Review and assessment of existing biomass potentials

Introduction

Studies for biomass availability and supply deliver strongly ranging results. Estimates for the technical potential at global level go up to 1500 EJ; with a more realistic range between 200 and 500 EJ. When a large variety of sustainability criteria (with ecological, economic and social dimensions) are taken into account, further variation of potentials will be evident. Studies at the European level also deliver strongly varying results depending on the land availability (19 – 50 million hectares in EU-27) and energy crop yields. 1 million ha corresponds to 2 -10 Mtoe depending on the local level of the feasible yield. Assessing why these differences occur requires detailed comparison but overall it is clear that the main starting points for these studies were very different, they build on a complete different set of assumptions and the models/ tools used vary greatly.
The presented comparative inventory of existing studies of biomass availability is the result of a review of the main biomass potential studies performed at national (EU countries only) and EU levels.

Methodology

The methodology for this comparison of biomass resource assessment studies is based on the results of the BEE project (link to BEE website: www.eu-bee.info)

- using the BEE reference list of the main biomass resource assessment studies
- applying the harmonized definition of biomass assessment methods, biomass types and biomass potentials.

From the long list of about 250 studies in the BEE/BIOMASS FUTURES literature database, about 30 studies were selected for further analysis that corresponded to the following criteria (see Table below).

Table : Criteria for selection of studies for detailed analysis.

Name	**Description**
Geographical coverage	To cover all EU countries, with focus on studies that provide data at national level
Biomass types	To cover the full range of different biomass types (forestry biomass, energy crops, agricultural residues, waste and total)
Potential types	To cover the full range of different potential types (theoretical, technical, economic and implementation potential)
Analysed in BEE	BEE studies are used as a basis with few additions
Methods	To cover a representative range of different methods
Time frame	To cover years 2010 to 2020

The selected studies include the main biomass potential studies performed at EU27 levels. To create a systematic overview the main characteristics of these studies and their main differences and similarities in terms of types of biomass feedstock assessed, methodology applied, type of potential addressed where extracted. They were assessed by addressing different biomass types (biomass from forestry, energy crops, biomass from agriculture, biomass from waste, and total resource assessments) and distinguishing between technical, economic, competitive economic and implementation potentials given various policy and environmental constraints.

Among the most obvious reasons for large differences between estimates of the biomass resource assessments reviewed by the BEE project (BEE 2008) is the conceptual potential type that is addressed. The BEE method handbook concluded that "*the type of biomass potential is an important parameter in biomass resource assessments, because it determines to a large extend the approach and methodology and thereby also the data requirements*".

Four types of biomass potentials were distinguished also for the Biomass Futures analysis:

- Theoretical potential - the overall maximum amount of terrestrial biomass which can be considered theoretically available for bioenergy production within fundamental bio-physical limits.
- Technical potential - the fraction of the theoretical potential which is available under the regarded techno-structural framework conditions with the current technological possibilities (such as harvesting techniques, infrastructure and accessibility, processing techniques).
- Economic potential - the share of the technical potential which meets criteria of economic profitability within the given framework conditions.
- Implementation potential - the fraction of the economic potential that can be implemented within a certain time frame and under concrete socio-political framework conditions, including economic, institutional and social constraints and policy incentives. The implementation potential was not assessed by this illustration case.
- Sustainable potential – integration of environmental, economic and social sustainability criteria in biomass resource assessments. Some studies applied environmental constraints at higher levels of potential, e.g. to the technical potential already, ignoring economic constraints (see EEA 2006: environmentally compatible potential). This makes a comparison across studies that assessed the sustainable potential even more difficult.

Results

Table 2 gives an overview o the studies analysed in Biomass Futures. Following the BEE review approach the studies were broadly classified according to geographical coverage, method applied and type of biomass covered.

The database is still being harmonized but some first conclusions can be drawn from the analysis and make the database fully accessible. The range of potentials for different biomass types and potential types are very wide (Fig 1). However, the ranges get smaller when looking at a more detailed representation of biomass types (Fig 2).

