European Commission

Carbon accounting of forest bioenergy

Biogenic CO_2 modeling and the role of forest bioenergy in EU energy and climate policy.

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Joint Research Centre – Institute for Energy and Transport

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EEA-JRC joint expert workshop on bioenergy carbon accounting, Copenhagen.

Preliminary remarks

- The views expressed are purely those of the speaker and may not in any circumstances be regarded as stating an official position of the European Commission

- Bioenergy production affects many other aspects then climate change: security of energy supply, socioeconomics, biodiversity, rural developments etc. that are not dealt with in this presentation.

Agenda

Introduction

Background info

JRC Literature review

Topics and issues:

- Temporal scale of the analysis
- Baseline definition
- Analytical methods and spatial scale

Market mediated effects:

- iWUC
- iFUC

Beyond carbon accounting

- Other climate forcers
- Climate metrics
- Biodiversity

Workshop agenda

	DAY 1
13:30-13:50	Welcome and brief introduction of the participants (tour de table), Mihai Tomescu (EEA)
13:50-14:10	Framing the day - Jacopo Giuntoli (JRC)
14:10-14:30	Carbon accounting of forest bioenergy, a review – Luisa Marelli (JRC)
14:30-14:50	Questions arising from the bioenergy 2013 EEA analysis – forest part, Jan-Erik Petersen (EEA)
14:50 -15:10	Current and future use of EU forests and carbon accounting via consumption data, Udo Mantau (EUWOOD)
15:10 -15:30	State-of-the science, methodologies – review by Uwe Fritsche (IINAS)
15:30-15:50	Coffee break
15:50-16:10	Expected outcomes of the day, planning of discussion, set-up of 2 break-out groups: a) Biogenic carbon accounting, methodologies, system boundaries b) Baseline, boundaries, data and information sources , baseline, current projected wood use
16:10-18:00	Group discussions
19:00-	Joint dinner

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Workshop agenda

DAY 2	
09:00-10:30	Reporting back from break out groups, followed by plenary discussion
10.30-10.45	Coffee break
10.45-11.00	Introduction to break-out groups
11.00-12.30	Two break-out groups on a) next steps for improving information basis and analytical approaches for biogenic carbon accounting b) approaches for identifying and estimating low carbon risk bioenergy sources in forest biomass
12.30	Lunch
14:00-15:15	Reports back from break-out group and plenary discussion
15.15-15.30	Coffee break
15:30-16:00	Summing up, conclusions and next steps

Biomass combustion DOES EMIT CO_2!

Carbon Intensity:

- Wood: 102 gCO_2 / MJ energy
- Hard Coal: 96 gCO_2 / MJ energy
- Natural Gas: 56.4 g CO_2 / MJ energy

- Wind – Solar: 0 gCO_2 / MJ energy

BUT:

Bioenergy is renewable - Re-growing of biomass can reabsorb the CO_2 emitted making bioenergy carbon neutral.

Timing is fundamental

Timing is fundamental

Length of carbon cycle:

- Energy crops: year (s)
- Forests : several decades – a century
- Peat : millennia
- Fossil: million years

Background info: EU climate policy

- Combustion of any biomass feedstock is considered to have zero CO_2 emissions (ETS, RED, FQD);
- LULUCF:
  - Agreed for Kyoto-2
  - Accounting rules for EU defined (Decision 529/2013)
  - Not yet agreement whether LULUCF will be accounted in EU -20% GHG target.
  - Anyway, valid only for EU MS and Kyoto-2 signatories → possible C leakages from imports.

Background info

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Background info: EU climate policy

- RED: GHG calculations independent from international C-accounting, only for threshold yes/no eligibility.
- RED uses simplified attributional LCA to compare bioenergy/biofuel to fossil fuel comparator.
- Bioenergy/biofuel climate impact is based solely on 3 long-lived GHG emissions.
- GHG savings targets at 2020 (roadmaps for 2030 – 2050)
- GWP at time horizon 100 years is used as metric

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Background info

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Background info: LCA

Attributional LCA (ALCA):

- Comparison of two or more systems delivering the same functional unit (e.g. 1 MJ of fuel, the transport of 1 tonne of products per 1 km, 1 MJ of electricity etc…).
- Only the foreground system is modelled, not suitable to assess the impacts of decisions that cause a change in the background system (e.g. policy assessment).
- The result of a comparative ALCA is that '***IF system A replaces system B, you have x% GHG savings***'
- Example: RED methodology

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Background info: LCA

Consequential LCA (CLCA):

- Assesses the consequences that a decision in the foreground system has for other processes and systems of the economy.
- This is the case of environmental impacts of a policy impacting several sectors of the economy.
- The result of a CLCA is that ***'in Scenario 2 you have a different level of consumption of products A, B, C and D and the total emissions x are % lower than Scenario 1'***
- Example: ILUC modelling

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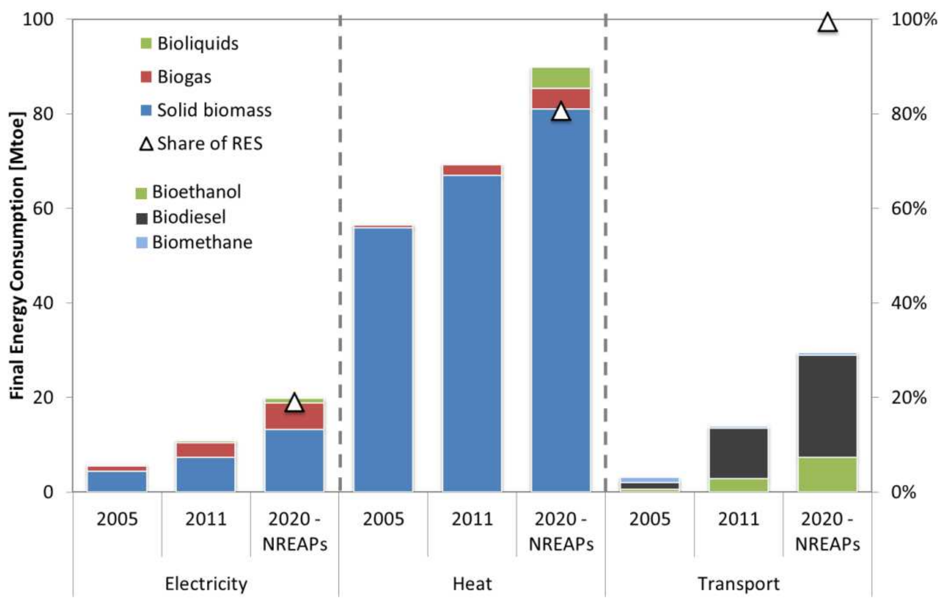
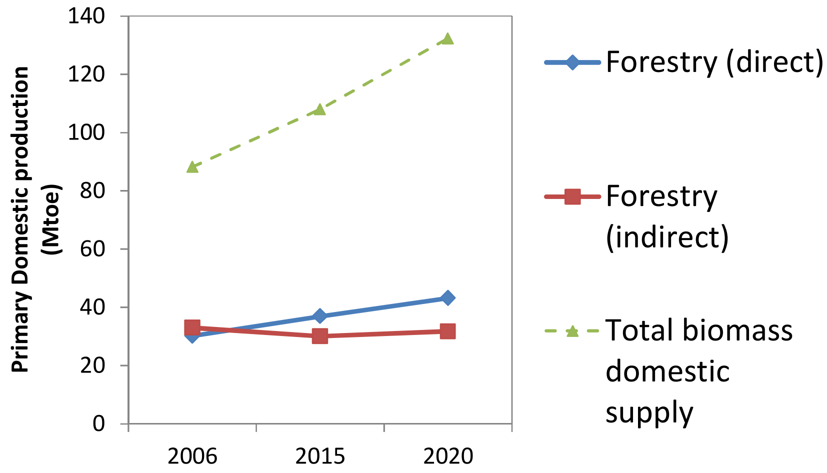
Background info: NREAPs

- Bioenergy to cover almost 60% of all RES in EU 2020
- Forest bioenergy to come mostly directly from the forest (primary residues, additional harvesting)

Bioenergy demand in EU. Source: NREAPs / EEA



Domestic forest bioenergy supply in EU. Source: NREAPs



Background info

Background info: EU wood pellets imports

Wood pellets production and consumption in EU. Source: IEA bioenergy

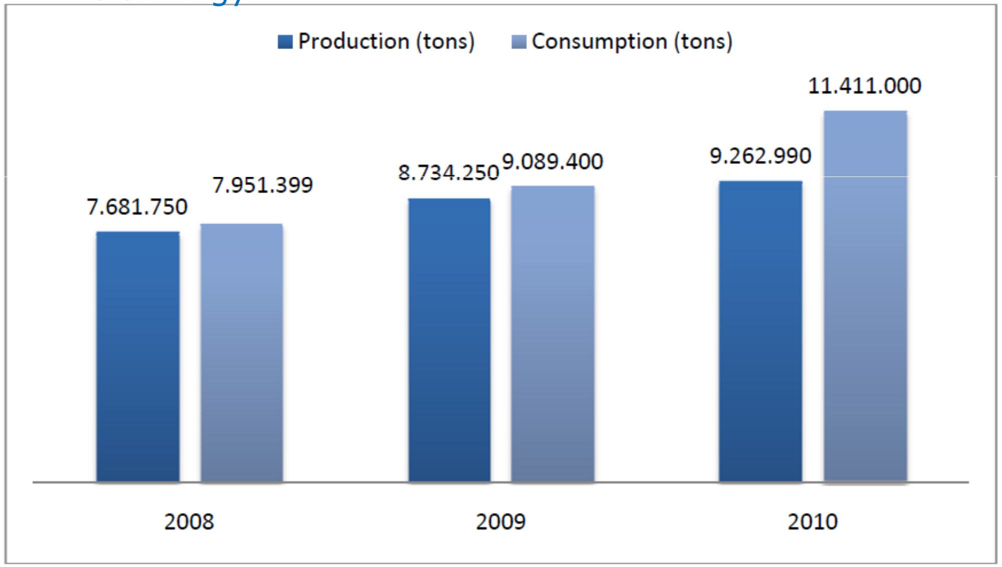


Fig. 1.5 – Production and consumption of wood pellets in EU

Wood pellets import origin to EU. Source: IEA bioenergy

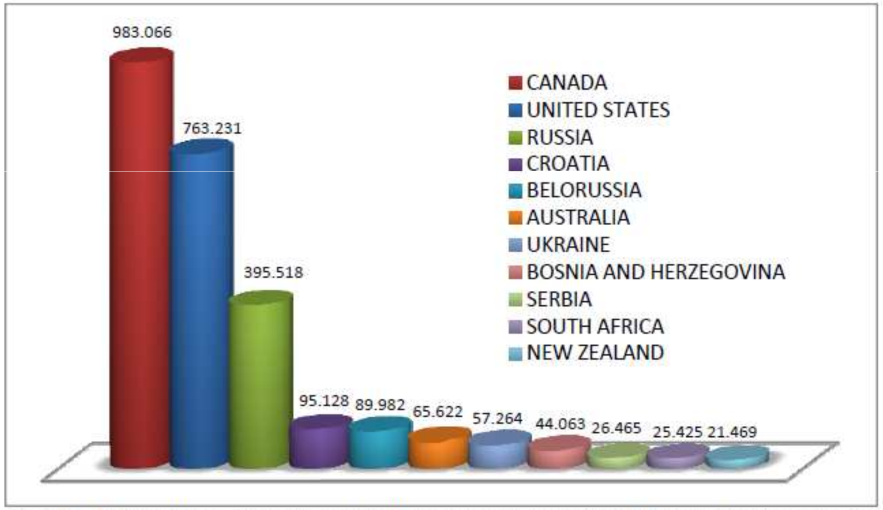


Fig. 1.8 – Extra EU imports of wood pellets by country in 2010 (tons). Source Eurostat

No statistical data on the type of feedstock!

Background info

Definitions

- Stemwood
- Forest residues
- C-debt
- Baseline

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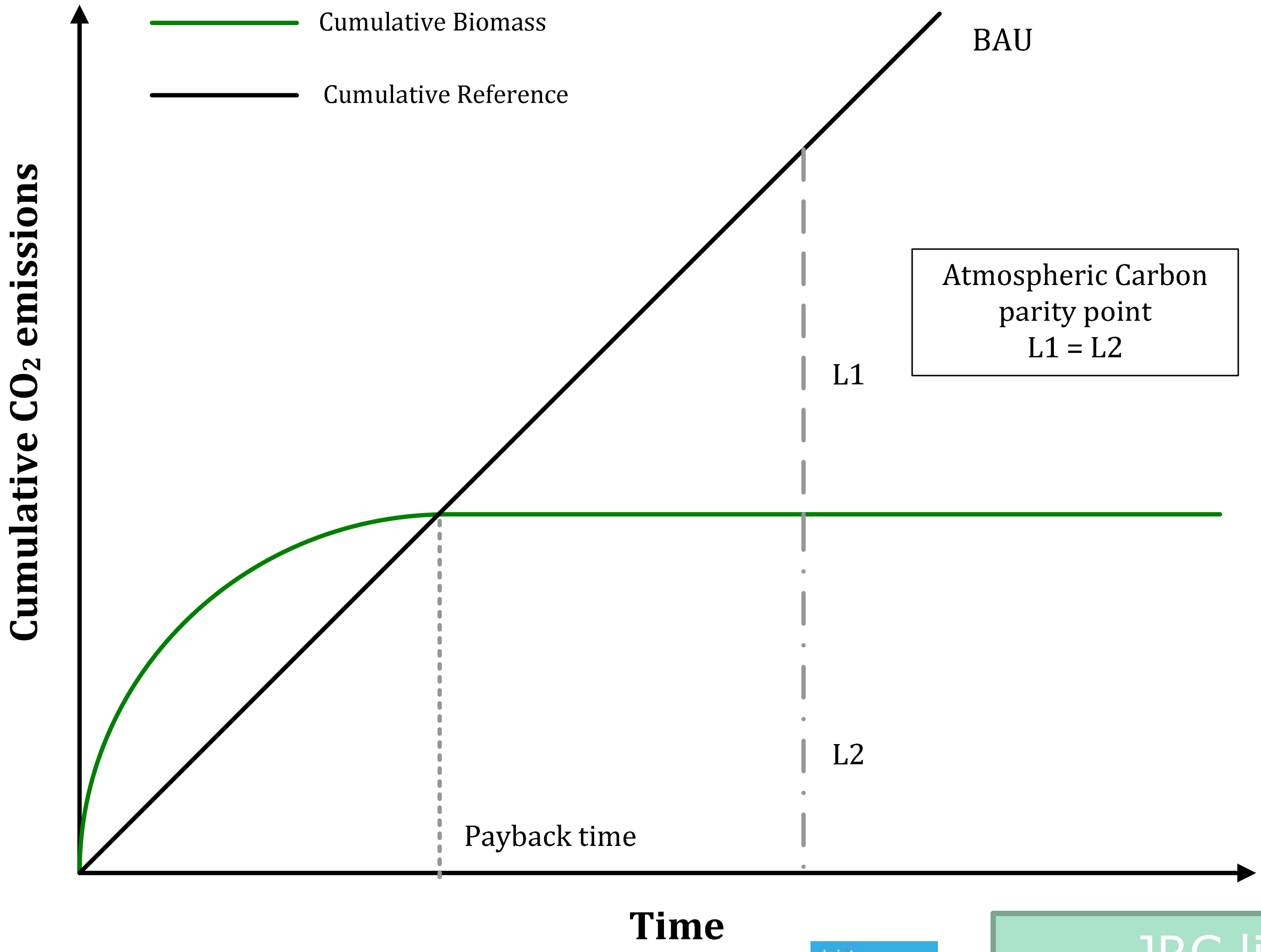
Visual description of payback time and carbon neutrality



