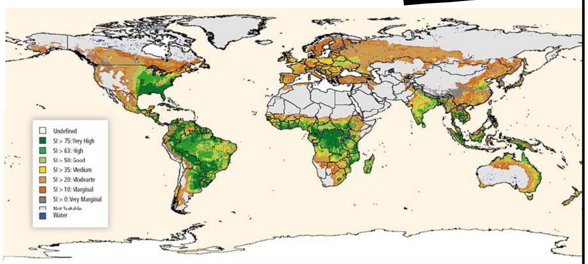

IPCC, Biomass, 2011 78

Status of technology for biomass

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Plant	Type of Product	Basic and Applied R&D	Demonstration	Early Commercial	Commercial
Low Moisture Lignocellulosic	Densified Biomass	Torrefaction	Hydrothermal Oil (Hy Oil) / Pyrolysis Oil (Py Oil)		Pelletization
	Charcoal		Pyrolysis (Biochar)		Carbonization
	Heat			Small Scale Gasification	Combustion Stoves
					Combustion
				Py /Hy Oil	Home/District Industrial
	Power or CHP				Combustion coupled with Steam Cycles
			Stirling Engine	ORC[1]	
					Co-Combustion or Co-firing with Coal
			Indirect	Parallel	Direct
					Gasification (G) or Integrated Gasification (IG)
		IG-Fuel Cell	IG-Gas Turbine / IG-Combined Cycle	G and Steam Cycles	
Wet Waste	Heat or Power or Fuel				Anaerobic Digestion to Biogas
				2-stage	Landfills (1-stage)
		Microbial Fuel Cells	Biogas Upgrading to Methane / Reforming to Hydrogen (H_2)		Small Manure Digesters
			Hydrothermal Processing to Oils or Gaseous Fuels		
Sugar	Fuels		Microbial Processing[2]		Sugar Fermentation
		H_2	Gasoline/ diesel/jet fuel	Biobutanols[3]	Ethanol
Oils	Fuels		Hydrogenation	Extraction and Esterification	
				Renewable diesel	Biodiesel

IPCC, Biomass, 2011 79

Thermochemical processes

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- **Biomass combustion** is a process where carbon and hydrogen in the fuel react with excess oxygen to form CO_2 and water and release heat. Combustion processes are well understood and a wide range of existing commercial technologies are tailored to the characteristics of the biomass and the scale of their applications. Biomass can also be co-combusted with coal in coal-fired plants
- **Pyrolysis** is the thermal decomposition of biomass occurring in the absence of oxygen (anaerobic environment) that produces a solid (charcoal), a liquid (pyrolysis oil or bio-oil) and a gas product. The relative amounts of the three co-products depend on the operating temperature and the residence time used in the process.
- **Biomass Gasification** occurs when a partial oxidation of biomass happens upon heating. This produces a combustible gas mixture (called producer gas or fuel gas) rich in CO and hydrogen (H_2) that has an energy content of 5 to 20 MJ/Nm^3 (depending on the type of biomass and whether gasification is conducted with air, oxygen or through indirect heating).

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Chemical processes

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- **Transesterification** is the process through which alcohols (often methanol) react in the presence of a catalyst (acid or base) with triglycerides contained in vegetable oils or animal fats to form an alkyl ester of fatty acids and a glycerine by-product. The fatty acid alkyl esters are typically referred to as 'biodiesel' and can be blended with petroleum-based diesel fuel.
- The protein-rich residue, also known as cake, is typically sold as animal feed or fertilizer, but may also be used to synthesize higher-value chemicals
- The **hydrogenation** of vegetable oil, animal fats or recycled oils in the presence of a catalyst yields a renewable diesel fuel—hydrocarbons that can be blended in any proportion with petroleum-based diesel and propane as products. This process involves reacting vegetable oil or animal fats with H_2 (typically sourced from an oil refinery) in the presence of a catalyst. Hydrogenation of vegetable oils and animal fats can still be considered a first-generation route as it is demonstrated at a commercial scale.

IPCC, Biomass, 2011 81

Biochemical processes

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- **Anaerobic digestion (AD)** involves the breakdown of organic matter in agricultural feedstocks such as animal dung, human excreta, leafy plant materials, urban solid and liquid wastes, or food processing waste streams by a consortium of microorganisms in the absence of oxygen to produce biogas, a mixture of methane (50 to 70%) and CO_2. In this process, the organic fraction of the waste is segregated and fed into a closed container (biogas digester). In the digester, the segregated biomass undergoes biodegradation in the presence of methanogenic bacteria under anaerobic conditions, producing methane-rich biogas and effluent.
- **Fermentation** is the process by which microorganisms such as yeasts metabolize sugars under low or no oxygen to produce ethanol. Among bacteria, the most commonly employed is *Escherichia (E.) coli*, often used to perform industrial synthesis of biochemical products, including ethanol, lactic acid and others. *Saccharomyces cerevisiae* is the most common yeast used for industrial ethanol production from sugars.