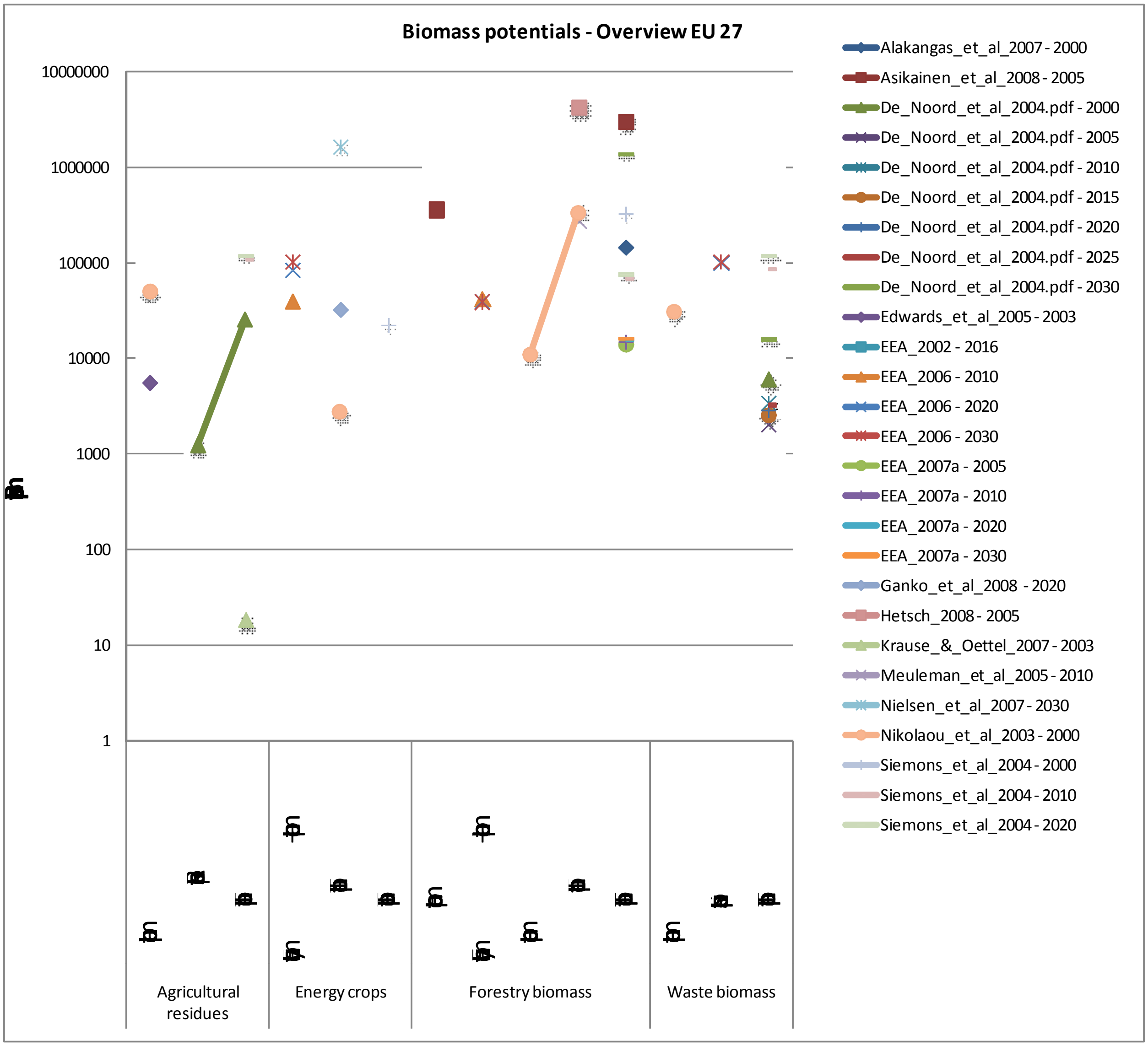
Table : Overview of studies analysed in Biomass Futures and classification into types of methodologies and biomass categories.