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JRC literature review

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AUTHOR	AREA	FOREST TYPE	STUDY BOUNDARIES	SCENARIOS	FOSSIL REFERENCE SYSTEM	PAYBACK TIME (yr)
(McKechnie 2011)	Ontario	Temperate	Landscape	REF: BAU wood for products, BIO: BAU + additional harvest without residues	Electricity coal	Roundwood 38
					Gasoline (ethanol)	Roundwood >100
(Holtsmark 2012a)	Norway	Boreal	Forest management unit	REF: BAU wood for products, BIO: BAU + additional harvest without residues	Electricity coal	190
					Gasoline (ethanol)	340
(Colnes 2012)	US SE forests	Temperate	Landscape	REF: BAU wood for products & energy , BIO: 22 new biomass power plants running on additional harvest in the same defined landscape	Various,	35 to 50
(Walker 2010)	Massachusetts	Temperate	Representative stand	REF: 2 baseline harvest scenarios (20-32%, no residues), BIO: 3 scenarios with additional harvest(38, 60, 76 % + 2/3 residues),	Oil, thermal or CHP	3-15
					Electricity coal	12-32
					Gas thermal	17-37
					Electricity Natural Gas	59 - >90
(Zanchi 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings increased from 60% to 80% of Net annual increment (SFM), NO upstream emissions, only end use emissions (same for biomass and coal), 1) NO residues collection 2) residues collection only from the additional fellings	Electricity coal	1) 175 2) 75
(Zanchi 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings increased from 60% to 80% of Net annual increment (SFM), NO upstream emissions, only end use emissions (N.G. 40% less emissions than biomass), 1) NO residues collection 2) residues collection only from the additional fellings	Electricity Natural Gas	1) 300 2) 200
(Zanchi 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings (NO residues collection) increased from 60% to 80% of Aboveground biomass (no SFM), NO upstream emissions, only end use emissions 1) coal with same emissions as biomass 2) natural gas with 40% le[illegible] 3) oil with 20% less emissi[illegible]	1) Electricity coal 2) Electricity Natural Gas 3) Electricity Oil	1) 230 2) 400 3) 295

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JRC literature review

AUTHOR	AREA	FOREST TYPE	STUDY BOUNDARIES	SCENARIOS	FOSSIL REFERENCE SYSTEM	PAYBACK TIME (yr)
(Zanchi 2011)	Austria	Temperate forest	Forest management unit	Short rotation plantation on Marginal Agricultural Land with low C stock	Any fossil fuel	<0
(Zanchi 2011)	Austria	Temperate forest	Forest management unit	Forest Clearing – Substitution with short high productivity plantation (10 years rotation), wood for bioenergy. 1) coal with same emissions as biomass 2) natural gas with 40% less emission than biomass 3) oil with 20% less emission than biomass,	1) Electricity coal 2) Electricity Natural Gas 3) Electricity Oil	1) 17 2) 25 3) 20
(Zanchi 2011)	Austria	Temperate forest	Forest management unit	Forest Clearing – Substitution with short high productivity plantation (10 years rotation), 50% wood for bioenergy, 50% for HWPs (additional to baseline)	1) Electricity coal 2) Electricity Natural Gas	1) 0 2) 8
(Zanchi 2011)	Austria	Temperate forest	Forest management unit	Forest Clearing – Substitution with short low productivity plantation (20 years rotation), wood for bioenergy.	1) Electricity coal 2) Electricity Natural Gas 3) Electricity Oil	1) 114 2) 197 3) 145
(Mitchell 2009)	U.S.	Temperate	Forest stand	Coast range forest type Forest biomass removed for fire prevention Understory removal, overstory thinning, and prescribed fire every 25 years	Average fossil fuel via solid biomass	old growth 169 second growth 34
(Mitchell 2009)	U.S.	Temperate	Forest stand	Coast range forest type Forest biomass removed for fire prevention Understory removal, overstory thinning, and prescribed fire every 25 years	Average fossil fuel via ethanol	old growth 339 second growth 201
(Mitchell 2009)	U.S.	Temperate	Forest stand	West cascades forest type Forest biomass removed for fire prevention Understory removal, overstory thinning, and prescribed fire every 25 years	Average fossil fuel via solid biomass	old growth 228 second growth 107
(Mitchell 2009)	U.S.	Temperate	Forest stand	West cascades forest type Forest biomass removed for fire prevention Understory removal, overs [illegible] fire every 25 years	Average fossil fuel via [illegible]	old growth 459 [illegible]

JRC literature review

AUTHOR	AREA	FOREST TYPE	STUDY BOUNDARIES	SCENARIOS	FOSSIL REFERENCE SYSTEM	PAYBACK TIME (yr)
(McKechnie 2011)	Ontario	Temperate	Landscape	REF: BAU wood for products, RESIDUES = BAU + residues harvest,	Electricity coal	Residues 16
					Gasoline (ethanol)	Residues 74
(Zanchi 2011)	Austria	Temperate	Forest Management Unit	Norway Spruce, Fellings Residues (from baseline felling rates and no leaves) increased from 0% to 14% of aboveground biomass left from fellings, NO upstream emissions, only end use emissions 1) coal with same emissions as biomass 2) natural gas with 40% less emission than biomass 3) oil with 20% less emission than biomass,	1) Electricity coal 2) Electricity Natural Gas 3) Electricity Oil	1) 0 2) 16 3) 7
(Repo 2012)	Finland	Boreal	Forest stand	Baseline scenario clear cut for materials; 3 scenarios with different residues harvest	Electricity Natural gas	Branches 8 Thinning 20 Stumps 35
(Repo 2012)	Finland	Boreal	Forest stand	Baseline scenario clear cut for materials; 3 scenarios with different residues harvest	Electricity Heavy fuel oil	Branches 5 Thinning 12 Stumps 22
(Mitchell 2009)	U.S.	Temperate	Forest stand	Coast range forest type Forest biomass removed for fire prevention Understory removal, overstory thinning, and prescribed fire every 25 years	Average fossil fuel via solid biomass	old growth 169 second growth 34
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(Mitchell 2009)	U.S.	Temperate	Forest stand	West cascades forest type Forest biomass removed for fire prevention Understory removal, overstory thinning, and prescribed fire every 25 years	Average fossil fuel via ethanol	old growth 459 second growth 338

Biomass source	CO_2 emission reduction efficiency					
	Short term (10 years)		Medium term (50 years)		Long term (centuries)	
	coal	natural gas	coal	natural gas	coal	natural gas
Temperate stemwood energy dedicated harvest	---	---	+/-	-	++	+
Boreal stemwood energy dedicated harvest	---	---	-	- -	+	+
Harvest residues*	+/-	+/-	+	+	++	++
Thinning wood*	+/-	+/-	+	+	++	++
Landscape care wood*	+/-	+/-	+	+	++	++
Salvage logging wood*	+/-	+/-	+	+	++	++
New plantation on marginal agricultural land (if not causing iLUC)	+++	+++	+++	+++	+++	+++
Forest substitution with fast growth plantation	-	-	++	+	+++	+++
Indirect wood (industrial residues, waste wood etc)	+++	+++	+++	+++	+++	+++

+/-: the GHG emissions of bioenergy and fossil are comparable; which one is lower depends on specific pathways,

-; --; ---: the bioenergy system emits more CO_2eq than the reference fossil system

+; ++; +++-: the bioenergy system emits less CO_2eq than the reference fossil system

**For residues, thinning & salvage logging it depends on alternativ*

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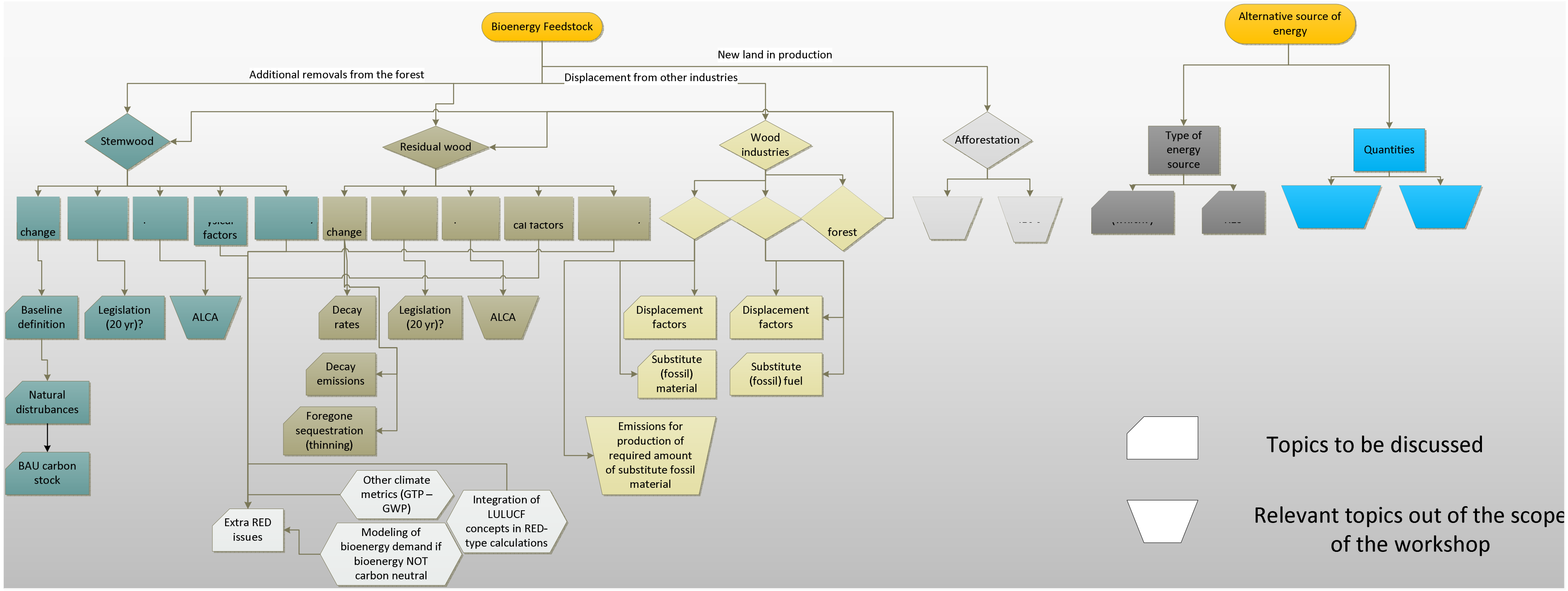
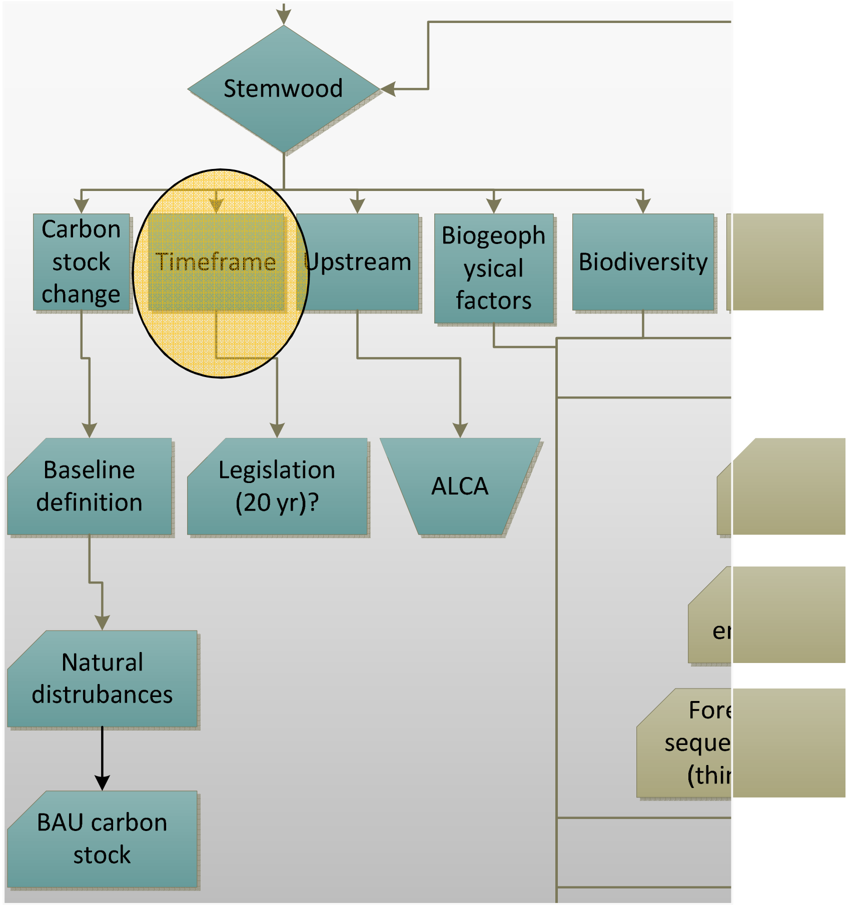
Sensitivity

FACTOR	PAYBACK TIME
Higher Carbon intensity of substituted fossil fuel	Shorter
Higher Growth rate of the forest	Shorter
Higher Biomass conversion efficiency	Shorter
Higher Decay rate for residues	Shorter

Topics and issues

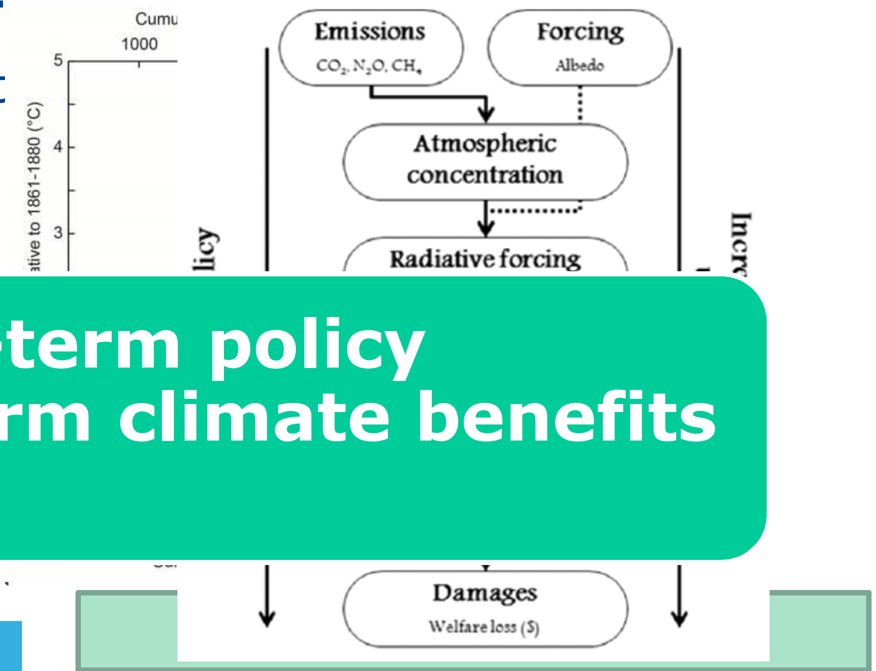



Stemwood
Carbon stock change
Timeframe
Upstream
Biogeophysical factors
Biodiversity
Baseline definition
Legislation (20 yr)?
ALCA
Natural distrubances
BAU carbon stock

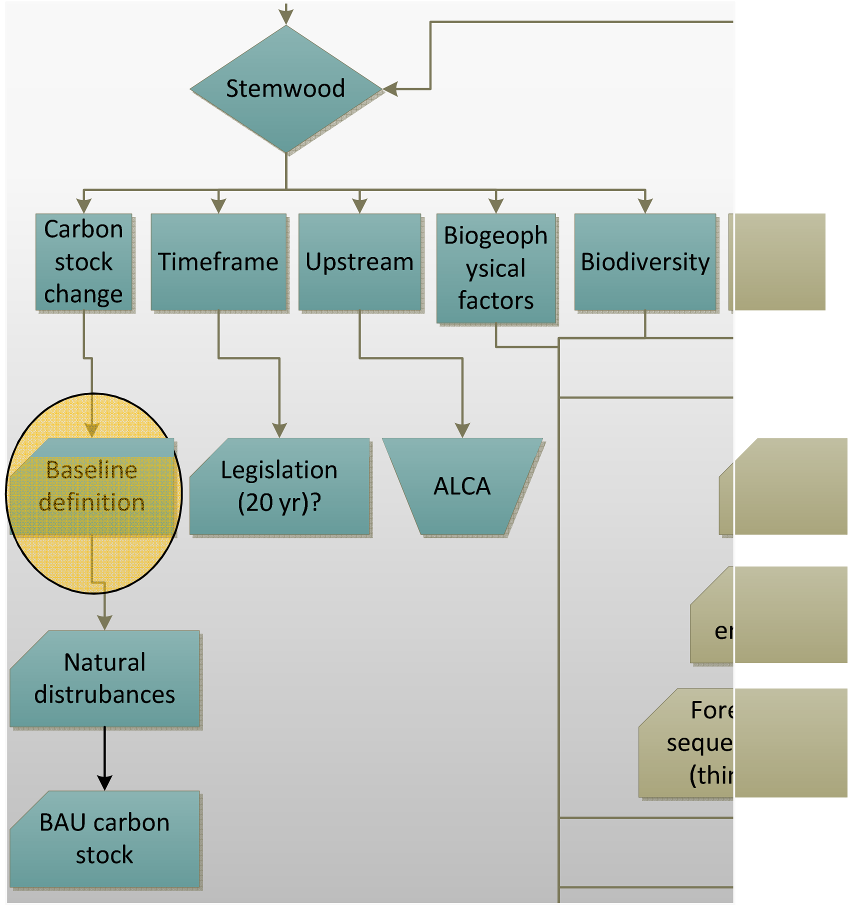
Timescale

Timescale of the analysis

- EU 2020 policy targets: **7 years!**
- Timeframe LUC emissions: Annualized over **20 years**
- IPCC Carbon budget to stay within 2°C: global warming dependent on total cumulative CO2 emissions.
- But impacts may depend on traject emissions).