IPCC, Biomass, 2011 82

Biochemical processes

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- The major raw feedstocks for biochemical conversion today are
  - sugarcane,
  - sweet sorghum,
  - sugar beet
  - starch crops (such as corn, wheat or cassava)
- The major commercial product from this process is ethanol, which is predominantly used as a gasoline substitute in light-duty transport.

IPCC, Biomass, 2011 83

Different price for different products

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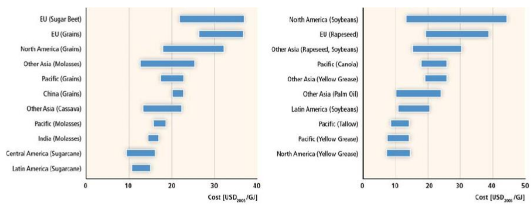

Snapshots of regional ranges of current (2008-2009) estimated production costs for ethanol and biodiesel from various biomass feedstocks and wastes

IPCC, Biomass, 2011 84

Biofuel production summary

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- Existing bioenergy systems rely mostly on wood, residues and waste for heat and power production, and agricultural crops for liquid biofuels.
- Energy yields per unit area range from 16 to 200 GJ/ha (1.6 to 20 TJ/km2) for biofuel feedstocks, from 80 to 415 GJ/ha (8 to 41.5 TJ/km2) for lignocellulosic feedstocks
- Handling and transport of biomass from production sites to conversion plants may contribute 20 to 50% of the total costs of bioenergy production.
- Densification via pelletization or briquetting is required for transport distances over 50 km.
- International costs of delivering densified feedstocks are sensitive to trade and are in the USD2005 10 to 20/GJ range for pellet fuels, and competitive with other market fuels in several regions, thus explaining why such markets are increasing.

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Major pellet trade flows

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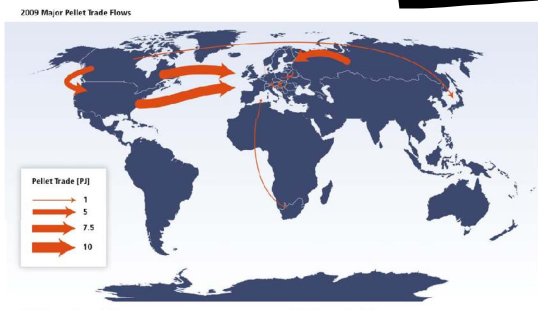

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Biomass electricity, 2008

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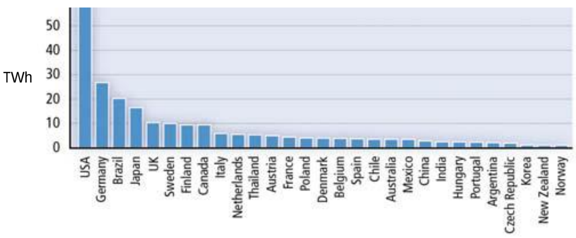

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Biomass heat, 2008

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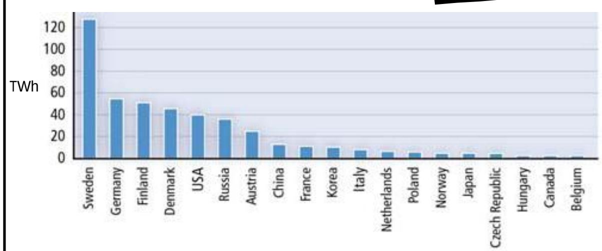

IPCC, Biomass, 2011 88

Global trade in biomass and bioenergy

- World net trade of *liquid biofuels* amounted to 120 to 130 PJ in 2009, compared to about 75 PJ for wood pellets
- Global fuel *ethanol* production grew from around 0.375 EJ in 2000 to more than 1.6 EJ in 2009.
- USA and Brazil, the two leading ethanol producers and consumers, accounted for about 85% of the world's production.
- EU total consumption of ethanol for transport in 2009 was 94 PJ, with the largest users being France, Germany, Sweden and Spain.
- World *biodiesel* production started below 20 PJ in 2000 and reached about 565 PJ in 2009. EU produced 334 PJ, with Germany, France, Spain and Italy being the top EU producers.
- In 2009, more than 13 Mt (230 PJ) of *wood pellets* were produced in 30 European countries, the USA and Canada.
- Largest EU consumers were Sweden (1.8 Mt or 32 PJ), Denmark, the Netherlands, Belgium, Germany and Italy (roughly 1 Mt or 18 PJ each)