#	PDF Name	Geogr. coverage	Method	Types of biomass	Time frame
1	EC_Biomass_Action_Plan_2005	EU	Resource-focused	All biomass	2010 (2020, 2030)
2	Schneider_et_al_2008	EU	Resource-focussed (land endowments for 5 land qualities, pasture, and forest), demand and GHG policy driven (each bioenergy option has an exogenously estimated emission coefficient)	Switchgrass, Reed Canary Grass, Miscanthus, Poplar, Willow, Arundo, Cardoon, Annual crops, trees	2005-max 2150
3	Eriksson&Nilsson_2006	EU 25 + Belarus + Ukraine	Resource-focused. Based on land use area, growth and factors to conclude from yield to technical potential ; three different assumptions for the three time frames plus2 different versions on harvests in forest residues and energy crops (a-low, b-high)	Forest residues, forest industry by-products, crop residues (from trade. agriculture), energy crops	Short term (10-20y), medium term (20-40y), long term (>40)
4	Krause_&_Oettel_2007	EU 27	Resource focuced. Biogas potential estimation is based on european databases and survey of previous studies on national and european level. The demand of biogas speeded up in the last years, growing sixfold in the period 1990-2004, with an avg yearly increase of 13%.	Animal manure, sewage sludge, municipal solid wastes, industrial wastes, energy crops	2003 to 2005
5	McCormick_&_Kåberger_2007	EU, case cities in Sweden, Austria, Finland, UK, Italy and Poland	Methodology to investigate key barriers to expanding bionergy in the EU, six case studies	Not specified	Current situation
6	Harmelink_et_al_2006	EU/country	Demand-driven. In a step-wise approach policy instruments are characterised and analysed, leading to a quantitative assessment of the likely growth in renewable energy production for each individual technology and country in case no policy changes occur.	Not specified	2010
7	Faber_et_al_2006	EU; special focus on the Netherlands; Germany as an illustrative case	Both resource-focused and demand-driven. Studying the development of relevant policies and legislation, in particular the relevant EC Directives; literature reviews and interviews with experts; reviewing the biomass promoting policies throughout the EU; economic analyses	Biomass for generating electricity and heat. Biomass for chemistry and transport fuels is excluded.	Current situation
8	De_Noord_et_al_2004.pdf	EU15 plus Norway	resource focussed	Energy crops, Foresty, Solid manure, Liquid manure, MSW, Barley residues, Maize residues, oil crops residues,	2000 and somethimes 2030

				Rapeseed residues, Wheat residues, Landfill gas, Sewage sludge, Industrial waste	
9	Kloek_Jordan _2005	EU15+10 + RO+BG+HR r+Turkey+IS + NO+CH	Using an EU 'List of Wastes' as described in 2000/532/EC	Organic part MSW, excess manure, construction/demolition wastes	1995-2003
10	Siemons_et_ al_2004	EU15+accession countries plus BG and RO	Modelling of demand, supply and technology development function. Equilibrium of these function determines the role of biomass as source of renewable energy	Tradeable biomass: forestry byproducts, wood fuels, agricultural residues, industrial residues, energy crops; Non-tradeable biomass: wet manure, organic waste (biodigredeable municipal waste, demolition wood, dry manure, black liquor), sewage gas, landfill gas; transport fuels: biodiesel, bioethanol.	2010 and 2020
11	Edwards_et_ al_2005	EU25+2	Resource focussed. Calculate the straw potental (theorethical), taking the environmental and competitive constrains into account, followed by the economically and logistically availability. Resulting in suitable location for power plants based on the available straw density.	Straw from wheat and barley	Actual situation in 2005
12	EEA_2002	Europe	resource focused, the starting point of the document is the currently available BMW and the aim is reducing these amounts.	Biodegradable municipal waste	1996 - 2016
13	Fischer_et_al _2007a	Europe	Resource-forcused. the Agro-Ecological Zones methodology for the potential productivity assessment. estimates cultivated and pasture land availabilities for biofuel feedstock production. Then combined land use and energy yields scenarios.	1 st generation feedstock groups (Cereals, Oilcrops, Sugar crops) and 2 nd generation feedstock groups (Herbaceous and woody ligno-cellulosic plants).	2000-2002, 2030
14	Ganko_et_al_ 2008	Europe	Resource focused approach. Food and fibre production cannot be affected. Only surplus land available for energy crops.	Lignocellulose energy crops (woody and herbaceous), forestry and wood industry by-products, agriculture residues	2020
15	Nikolau_et_al . 2003	Europe	Resource focused approach. The resource assessment in this study was made in three steps: Technical resource potential, defined as the total annual production of all resources given no limits. Available potential, defined as all resources available with estimated, realistic limits. Finally, energy potential expressed in PJ/year.	Agricultural crop residues, animal wastes, energy crops, forestry residues, wood industry and food processing by-products, biological wastes.	2000
16	Junginger_20 07	Europe (case countries Sweden and the Netherlands)	Literature review of (1) multinational biomass comparisons, (2) national biomass policy descriptions and evaluations, and (3) international comparison of general renewable energy policy evaluations.	All biomass	Current situation