How to reconcile short-term policy objectives with long-term climate benefits of bioenergy?


Stemwood
Carbon stock change
Timeframe
Upstream
Biogeophysical factors
Biodiversity
Baseline definition
Legislation (20 yr)?
ALCA
Natural distrubances
BAU carbon stock

Baseline

Baseline definition (1)

- Predicting the future is never easy:
  - o Depends on geographic location, current and future silvicultural practices, type of feedstock (residues, additional harvest, additional thinning, salvage logging etc…);
  - o Future demand for wood products;
  - o Occurrence of natural disturbances;
  - o Impact of natural disturbances on C-stocks;
  - o Impact of climate change and atmospheric CO_2 concentration on forest growth.

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Baseline definition (2)

Should the reference baseline be BAU or Unmanaged forest?

How to forecast natural disturbances and their impact on C-stocks?

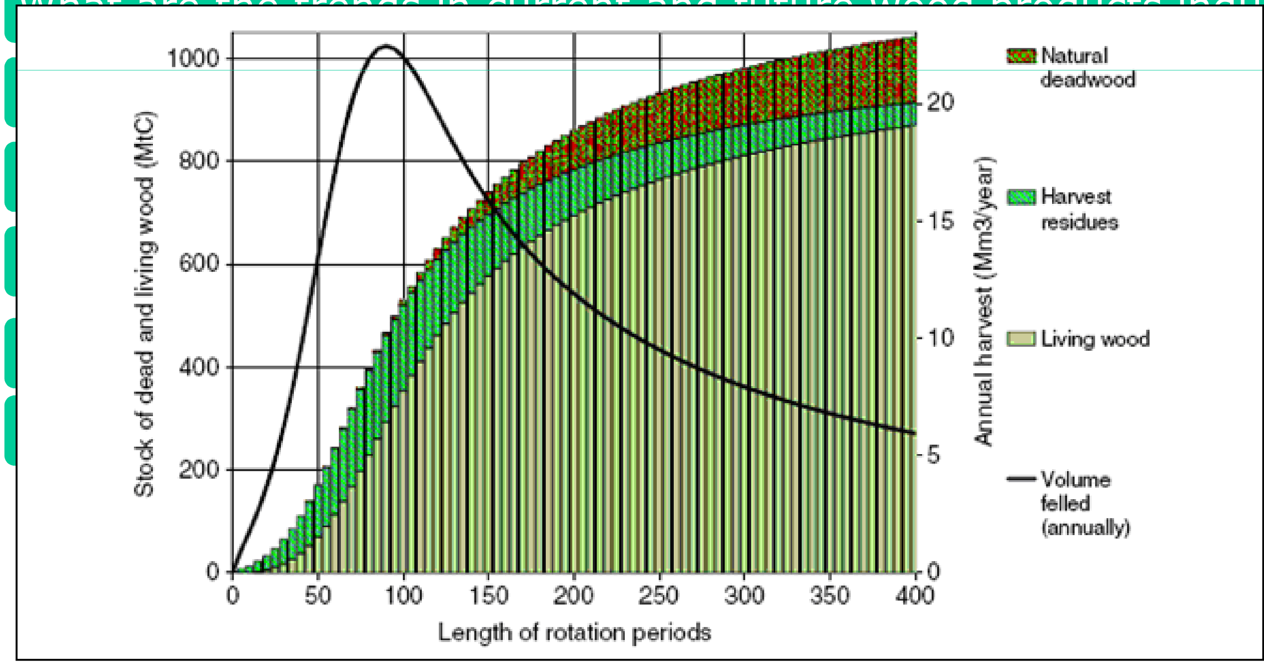
What are the trends in current and future wood products industries?

…ands?

…casting.

…s of decaying wood?

…er reach payback?



Source: **Holtsmark et al., 2012**

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Baseline

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Source: **Böttcher et al., 2011**

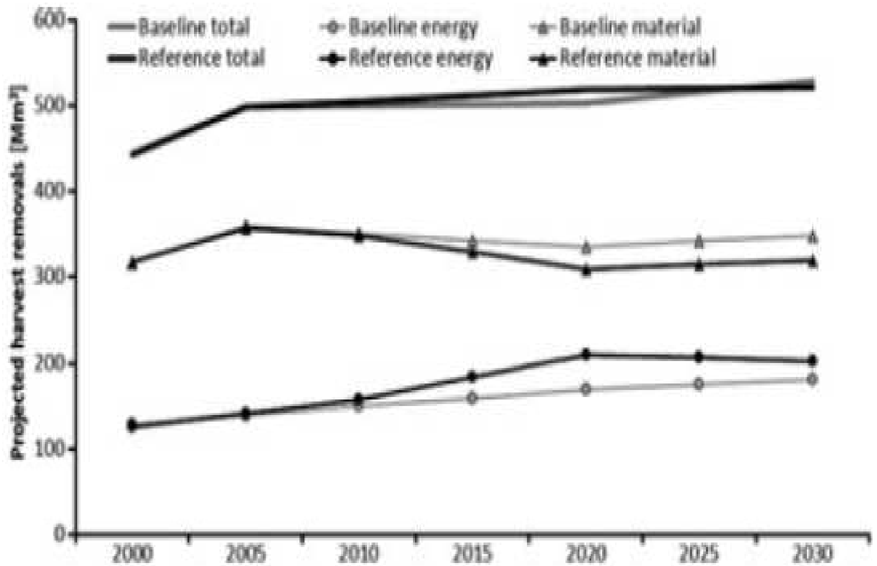
Analytical approa

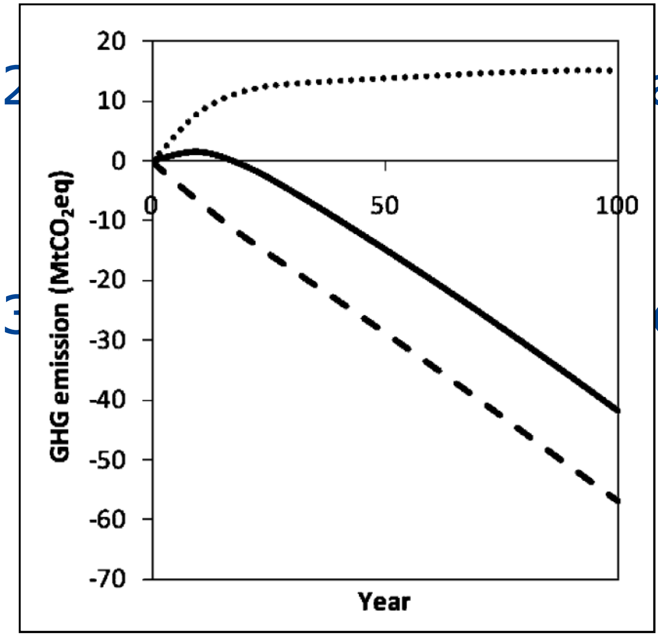
Three main approaches:

1. Forestry models and payba

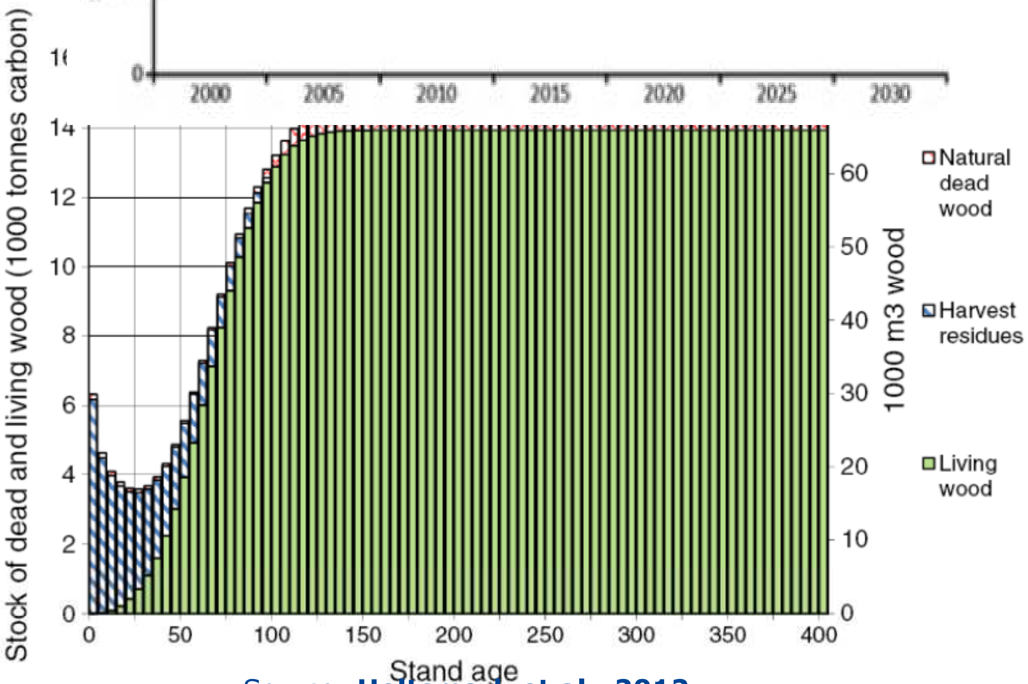
2 ... at

3 ... or





Source: **McKechnie et al., 2011**



Source: **Holtsmark et al., 2012**

A false hope: landscape vs. stand level analysis

The argument:

- A forest (or region) managed according to SFM principles has seen its carbon stock increasing during the past years.
- The stand harvested for bioenergy may give rise to a carbon debt but if the rest of the forest landscape has an increasing C-stock then the wood combusted should be considered as carbon neutral.

The error:

- By assigning the benefit of the carbon sequestration accrued in the remaining forest to the harvested stand we are assigning benefits which are clearly outside the system boundaries of the analysis (the wood harvested from the stand). If the analysis were done properly at landscape level then it would need to consider also that the biomass removals are at landscape level (continuous harvest)!

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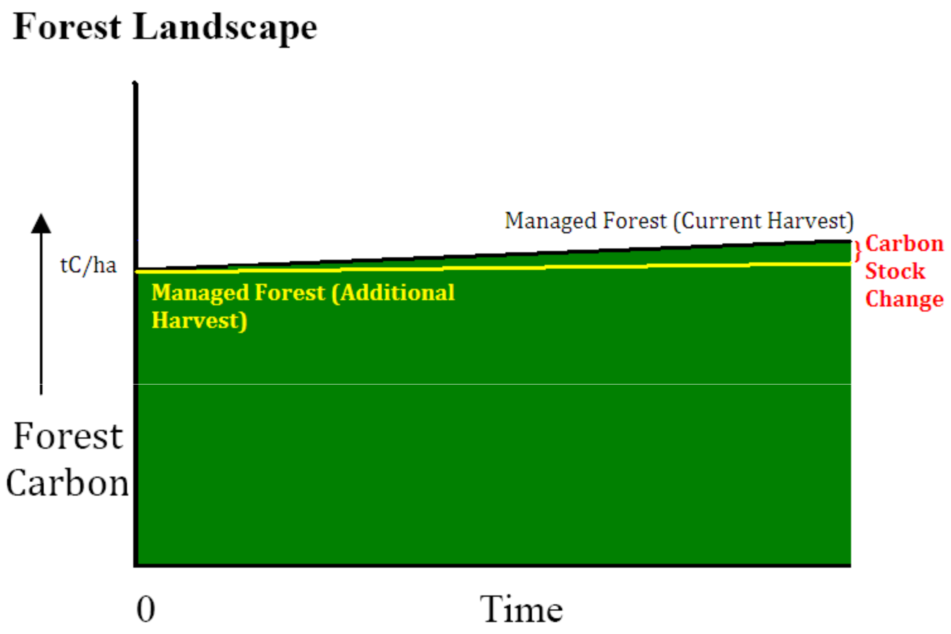
Spatial scale

A false hope: landscape vs. stand level analysis

It should always be kept in mind that:

- A reduction in CO_2 sequestration technically corresponds to a CO_2 emission.
- Any consideration should be referred to **a relative scenario**.



A sustainably managed forest with increasing C-stocks can continue to be a net C-sink even with the additional production of bioenergy BUT its C-stock will be smaller than it would have been if bioenergy was not produced. This relative decrease in C-stocks needs to be allocated to the bioenergy produced.

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Spatial scale

A false hope: landscape vs. stand level analysis

The exception:

- Relevant in the case in which an increase in bioenergy demand spurred also an intensification in the management in the rest of the landscape (e.g. fertilization).
- The additional biomass from increased productivity could be considered carbon neutral (at the net of emissions associated with the intensified management).However, the results of such a management change will be visible in long times and this should also be accounted for in the analysis.

The counter-argument:

- If at present forests are NOT fertilized to increase productivity of high-value stemwood, should we assume that fertilization will be automatically triggered by an increase in bioenergy (low-value) demand?

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Spatial scale

Consequential LCA

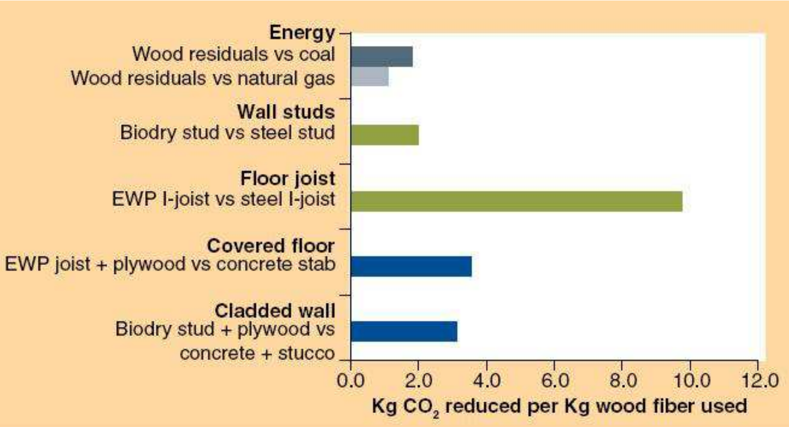
Aim: analyse the impacts of a decision on both the foreground system and on the background system.