IPCC, Biomass, 2011

Biomass trade, 2009

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Biomass policy instruments

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Country	Policy Instruments							
	Binding Targets/ Mandates[1]	Voluntary Targets[1]	Direct Incentives[2]	Grants	Feed-in Tariffs	Compulsory grid connection	Sustainability Criteria	Tariffs
Brazil	E, T		T					removed
China		E, T[4]	T	E, T	E, H	E, H		n/a
India	T, (E[3])	T(BD)	E	E, H, T	E			n/a
Mexico	(E[3])	(T)	(E)			(E)		Eth
South Africa	T, E	E, (T)	(E), T					n/a
Canada	E, T, H	E[4], T[4]	T	E, H, T				Eth
France		E[3], H[3], T	E, H, T		E			as EU below
Germany	E[3], T		H	H	E	E	(E, H, T)	as EU below
Italy	E[3]	E[3], T	T	E, H, T	E	E		as EU below
Japan		E, H, T				E		Eth, B-D
Russia		(E, H, T)	(T)					n/a
UK	E[3], T[3]	E[3], T	E, H, T	E, H, T	E		T	as EU below
USA	T, T[4], E[4]	E[4]	E, H, T	E, T	E			Eth
EU	E[3], T	E[3], H[3], T	T	E, H, T		E	(T)	Eth, B-D

E = electricity, H = heat, T = transport, Eth = ethanol and BD = biodiesel

IPCC, Biomass, 2011

Bioenergy trade barriers

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- **Technical standards**
- **Sustainability criteria and biomass and biofuels certification**
  - chain of custody (CoC)
  - lack of transparency in the development of some methodologies, for example, in the EU legislation
  - Criteria, especially those related to environmental and social issues varies
  - Criteria may act as trade barriers
- **Sanitary and phytosanitary**
- **Logistics**

IPCC, Biomass, 2011

Socioeconomic impacts of bioenergy

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- **Global, regional, off-site environmental effects** GHGs; albedo; acidification; eutrophication; water availability and quality; regional air quality
- **Local/onsite environmental effects** Soil quality; local air quality; water availability and quality; biodiversity and habitat loss
- **Technology** Hazards; emissions; congestion; safety; genetically modified organisms/plants
- **Human rights and working conditions** Freedom of association; access to social security; job creation and average wages; freedom from discrimination; no child labour and minimum age of workers; freedom of labour (no forced labour); rights of indigenous people; acknowledgement of gender issues

IPCC, Biomass, 2011

Ranges of GHG emissions per unit energy output (MJ)

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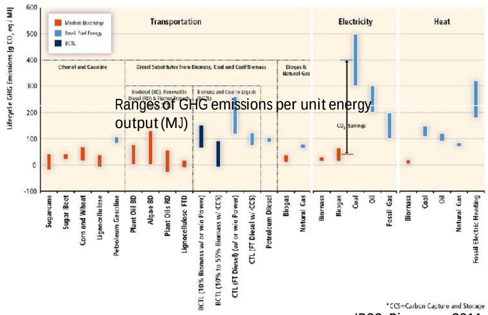

Ranges of GHG emissions per unit energy output (MJ)

IPCC, Biomass, 2011

Socioeconomic impacts of bioenergy

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		Fossil energy reference	Displacement factor[1]	Relative GHG savings[2] (%)
Finnish modern CHP plant (from logging residues)		Coal	78	86[e]
		Natural gas	30	86[e]
Finnish Fischer-Tropsch diesel[3] as a standalone plant or integrated with a pulp and paper mill plant; with/without electricity	Standalone plant	Fossil diesel	39[a]	78[f]
	Integrated plant, minimize biomass		50[b]	55[g]
	Integrated plant, minimize electricity		50[c]	78[h]
Finnish biodiesel (rapeseed oil)		Fossil diesel	-9[d]	-15[i]
North American ethanol (corn) powered by natural gas (NG) dry mill 1995 2005 2015 with CHP[3]2015 with CHP and CCS[3]		Fossil gasoline	18 24 31 51	26 39 55 72
Brazilian ethanol (sugarcane) 2005–2006 (average 44 mills) 2020 CHP[3] (mechanical harvest) 2020 CHP and CCS[3]		Fossil gasoline/ electricity marginal NG	29 36 51	79 120 160

IPCC, Biomass, 2011

Socioeconomic impacts of bioenergy

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- Emissions from the bioenergy chain including non-CO2 GHG and fossil CO2 emissions from auxiliary energy use in the biofuel chain.
- GHG emissions related to changes in biospheric carbon stocks often caused by associated LUC.
- Other non-GHG related climatic forcers including particulate and black carbon emissions from small-scale bioenergy use, aerosol emissions associated with forests and changes in surface albedo.
- Albedo increases associated with the conversion of forests to energy crops (e.g., annual crops and grasses) may reduce the net climate change effect from the deforestation.
- Effects due to the bioenergy use, such as price effects on petroleum that impact consumption levels.
- Other factors include the extent and timing of the reversion of cultivated land when the use for bioenergy production ends and how future climate change impacts relative to present impacts are treated.