17	Alakangas_et_al_2007	European	Both resource-focused and demand-driven. Project partners and subcontractors filled in a questionnaire form on economically and technically viable volumes of solid biomass fuels and report the energy use of biomass in 2004. By comparing biomass resources and current use, the potential to increase bioenergy production has been estimated.	Forest residues, domestic (residential) firewood, refined wood fuels, industrial by-products (solid), industrial waste liquors, wood residues, other biomass resources (agrobiomass, fruit biomass…)	2001-2004, 2010, 2020
18	Asikainen_et_al_2008	European	Resource-focused. Forest fuels potential includes logging residues from fellings, annual change rate of growing stock and stumps. Annual change rate is calculated as a difference between net annual increment and fellings. Cost of wood chips were estimated depending on annual use of forest fuels at a hypothetical plant and the annual harvestable amount of forest fuels in the environs of the plant.	Logging residues from fellings, annual change rate of growing stock and stumps.	2005
19	EEA_2007	European	Demand-driven. The forest biomass potential is modelled using the sustainability classification, projections of future industry demands for wood, international wood trade and prices of wood. A wide set of sustainable criteria which decrease or increase the forest biomass potential is taken into account.	Felling residues, wood from complementary fellings	2005, 2010, 2020, 2030
20	Hetsch_et_al_2008	European	Wood resource balance. Wood flows are analysed calculating independently the wood supply and use of wood fibres. The method considers national import and export patterns as well as use and re-use of wood fibres for material and energy purposes. An analysis of historical trends in policy was done to determine future needs for wood fuels in energy sector	Industrial wood, fuel wood, logging residues, bark, industrial wood residues, recovered wood and refined wood fuels	2005, 2010, 2020
21	Meuleman_et_al_2005	European	Demand driven. The estimation of biomass potential is based on expansion factors for amounts of forest residues. Projections of wood use for energy are derived from projections of future energy demand for EU	Forest wood biomass	2002, 2010
22	Nielsen_et_al_2007	European	Demand-driven. Due to the climate changes and constantly increasing emissions it is advised to extend the area covered with energy crops to produce more renewable energy.	Energy crops	2030
23	Päivinen_et_al	European	Forest area map was derived from forest area estimation by Häme et al., (2000), the calibration method by Päivinen et al. (2001) and its implementation (Schuck et al., 2002). Further, regional growing stock statistics referring to regional geographical units are combined to the forest area map	Forest wood	1996-2001
24	Schuck_et_al_2003	European	Geometrical correction of the satellite data using polynomial coefficients, separation of the corrected satellite data into three geographic strata, the Atlantic; Mediterranean; and Temperate and Boreal stratum. Estimation of forest variables for each stratum separately. The percentage forest proportion was estimated for each individual pixel of the image mosaic using the CORINE Land Cover	Forest wood	1995-2001