Expected impacts to be analysed:

- Displacement of wood for products
- Displacement of wood for energy
- Competition with other renewables
- Competition for land
- Rebound effect
- Intensified management (fertilization, more productive species etc..)

Market mediated effects: Displacement from wood industries

1. Indirect wood use change (iWUC): displacement of wood from the harvested wood product market and substitution with fossil-based materials



Source: **Lippke et al., 2011**

2. Indirect fuel use change (iFUC): displacement of wood as fuel from other industries and substitution with fossil fuels.

3. Wood displaced and substituted with wood from another geographical area.

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Displacement

Market mediated effects: Displacement from wood industries

Is competition between bioenergy and wood industries happening? Is it likely in the future?

What are the displacement factors?

Is end-of-life energy use better than landfill for carbon emissions?

Market mediated effects: fuels substitution and rebound effect

Current assumptions:

- Bioenergy substitutes a fossil source (e.g. calculation of payback time as compared to coal or natural gas);
- One unit of bioenergy substitutes one unit of fossil energy.

How will the carbon footprint of future energy mix evolve?

Does bioenergy compete with other renewables?

What is the substitution factor of bioenergy to fossil fuels?

Displacement

Consequential analysis

Systems to be modeled under various policy assumptions and on a global scale:

- **Future Energy mix:**
  - Bioenergy demand
  - Fossil fuels demand
- **Wood products market:**
  - Future demand
  - Feedstocks
  - Alternative materials
- **Land use:**
  - Afforestation
  - LUC to SRF
- **Forest models:**
  - Forest growth
  - Management changes
  - Imports

Aim: analyze the impacts of a decision on both the foreground system and on the background system.

Consequential analysis

Beyond carbon accounting

Biogeophysical factors:

- Surface albedo changes, evapotranspiration, organic and black carbon emissions could significantly affect climate benefits/deficits

Shall climate policies be changed to go beyond GHG emissions?

Could a more complete climate impact analysis of bioenergy be used to drive policies?

Climate metrics:

- GWP(100) has become the standard policy tool;

Instantaneous (GTP) or Integrated metrics (GWP)?

Absolute or normalized metrics?

Time horizon should align with the timescale chosen?

Beyond carbon accounting

Biodiversity

What would be the consequences of extreme intensification of forest management on biodiversity?

For every expert, there is an equal and opposite expert.

Even the wisest and best science-educated of politicians may have difficulty making good decisions when, as is often the case, "experts" disagree. There are some hilarious examples of this in the history of science—for example, Lord Kelvin's declaration that x-rays must be a hoax, and Ernest Rutherford's even more famous dismissal of atomic energy as "moonshine."

Sir Arthur C. Clarke, Science, 280 (1998), 1532-1533.

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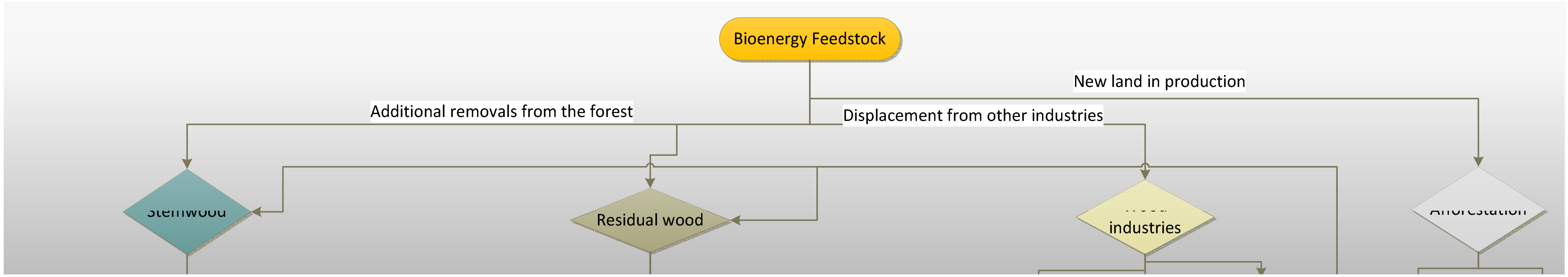
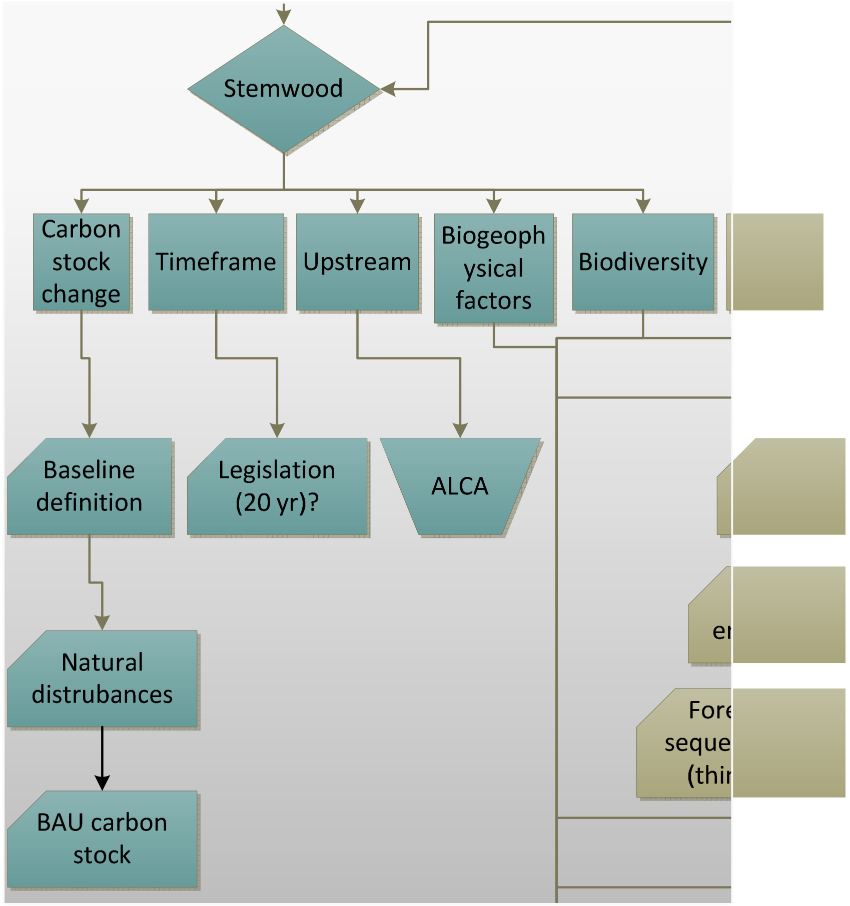
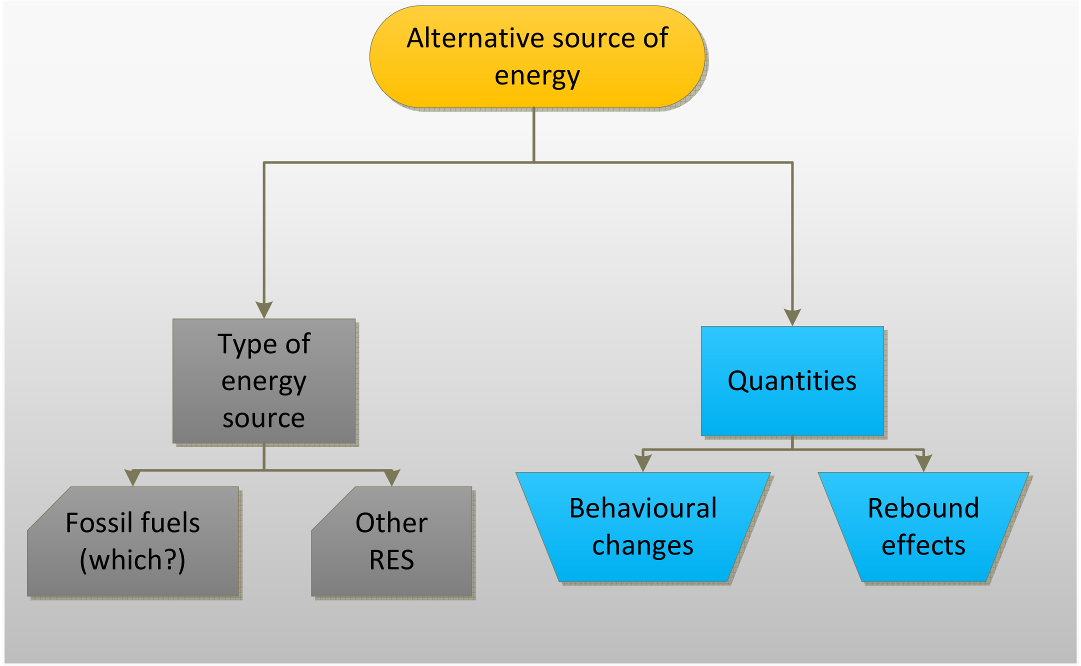
Topics and issues



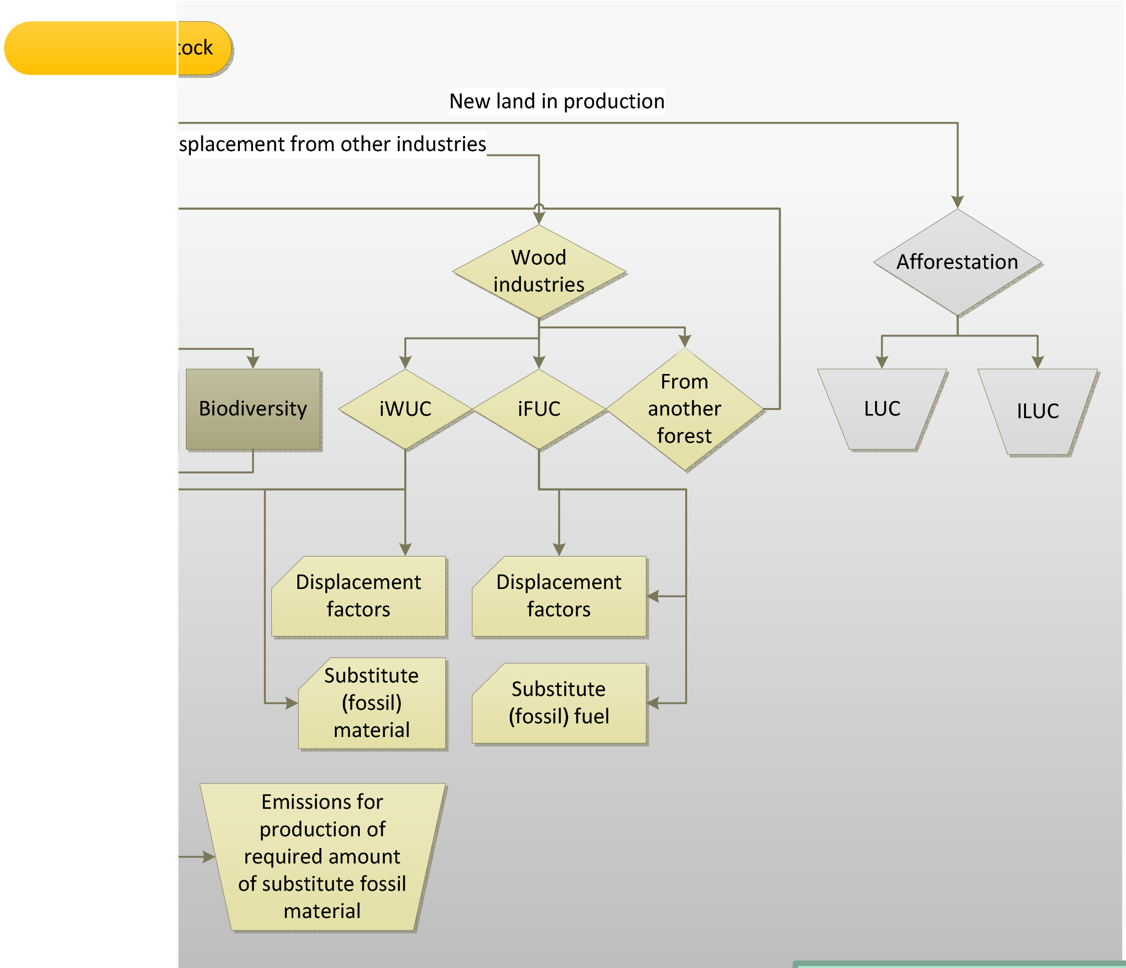

Stemwood
Carbon stock change
Timeframe
Upstream
Biogeophysical factors
Biodiversity
Baseline definition
Legislation (20 yr)?
ALCA
Natural distrubances
BAU carbon stock

Timescale

Topics and issues

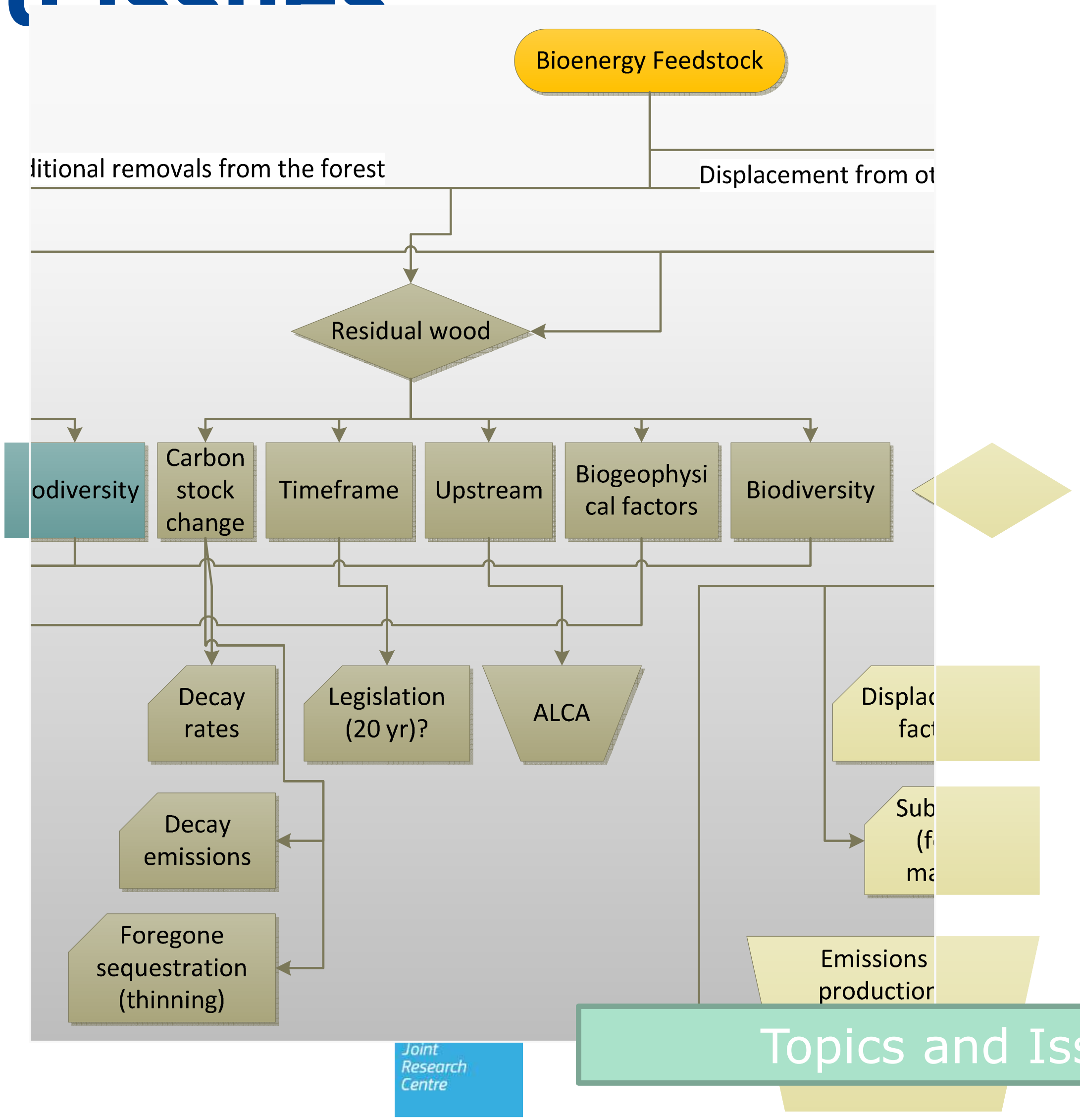


Topics and issues



Topics and Issues

Topics and issues



Topics and Issues

Large scale techno-economic models

		Unit	Reference		Maximising biomass carbon	Promoting wood energy
			2010	2030	2030	2030
Carbon stock	Forest biomass	Tg C	11508	13214	14130	13100
	Forest soil	Tg C	14892	15238	15319	14994
Carbon flows	Change in forest biomass	Tg C/yr		85.3	131.1	79.6
	Change in forest soil	Tg C/yr		17.3	21.4	5.1
	Net change in HWP	Tg C/yr		18.2	18.2	17.6
Substitution effects	For non-renewable products	Tg C/yr	NA	NA	NA	NA
	For energy	Tg C/yr	61.6	83.0	83.0	121.7
Totals	Stock (forest only)	Tg C	26400	28452	29449	28093
	Flow (sequestration + substitution)	Tg C/yr		203.7	253.6	224.0