IPCC, Biomass, 2011

Socioeconomic impacts of bioenergy

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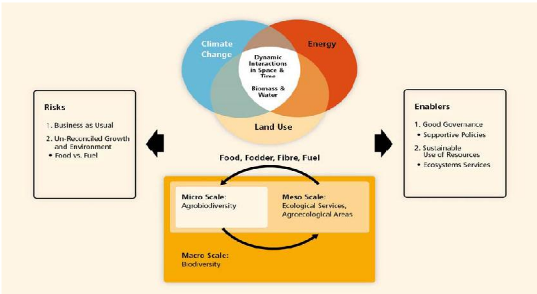

IPCC, Biomass, 2011

97

Overview of processing routes

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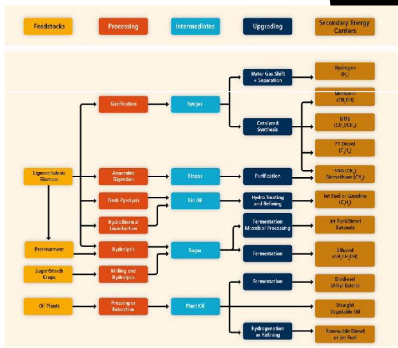

IPCC, Biomass, 2011

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Cost for energy crops

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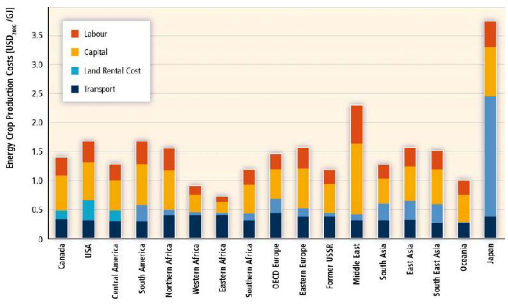

IPCC, Biomass, 2011

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Cost of bioenergy at 7 %

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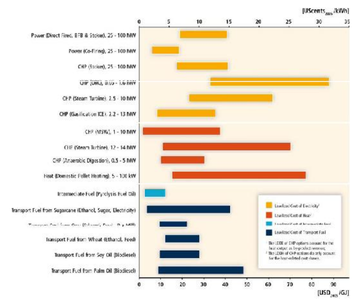

IPCC, Biomass, 2011

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Cost of bioenergy

Selected Bioenergy Technologies	Energy Sector (Electricity, Thermal, Transport)*	2020-2030 Projected Production Costs (USD_{2005}/GJ)
IGCC [1]	Electricity and/or transport	13–19 (4.5–6.9 cents/kWh)
Oil plant-based renewable diesel and jet fuel	Transport and electricity	15–30
Lignocellulose sugar-based biofuels[2]	Transport	6–30
Lignocellulose syngas-based biofuels[3]		12–25
Lignocellulose pyrolysis-based biofuels[4]		14–24 (fuel blend components)
Gaseous biofuels[5]	Thermal and transport	6–12
Aquatic plant-derived fuels, chemicals	Transport	30–140

IPCC, Biomass, 2011 101

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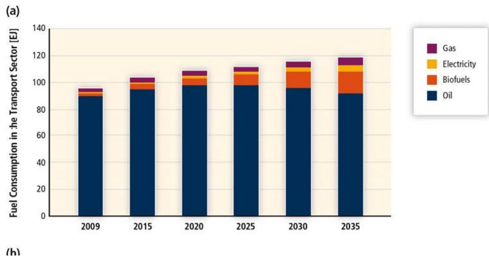
Use of transport fuels



IPCC, Biomass, 2011 102

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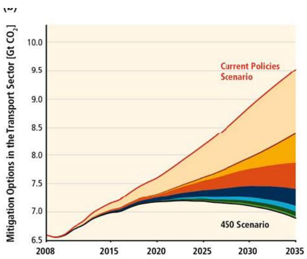
Use of transport fuels