			classification as training data. The approach of pixel-by-pixel ratio scaling was used for the calibration process which was applied to produce a pan-European forest map.		
26	De_Wit_&_Faaij_2008	European Union 27 + Switzerland, Norway, Ukraine	Bio-physical modeling of land required for food and feed. Agro Ecological Zones modelling of yields of energy and food crops. Bottom-up cost analysis of bioenergy crops production costs	Annual crops, grasses and SRC poplar/willow on agricultural land, and agricultural and forestry residues	2030
27	EEA_2006	European, EU-25	Demand-driven There is a need to increase the use of biomass for energy purposes with a strong consideration of environment	energy crops, forestry biomass, wastes	2030
28	EEA_2007b	European, EU--25	Demand-driven, The consumption of biomass is increasing and it is important to assess how much agricultural biomass is potentially available without harming the environment and without counteracting current and potential future EU environmental policies and objectives	agricultural biomass	2030
29	AlSaedi_et_al_2005	European, specific regions	Resource focused, based on literature review and partner's experience.	Biodegradable part of organic wastes and energy crops for biogas production through anaerobic digestion (AD).	2005
30	AlSaedi_et_al_2007	European, specific regions	Both resource and demand focused. The work was based on the results of the research carried out in 2002 by a team of Danish researchers, where environmental and economic costs and benefits of the centralised biogas technology, deriving advantages and drawbacks are quantified and monetised using a welfare methodology. The socio-economic analysis is carried out as a cost-benefit analysis.	Biodegradable part of organic wastes and energy crops for biogas production through anaerobic digestion (AD).	2005-2007



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Agricultural residues
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Forestry biomass
Waste biomass
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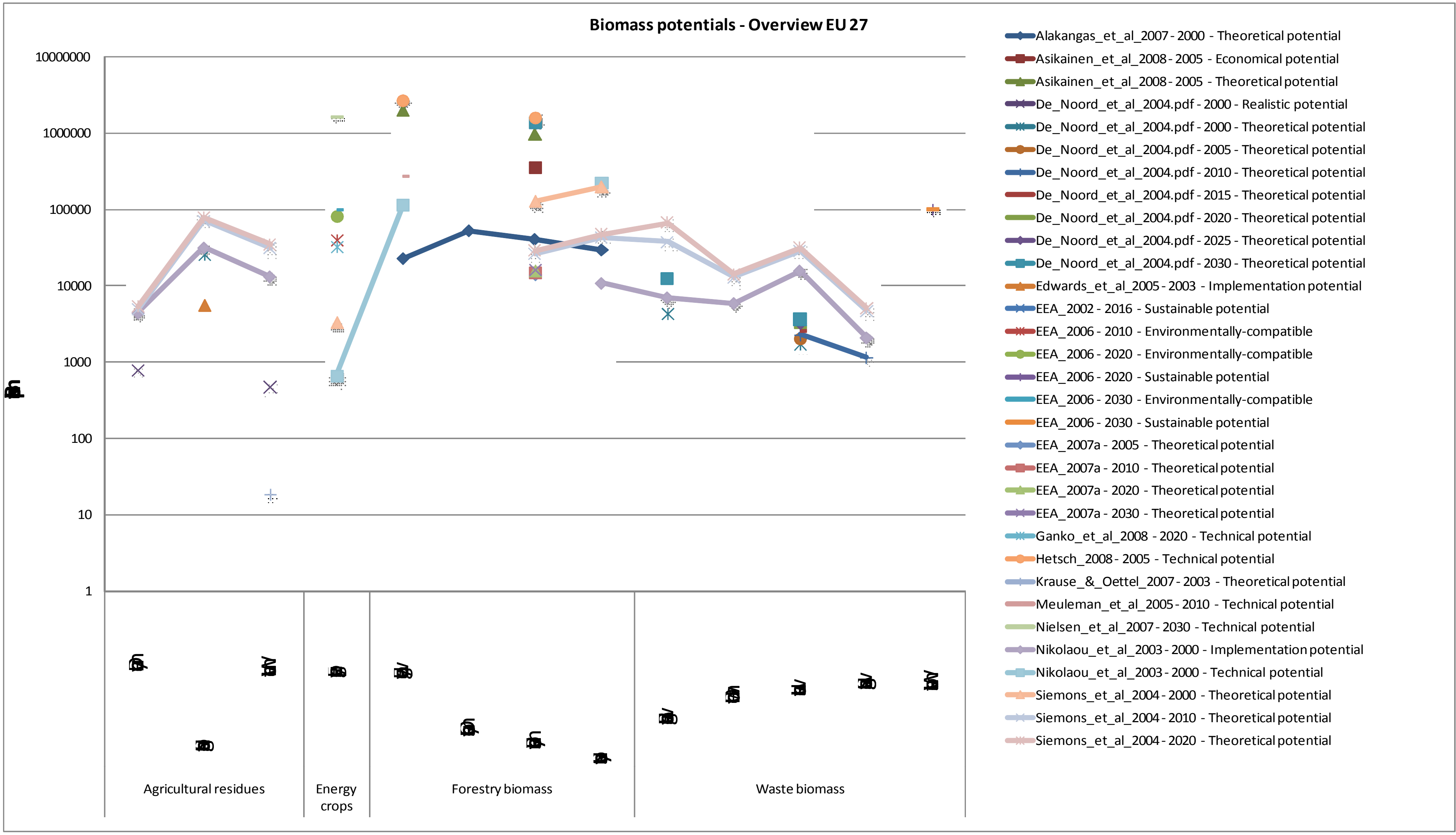