Carbon stocks and flows in the EFSOS scenarios, total Europe.
(Source: The European Forest Sector Outlook Study II *[UNECE & FAO 2011]*)

Large scale techno-economic models: Wood products displacement

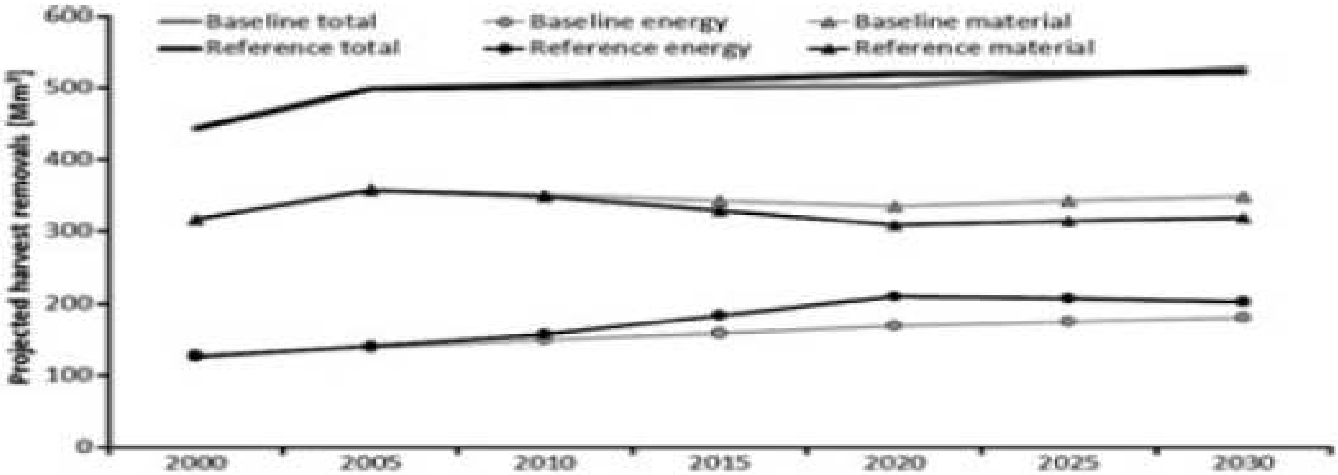
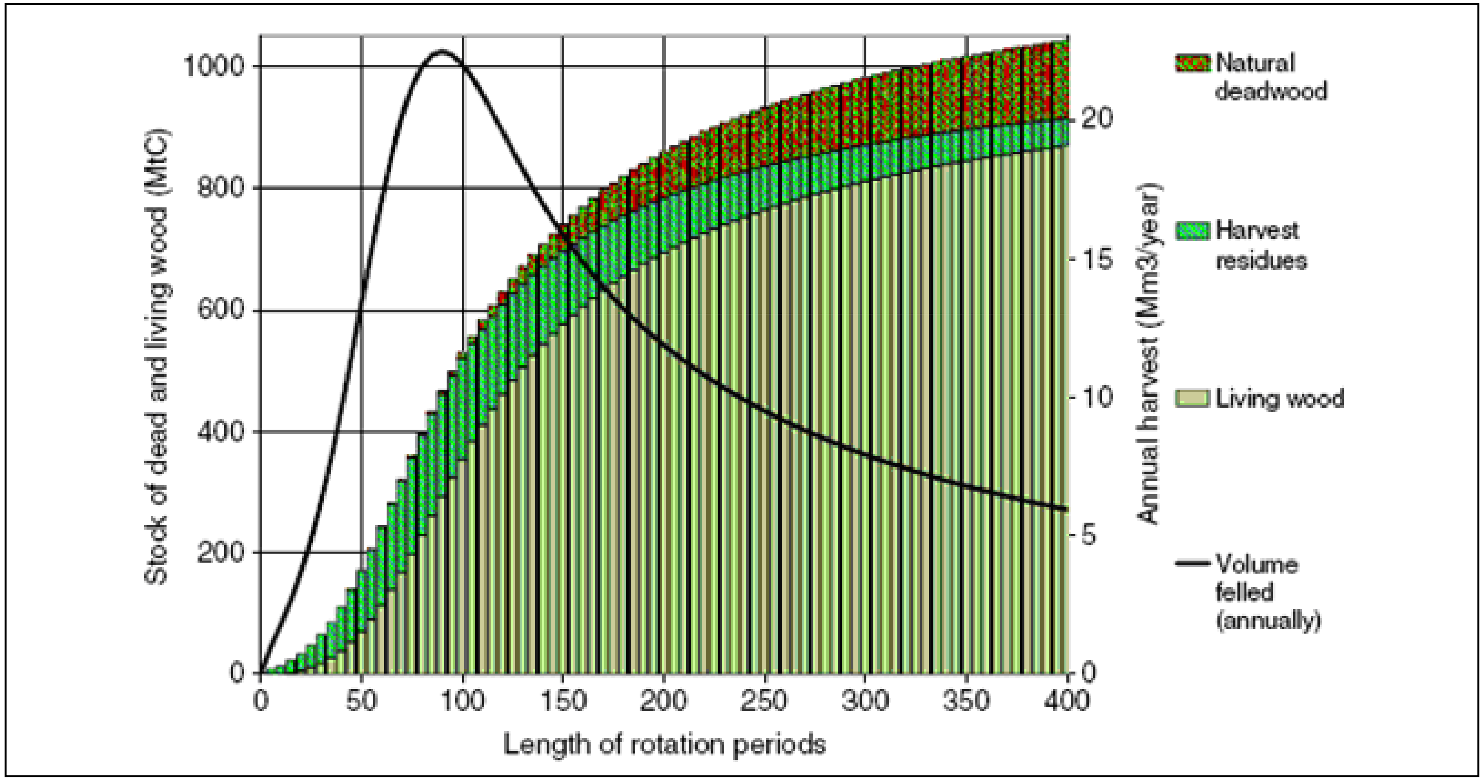


Fig. 1 Baseline and reference projection of domestic wood production (overbark) for the 24 EU countries for energy and material use (including sawnwood, pulp wood and other industrial roundwood). The original GLOBIOM data were scaled by historic wood demand (FAOSTAT, 2010) and adjusted in the year 2005 to correct for observed wood removals.

Baseline (no RED) and reference (RED) projection of domestic wood production (overbark) for EU-27 countries for energy and material use (including sawnwood, pulp wood and other industrial roundwood). Source: *[Böttcher 2011].*

Stemwood for bioenergy

Source: **Holtsmark et al., 2012**



Indicative carbon stock and NAI for a boreal forest

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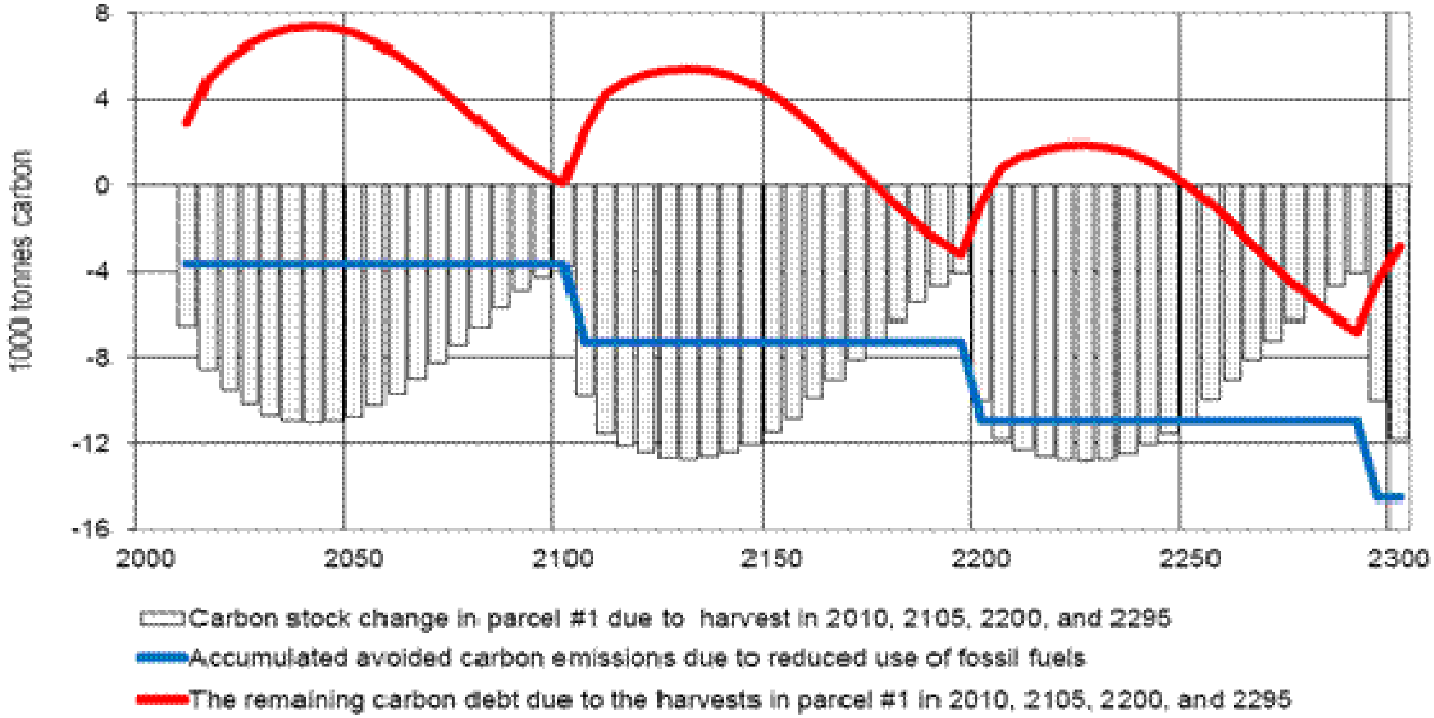
Quantification example: Roundwood

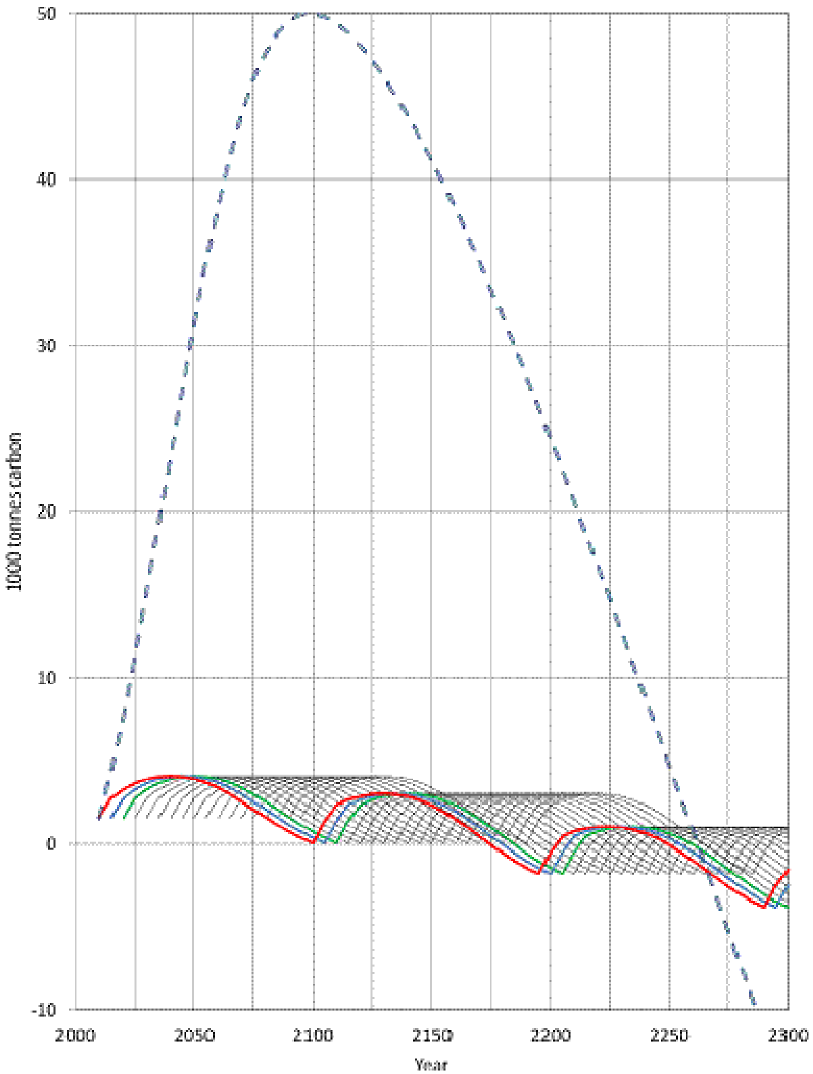
Source: **Holtsmark et al., 2012**



Consequences of continuous harvest in a forest parcel on its carbon stock, the accumulated reduction in fossil carbon emissions and the remaining carbon debt

European Commission

Quantification example: Roundwood



Cumulative carbon debt for continuous harvest on a whole forest.
The multi-wave-shaped curves show the development of the remaining carbon debt generated from the harvesting of 19 parcels as they subsequently mature. The total remaining carbon debt is given by the dotted blue curve