	Abatement 2020	2030	2035
Road	83%	80%	80%
Increased Efficiency	67%	51%	43%
Switch to Gas	3%	1%	1%
Switch to Electricity	2%	11%	19%
Switch to Biofuels	11%	17%	17%
Aviation	14%	15%	15%
Increase Efficiency	14%	12%	11%
Switch to Biofuels	0%	3%	4%
Navigation	2%	3%	3%
Other Transport	2%	2%	1%
Total [Gt CO_2]	0.4	1.7	2.6

IPCC, Biomass, 2011 103

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R&D needs

Esa Vakkilainen

Sustainability

- Since sustainability of biofuels is still a “loosely defined” topic from a scientific point of view, it is essential to accelerate the development of science based, rational and transparent criteria, indicators and methodology
- Across the full value chains, from feedstocks to end uses for EU relevant geographies, for both domestic and imported feedstocks or biofuels for the three dimensions of sustainability:
  - environmental (GHG, CO_2, N_2, CH_4, water, biodiversity, local emissions, soil, etc.)
  - Social
  - economic
- To better asses the issues around direct and indirect land use change and help manage the issues of competing uses of arable land and biomass.
- A better understanding of sustainability aspects of biofuel value chains versus other economic “value chains”, as well as non-market “common goods”, in particular to include systemic impacts over short versus long term time lines.

European Biofuels Technology Platform, 2010

Availability

- Develop a common view on sustainable biomass availability across different sectors, shared with all relevant stakeholders.
- Develop cost supply curves for existing and new feedstocks and given timeframes, regions and demand types. Define obstacles to mobilisation.
- Develop new plant varieties (crop/tree breeding and physiology); improve cultivation and management practices (propagation, cultivation systems, etc) to optimise water, energy and other inputs and increase productivity.
- Optimise associated equipment to minimise logistics chain costs and to meet conversion requirements (integrated harvesting, collection and transport solutions for fibre/bio-materials and energy).
- Develop large-scale logistics for new feedstocks or underutilised resources, optimise along the supply chain.
- Competition in biomass use. Research should focus on defining the methods and criteria to assess what types of biomass can contribute to a sustainable biofuels market without directly competing with other uses (particularly food).
- Use of wastes and residues – maximising efficiency of closed-loop cycles and biorefining.

European Biofuels Technology Platform, 2010

Biofuel chains

- Take a complete chain/biorefining approach with an integrated appreciation of economic, social, technical and environmental issues.
- R&D (short/mid-term applied and long-term fundamental research) efforts should target efficient, sustainable and integrated growing, harvesting, logistics, conversion and by-product utilisation
- Fundamental research on identification and optimisation of biomass strains is needed. Optimisation does not only refer to yield rates, but also to increased tolerance of contaminants.
- Applied R&D on conversion processes, leveraging on existing biofuels conversion technologies where possible.
- Work on sustainable industrial-scale production techniques and best practice is required. Main challenges: ensure cost-competitiveness with fossil fuels, improve energy balance, manage large quantities of water, prove scalability.
- LCA and energy balance of biomass-to-biofuel production chains
- Evaluate benefits and risks of GMO, including public awareness as well as potential impact on biodiversity.
- Use of wastes and residues

European Biofuels Technology Platform, 2010

Conversion

- Key priority for commercial biofuel technologies: improve environmental (GHG, energy balance, water, inputs, etc) and economic performance.
- For advanced biofuels (not yet commercially deployed), the focus is on: Ability to process a wide range of sustainable feedstocks while ensuring energy and carbon efficient process and selectivity towards higher added value products. Biofuels that perform at least as well as, but preferably better than, existing ones. Compatibility with existing fuel infrastructures at increasing blend rates should be aimed at.
- Conversion technologies targeting distillates for transport fuels deserve priority attention because of increasing demand (heavy duty road transport, air, marine).
- For advanced biofuels, activities on process optimisation/integration should focus on specific value chains such as those identified by the European Bioenergy Initiative, with ongoing pilot, demo and reference plant projects.
- Value chains leveraging on industrial synergies with existing facilities deserve priority attention as they might offer the best economic and industrial framework to manage the high risk/high cost of deploying promising new technologies, helping the transition from conventional to advanced biofuels.
- New “tools” need to be further evaluated and developed/adapted for EU feedstock applications: Synthetic biology to produce “drop in” biofuels (biofuels with chemical and physical composition fully compatible with current fuel infrastructures) Catalytic and chemical biomass conversion (i.e. catalytic conversion of sugars to furanics)
- Aviation and marine fuels: no specific technical challenges for processing technologies, but mostly (downstream) finetuning of processes already developed for road transport fuels.

European Biofuels Technology Platform, 2010