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Agricultural residues
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Alakangas_et_al_2007 - 2000 - Theoretical potential
Asikainen_et_al_2008 - 2005 - Economical potential
Asikainen_et_al_2008 - 2005 - Theoretical potential
De_Noord_et_al_2004.pdf - 2000 - Realistic potential
De_Noord_et_al_2004.pdf - 2000 - Theoretical potential
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De_Noord_et_al_2004.pdf - 2020 - Theoretical potential
De_Noord_et_al_2004.pdf - 2025 - Theoretical potential
De_Noord_et_al_2004.pdf - 2030 - Theoretical potential
Edwards_et_al_2005 - 2003 - Implementation potential
EEA_2002 - 2016 - Sustainable potential
EEA_2006 - 2010 - Environmentally-compatible
EEA_2006 - 2020 - Environmentally-compatible
EEA_2006 - 2020 - Sustainable potential
EEA_2006 - 2030 - Environmentally-compatible
EEA_2006 - 2030 - Sustainable potential
EEA_2007a - 2005 - Theoretical potential
EEA_2007a - 2010 - Theoretical potential
EEA_2007a - 2020 - Theoretical potential
EEA_2007a - 2030 - Theoretical potential
Ganko_et_al_2008 - 2020 - Technical potential
Hetsch_2008 - 2005 - Technical potential
Krause_&_Oettel_2007 - 2003 - Theoretical potential
Meuleman_et_al_2005 - 2010 - Technical potential
Nielsen_et_al_2007 - 2030 - Technical potential
Nikolaou_et_al_2003 - 2000 - Implementation potential
Nikolaou_et_al_2003 - 2000 - Technical potential
Siemons_et_al_2004 - 2000 - Theoretical potential
Siemons_et_al_2004 - 2010 - Theoretical potential
Siemons_et_al_2004 - 2020 - Theoretical potential

The methodology for the assessment of selected biomass studies foresees a categorization into different types of studies to make studies more comparable. The review of BEE and Biomass Futures of the selected studies resulted in categories for biomass types (Biomass from forestry, Energy crops. Biomass from agriculture, Biomass from waste, Total resource assessments) and potential types (Theoretical potential, Technical potential, Economic potential, Sustainable potential) and method types (Resource focussed statistical methods, Resource-focussed spatially explicit methods, Demand-driven cost-supply methods, Demand driven energy and/or economic modelling methods and integrated assessments). After categorization remaining differences between studies (see e.g. Fig. 2) are likely to originate from different input data used, scenario assumptions made and tools applied. More categories were planned for comparing scenarios assumptions (especially on markets, technologies etc.). However, no further categorizations for a detailed comparison of studies could be achieved. This is mainly due to the fact that detailed assumptions were not always displayed by the study authors. If provided, the assumptions were too individually chosen for each study so that a categorization was not appropriate.

A major conclusion of the Biomass Futures review of biomass assessments at EU country level is that a share of the differences between studies can be explained by an appropriate categorization of studies according to method, biomass type and potential types. Remaining discrepancies can be assessed by comparing individual studies only but not in a systematic manner due to lack of information provided by authors and individuality of assumptions.

References

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