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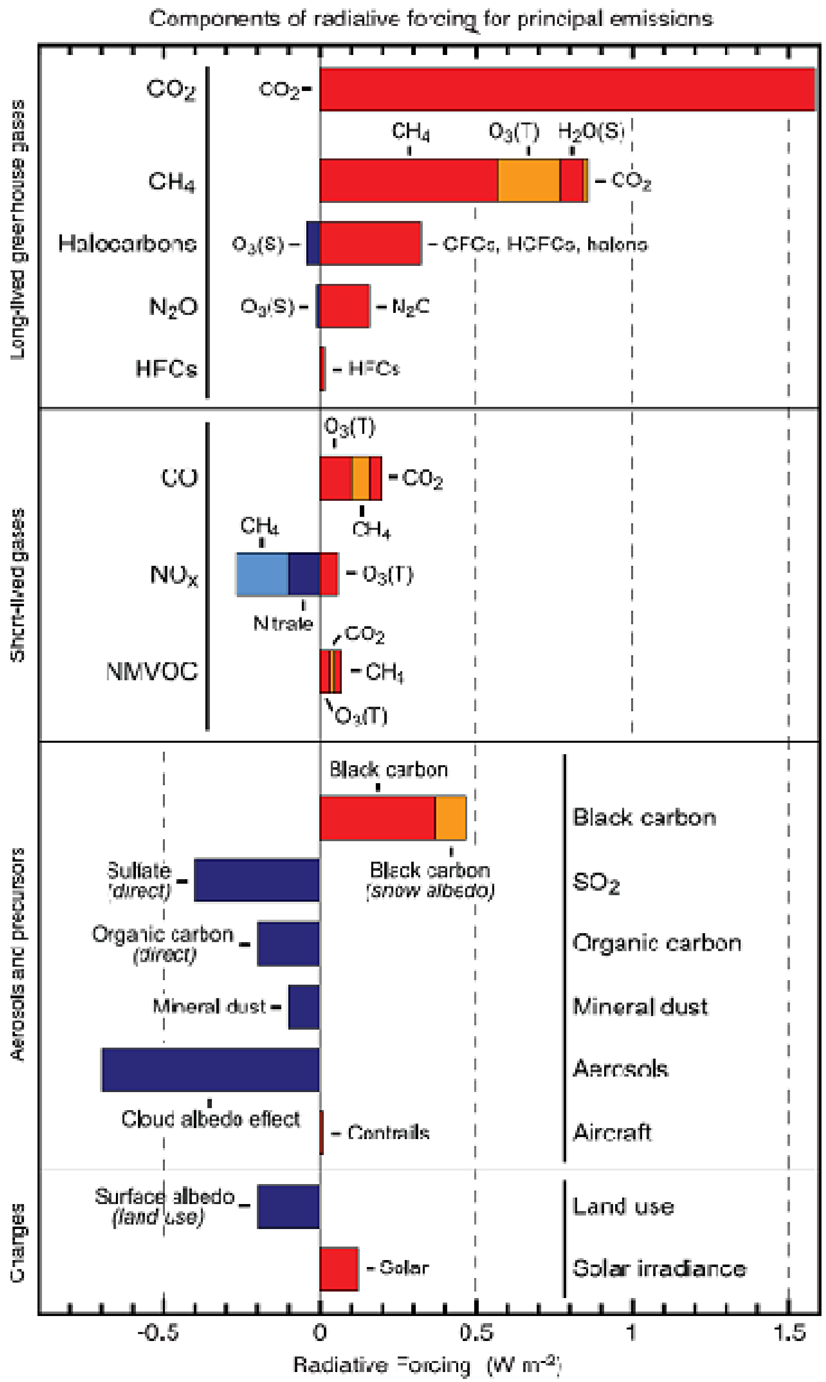
Other climate forcers



Including the albedo effect in boreal forest bioenergy production may offset most of the total GHG emissions (including biogenic CO2).

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Other climate forcers

GWP100. Source: ***[UNEP 2011].***	Mean value	Range
CO_2	1	
CH_4	25	16 – 34
CO	1.9	1 – 3
VOC	3.4	2 – 7
BC	680	210 – 1500
SO_2	-40	-24 - -56
OC	-69	-25 - -129
NO_x	~ 0	

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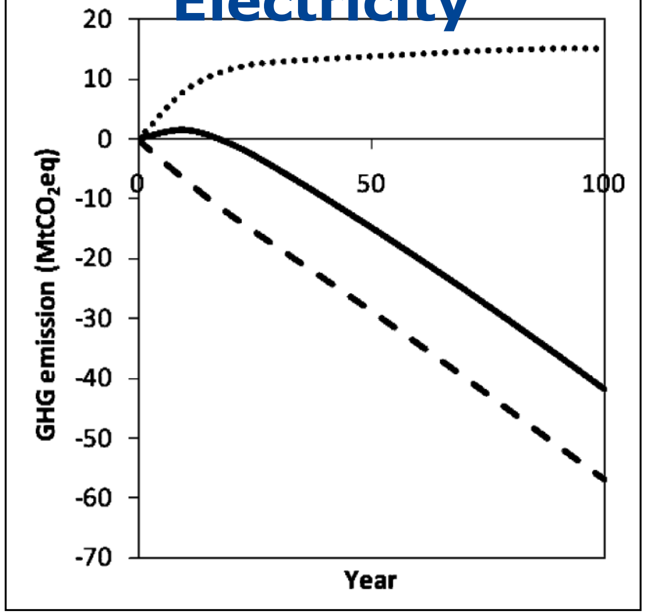
Sensitivity

Payback time changes with:

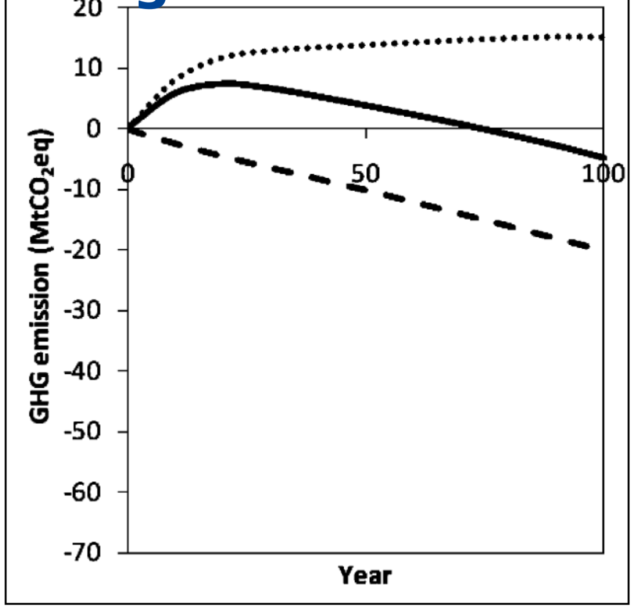
1.Fossil system substituted.

E.g. high savings from substituting coal electricity → smaller payback time.

Wood vs. Coal Electricity

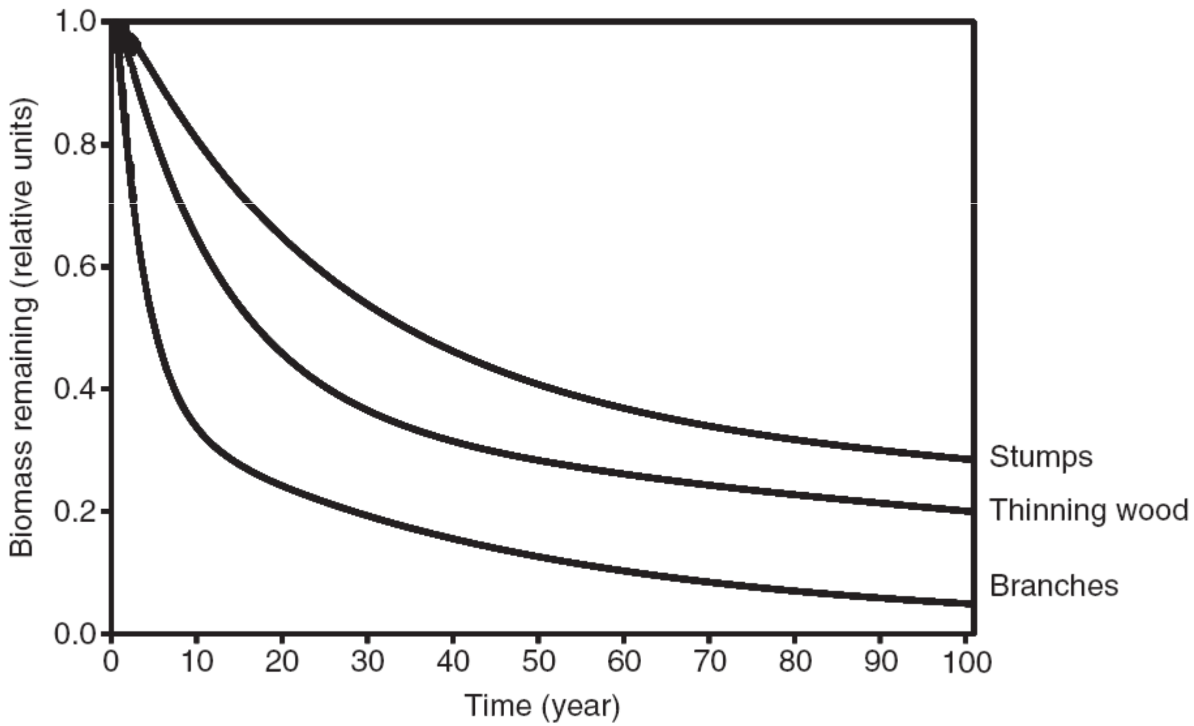


2nd gen ethanol (E85) vs. gasoline



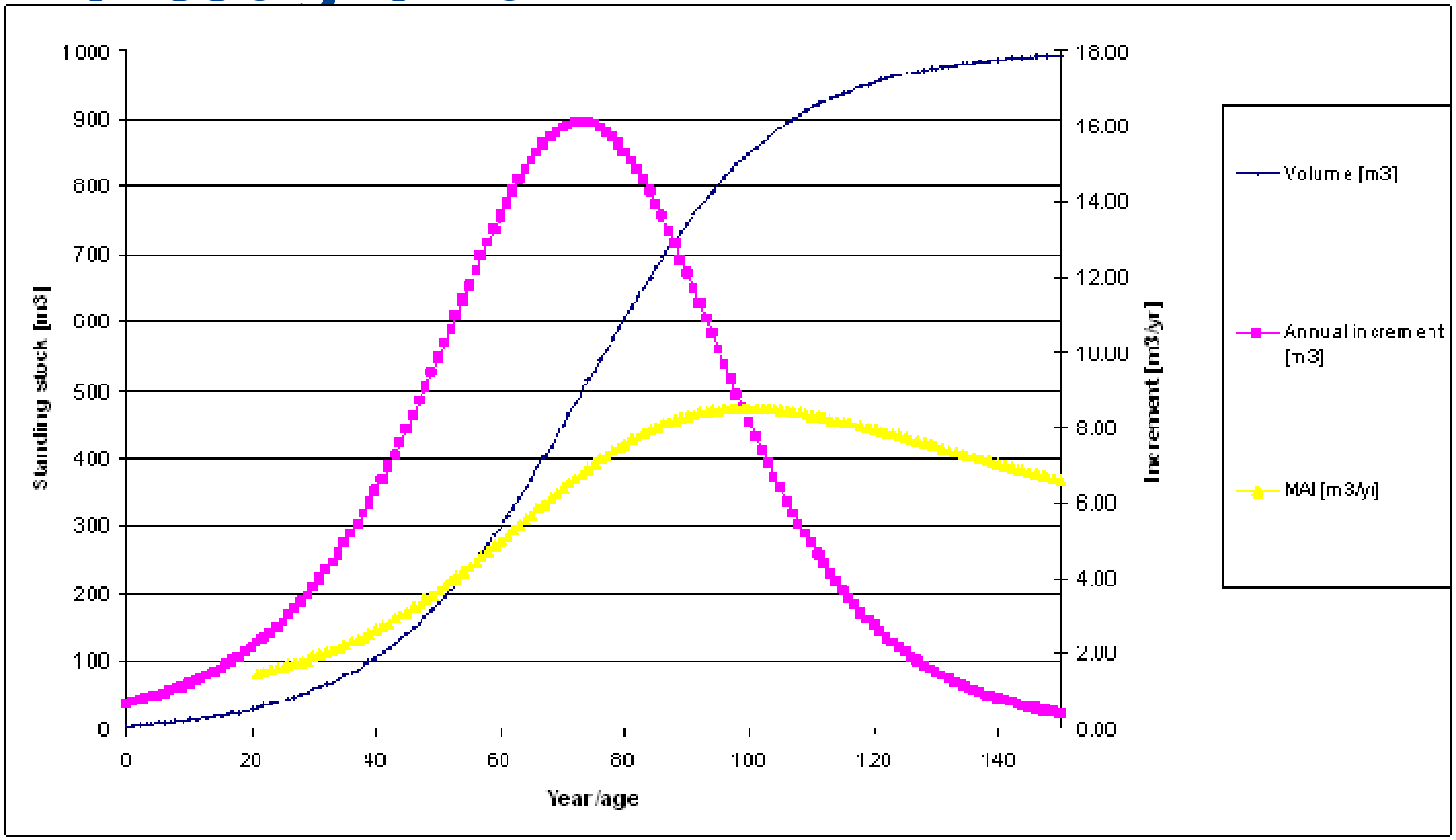
Sensitivity

1.Residues size and effects Soil-C and nutrients;



Source: **Repo et al., 2011**

Forest growth



Indicative carbon stock and mean and annual increment for a boreal forest

European Commission

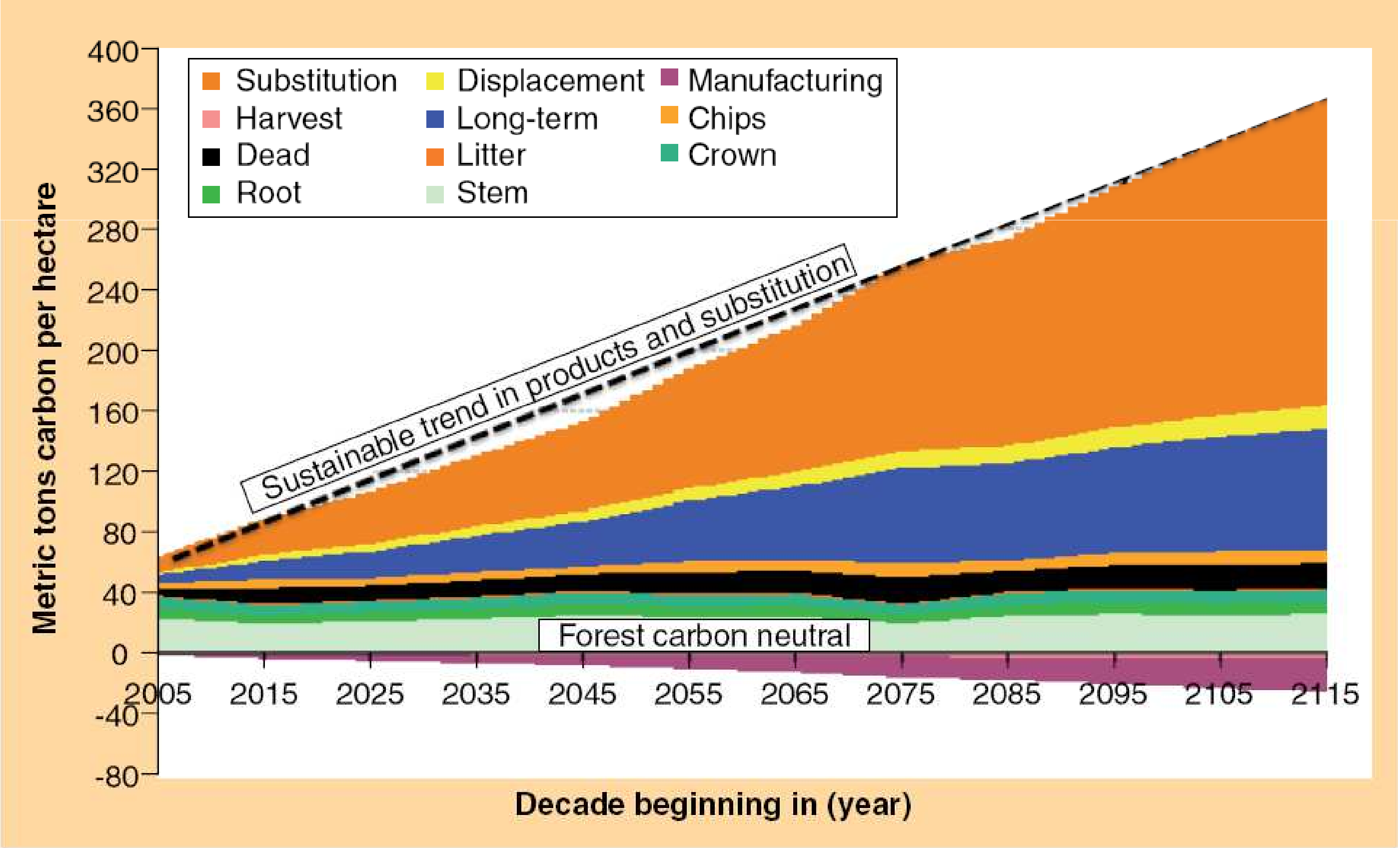
GWPbio index calculated for three different time horizons

Example with the Full Impulse Response Function (FIRF). Source: *[Cherubini 2011a]*.

Rotation (years)	GWP_{bio}	GWP_{bio}	GWP_{bio}
	TH = 20 years	TH = 100 years	TH = 500 years
1	0.02	0.00	0.00
10	0.22	0.04	0.01
20	0.47	0.08	0.02
30	0.68	0.12	0.02
40	0.80	0.16	0.03
50	0.87	0.21	0.04
60	0.90	0.25	0.05
70	0.93	0.30	0.05
80	0.94	0.36	0.06
90	0.95	0.39	0.07
100	0.96	0.43	0.08

Displacement: wood for products

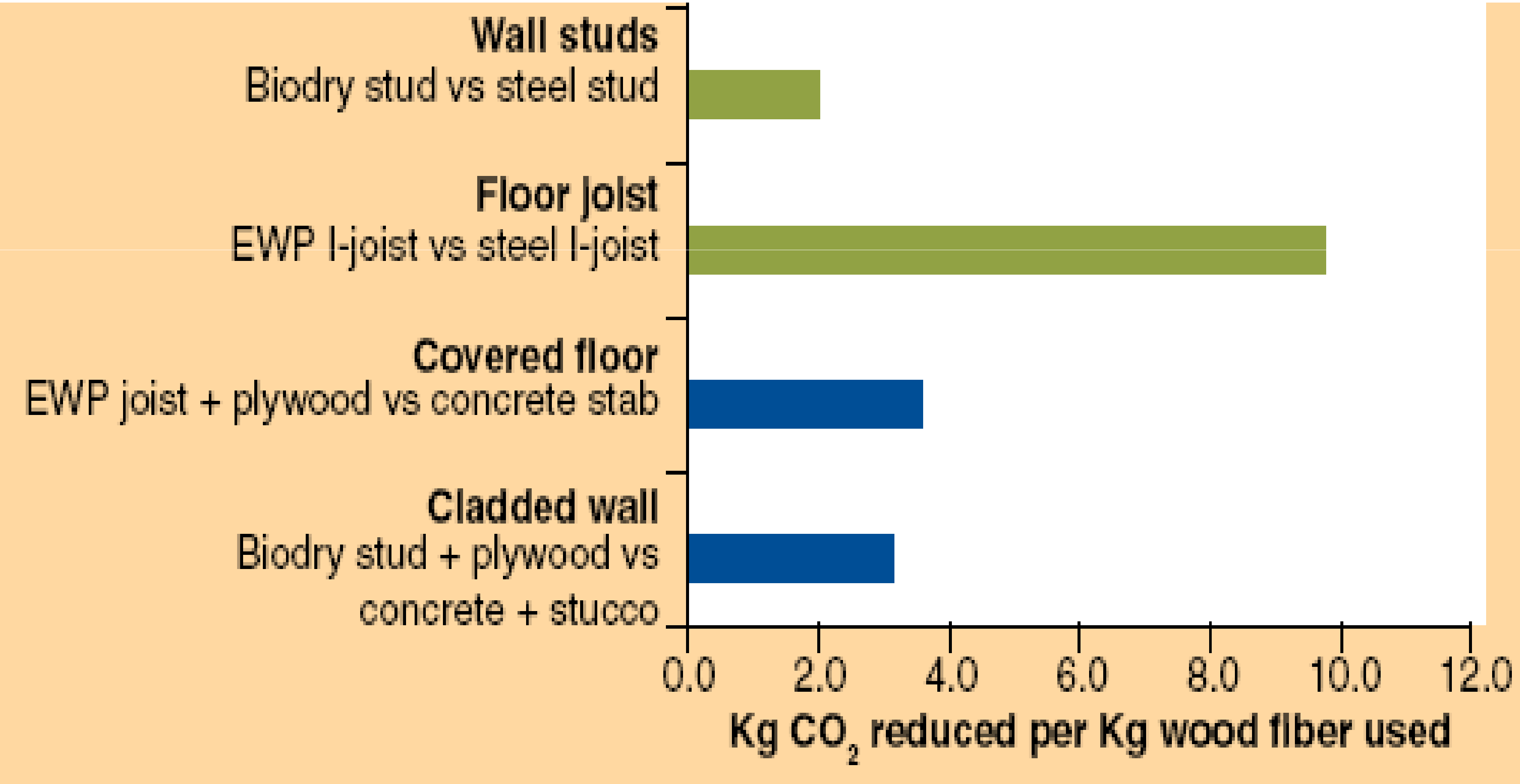
Use of wood for long-lived products: effective carbon capture and storage in the Harvested Wood Products carbon pool and substitution of GHG intensive materials



Source: **Lippke et al., 2011**

Consequential LCA

Displacement of wood for products:



Consequential LCA

Displacement of wood for energy

Most of the wood resources are already used somehow, if they were to be diverted from the current use, they would need to be replaced by other resources.
In a briefing published by the European Parliament Committee on Development *[Wunder 2012]*, the authors conclude that conflicts with local energy security are likely to occur if:

- the production of woody biomass for export (e.g. energy wood plantations) displace land uses that have a significant role in feeding local energy needs (e.g. open land with trees, orchards etc.) or in ensuring local income.
- woody biomass that currently feeds local energy needs (be it from forest use or from plantations) is redirected to export and hence no longer available for the local population.

Forsström et al. *[Forsström 2012]*. concludes that increased biofuel production based on woody biomass in Finland would cause an increase in the use of fossil energy in the other sectors.

Consequential LCA

Competition with other renewables

- Competition among renewables for incentives is considered beneficial in incentivation schemes

- Regulatory frameworks may be implemented in such a way that subsidizing the construction of a plant for the production of electricity from biomass may displace a plant based on other renewables or other types of biomass.

Consequential LCA

Competition for land

- An additional demand of bioenergy from forests may trigger, via market demand, an expansion of the forested land. Although the direct impact on GHG emissions is positive, because of the increase in the land carbon stock, the indirect impact of agricultural land diversion should be integrated in the analysis, unless it is on marginal land (abandoned or degraded).

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Consequential LCA

Rebound effect

York *[York 2012]* showed that the average pattern across most nations of the world over the past fifty years is one where 1 MJ of total energy use from non fossil sources (hydropower, nuclear, geothermal, solar, wind, tidal and wave energy, combustible renewables and waste) displaced less than 0.25 MJ of fossil fuel. Focusing specifically on electricity, each MJ of electricity generated by non fossil fuel sources displaced less than 0.1 MJ of fossil fuel electricity.

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Consequential LCA

Intensified management (fertilization, more productive species etc..)

- Most of the studies assume that the productivity of the forest that follows the harvest does not change in the next rotation
- the increased bioenergy demand may lead (through market effects) to changes in forest management (higher density of the stands, more productive species, fertilization etc.)
- Large scale techno-economic quantitative studies analyzing these impacts are not yet available.
- Fertilisation: from the Swedish University of Agricultural Sciences (SLU, March 2012): In Sweden Around 60 000 hectare of forest land are fertilised each year. The fertilised forest area in Sweden may increase, but hardly more than double. All forests are not worth fertilising. On fertile land you do not see any effect of fertilisation.

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Carbon impacts of using biomass in bioenergy and other sectors: forests (Matthews et al.)

Conifer under management; time horizon: 40 years
ABSOLUTE EMISSIONS (tCO2/ha*y)
- suspended management = - 14
- only fuel = - 0.5
- materials (fuel from residues)= – 6

DISPLACEMENT (tCO2/ha*y)
displaced fossil fuel = 5
displaced counterfactual materials = 17

TOTAL EMISSIONS :
Energy vs no manageent = 14 – 5.5 = 8.5
Products vs no management = 14 -6 – 17 = - 9

Carbon impacts of using biomass in bioenergy and other sectors: forests (Matthews et al.)

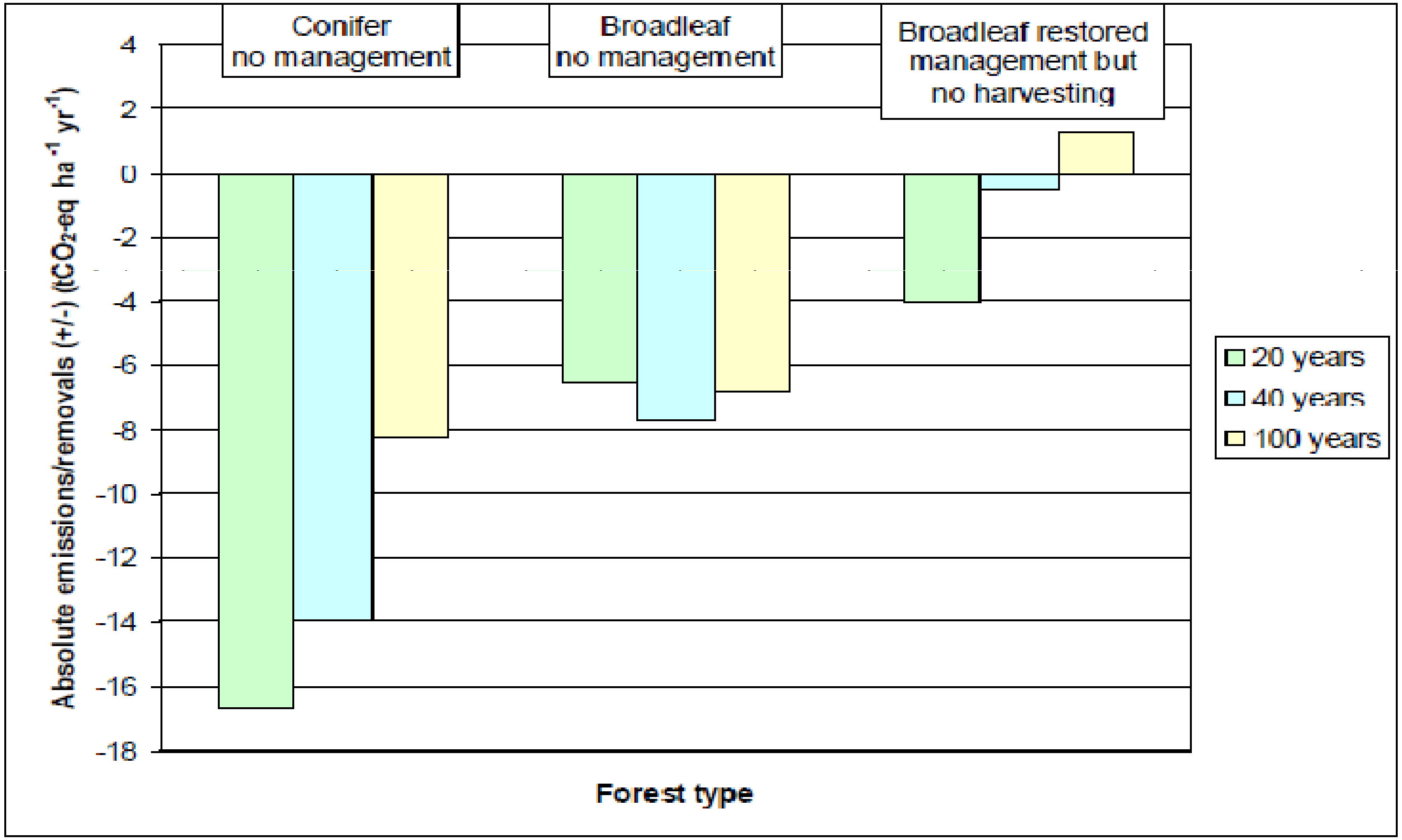

Figure 5.1. Rates of carbon sequestration (or emissions) estimated for characteristic UK forest types when management is suspended (Scenarios 00.00 and 00.01). Results are shown for time horizons of 20, 40 and 100 years.

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Carbon impacts of using biomass in bioenergy and other sectors: forests (Matthews et al.)

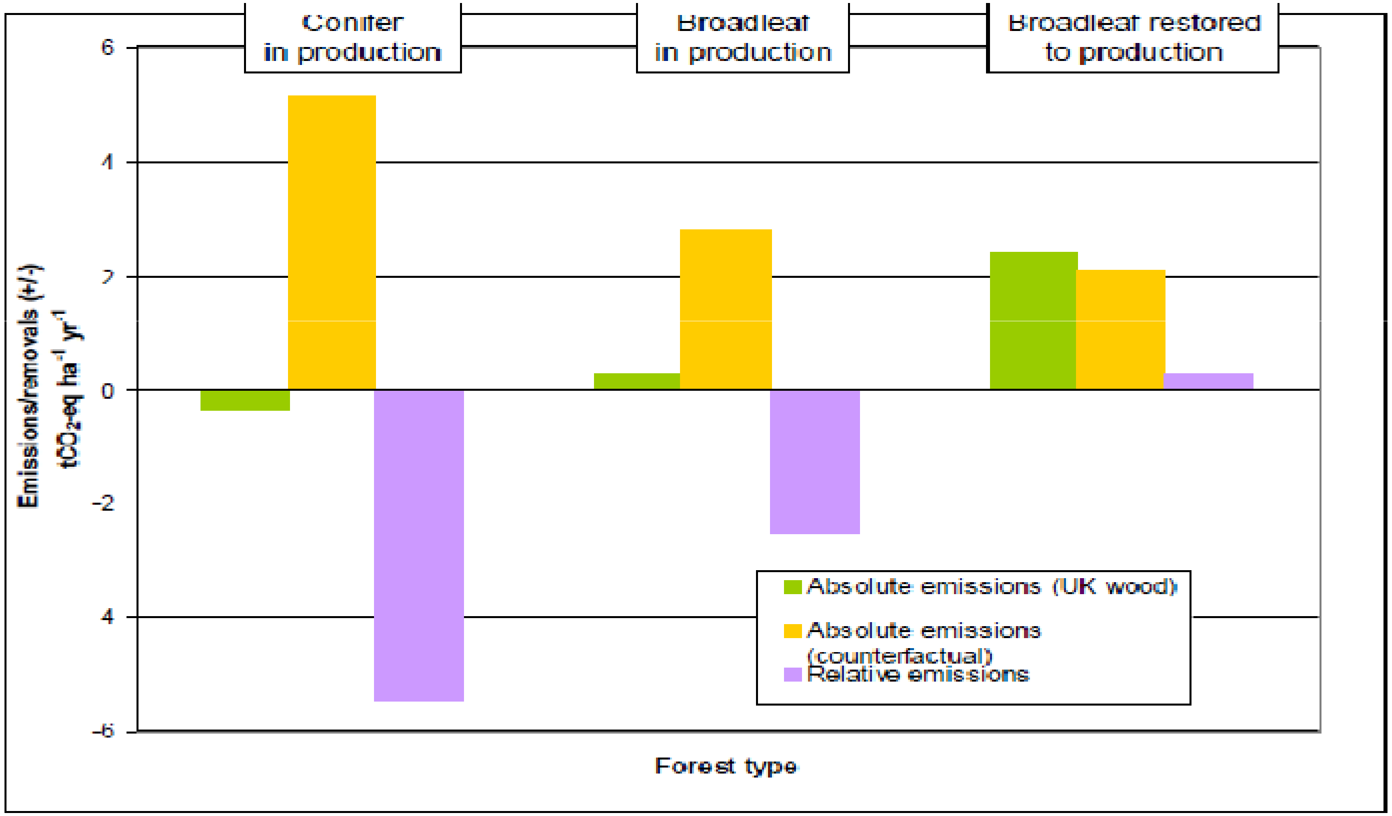

Figure 5.5. Estimation of relative GHG emissions estimated for characteristic UK forest types for example scenarios involving management for production of wood for fuel only (Scenario 01.06, without application of CCS). Absolute emissions are shown for production from UK forests, for a counterfactual scenario as well as the resultant relative emissions. Results are shown for 40 year time horizon.

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Problem definition

- **Carbon accounting/reporting:**

IPCC guidelines: CO_2 emissions/removals from forestry estimation based on changes in the forest carbon pools (biomass, soil, wood products) reported in the LULUCF sector. In order to avoid double counting, the carbon emissions from biomass combustion are not added to the total energy sector emissions

- **Bioenergy GHG LCA:**

Often a value of zero is assigned to direct biogenic CO_2 emissions resulting from biomass combustion. This is applied even though the changes in the above mentioned carbon pools are not accounted for.

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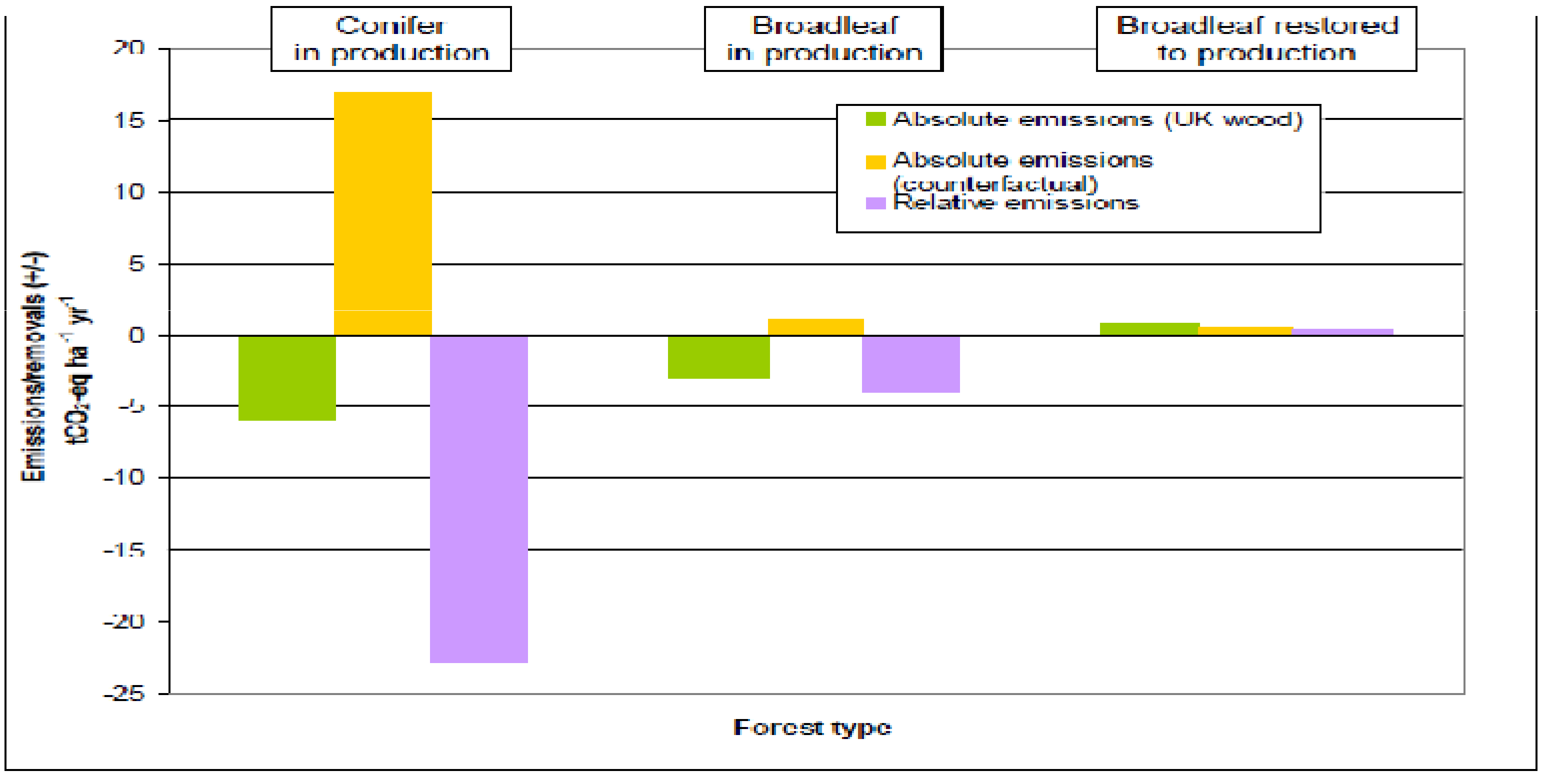
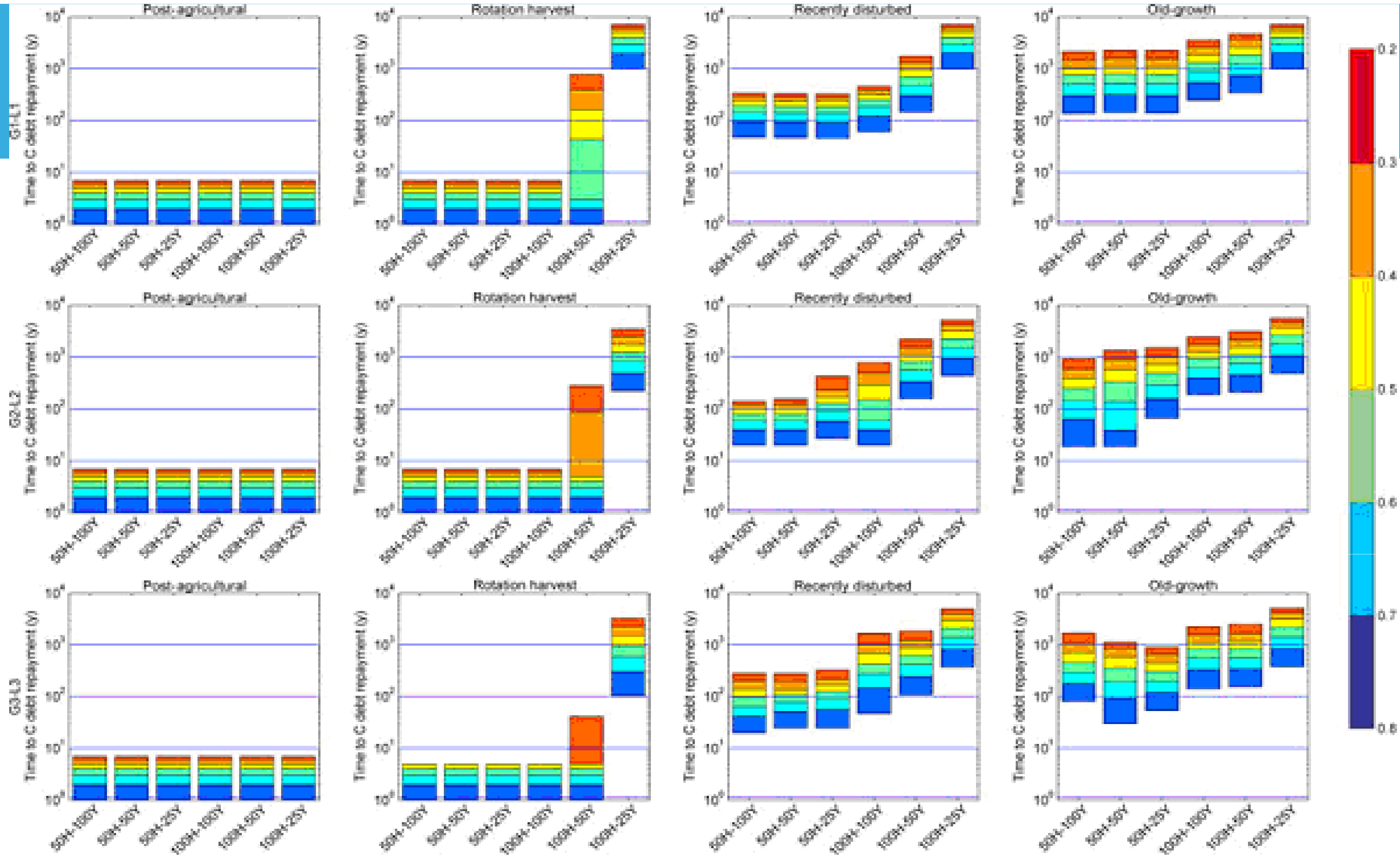


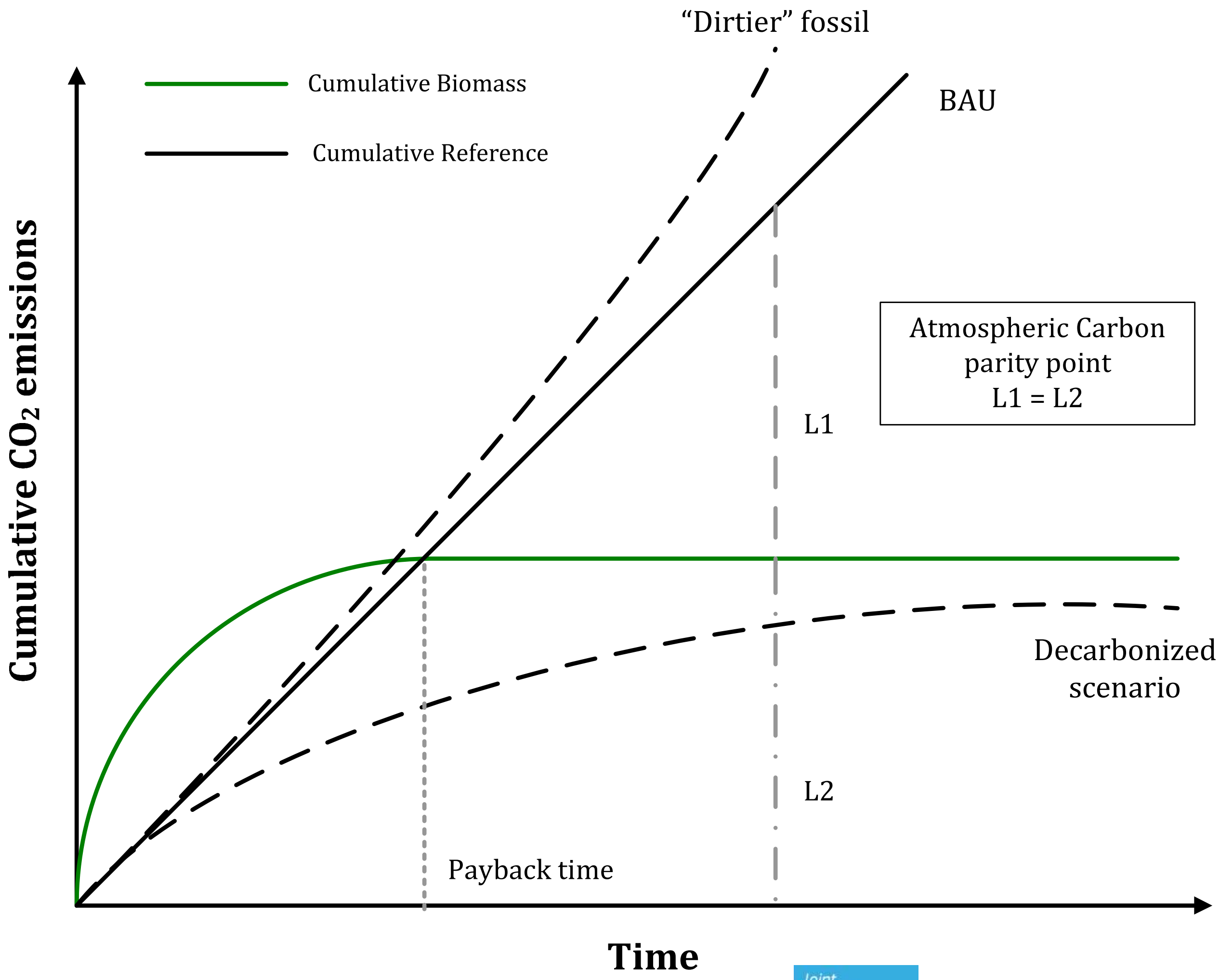
Figure 5.7. Estimation of relative GHG emissions for characteristic UK forest types for example scenarios involving management for production of wood for a range of materials and fuel (Scenario 23.05, for coniferous forest example, Scenario 05.07 for broadleaf forest examples, all without application of CCS). Absolute emissions are shown for production from UK forests, for a counterfactual scenario as well as the resultant relative emissions. Results are shown for 40 year time horizon.

Examples of Carbon Neutrality Factors as calculated in *[Zanchi 2010]*.

Carbon Neutrality				Ref = coal
Source of biomass	20 y	50 y	300 y	Notes
Forest residues (constant annual extraction)	0.6	0.7	0.9	Always positive but not C neutral
Additional thinnings	< 0	< 0	0.2	Atmospheric benefit after 200 -300 years
New forests from conversion from cropland	≥ 1	≥ 1	≥ 1	C neutral
New forests from conversion from grassland	> 0 to ≤ 1	≥ 1	≥ 1	Positive in the short-term, becomes C neutral in 1 – 2 decades
Conversion from managed forest to SRC	< 0	< 0	0.7	Atmospheric benefit after 70 years
Conversion from mature forest to SRC	< 0	< 0	0.4	Atmospheric benefit after 170 years
Conversion from managed forest to a 60 year rotation plantation	< 0	< 0	0.3 – 0.7	Atmospheric benefit after 150 – 200 years



Comparisons of the time required for a repayment of the Carbon Debt among three ecosystem types , each with six biomass harvesting regimes and four land-use histories. The four land use histories are: Post-agricultural (age = 0), Recently disturbed (age = 0, disturbance residual carbon), Rotation forest (average age = 25, rotation=50), Old-growth (age > 200). Different harvesting regimes are indicated on the x-axis, with 50% and 100% harvesting intensity represented as 50H and 100H, respectively. Harvest frequencies of 25, 50, and 100 years are represented as 25Y, 50Y, and 100Y. Three combinations of biomass growth and longevity; G1, G2, and G3 represent increasing growth rates. L1, L2, and L3 represent increasing biomass longevities. The color scale represents the conversion efficiencies, ranging from 0.2 to 0.8, to ascertain the sensitivity of C offsetting schemes to the range in variability in the energy conversion process. Source: *[Mitchell 2012]*.



Visual description of payback time and carbon neutrality.

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Conclusions

- the assumption of biogenic carbon neutrality is not valid for most of the forest potential bioenergy under short-term time horizons (especially roundwood).
- It is fundamental to integrate all the carbon pools in the bioenergy CO2 emissions assessment and their evolution in the time horizon of the analysis
- In comparative LCA the choice of the counterfactual scenario is fundamental
- Indirect impacts have to be internalized (displacement of wood for materials or from other energy sectors, rebound effect, competition for land, intensified management resulting from price increase)
- A comprehensive evaluation of the climate impacts of forest bioenergy should integrate also all of the climate forcers (aerosols, ozone precursors, evapotranspiration and albedo)
- The current share of pellets and woodchips from stemwood is in the order of few points %

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