Delivery of sustainable supply of non-food biomass to support a resource-efficient Bioeconomy in Europe

S2Biom summer school, Athens, Greece, 17-20 May, 2016

Sustainable supply of non-food biomass for a resource efficient bio-economy: Review on the state-of-the-art

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Renewable energy in Europe

- **Primary production of renewable energy, (EU-28, 2012):**
  - 177 million toe (7,400 PJ) - 22.3% of total primary energy production from all sources
  - Biomass and renewable waste – most important RES, accounting for 65.5% of primary renewables production
- **Gross inland energy consumption[1] of RES, (EU-28, 2012):**
  - ~185 million toe (7,750 PJ) - 11% of total gross inland energy consumption
  - Biomass and renewable wastes provided 7.3% (123 million toe or 5,150 PJ) representing around two thirds of this share

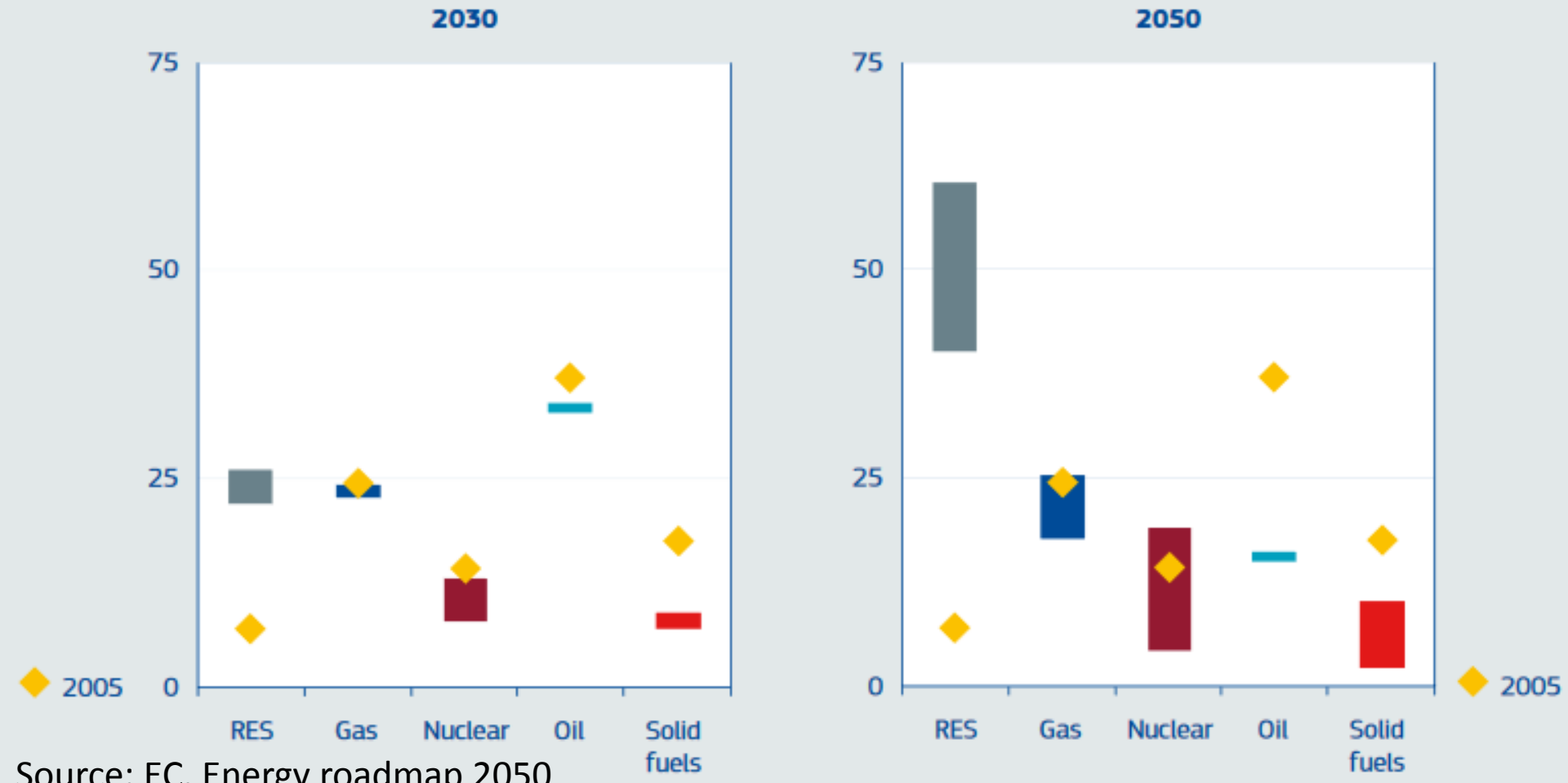
[1] Gross inland energy consumption = primary production + recovered products + net imports + variations of stocks – bunkers

Policy context: RES targets

- **2020:**
  - to decrease greenhouse gas (GHG) emissions by 20%,
  - to increase energy efficiency by 20%
  - to raise the share of energy consumption produced from renewable resources to 20% as compared to 1990
- **2030:**
  - 40% GHG emission reduction
  - 27% share of energy consumption produced from renewable resources compared to 1990
- **2050 (Energy Roadmap 2050):**
  - 80-95% GHG emission reduction compared to 1990
  - Several decarbonisation scenarios are developed

Policy context: RES projections

EU decarbonisation scenarios — 2030 and 2050 range of fuel shares in primary energy consumption compared with 2005 outcome (%)



Source: EC, Energy roadmap 2050

Policy context: Bioeconomy

- **Strategy "Innovating for Sustainable Growth: a Bioeconomy for Europe" aims to shift the European economy towards greater and more sustainable use of renewable resources:**
  - More innovative, low-emissions economy
  - Balancing the demands for sustainable agriculture and fisheries
  - Food security
  - Sustainable use of renewable biological resources for industrial purposes…

… while ensuring biodiversity and environmental protection

Policy context: Resource efficiency

- **Resource efficiency** means using the Earth's limited resources in a sustainable manner while minimising impacts on the environment
- **Resource-efficient Europe flagship initiative** - part of the Europe 2020 Strategy
- **Roadmap to a resource efficient Europe**
  - sets out a framework for the design and implementation of future actions
  - outlines the structural and technological changes needed by 2050
  - includes milestones to be reached by 2020
- **Circular economy** – replacing linear economy
- **Resource efficient bioeconomy** requires that the supply of biomass remains sustainable while achieving the EU target

S2Biom State-of-the-art

- **Aim of the state-of-the-art review:**
  - To provide an overview about various studies which investigated the present and potential sustainable supply of non-food biomass in the EU
  - To use it as a baseline for the update, comparison and refining of the datasets of S2Biom project
- **Present use and potential of sustainable supply of non-food biomass:**
  - forest biomass
  - non-food lignocellulosic crops
  - agricultural residues
  - residual biomass from waste

Forest biomass in EU-28

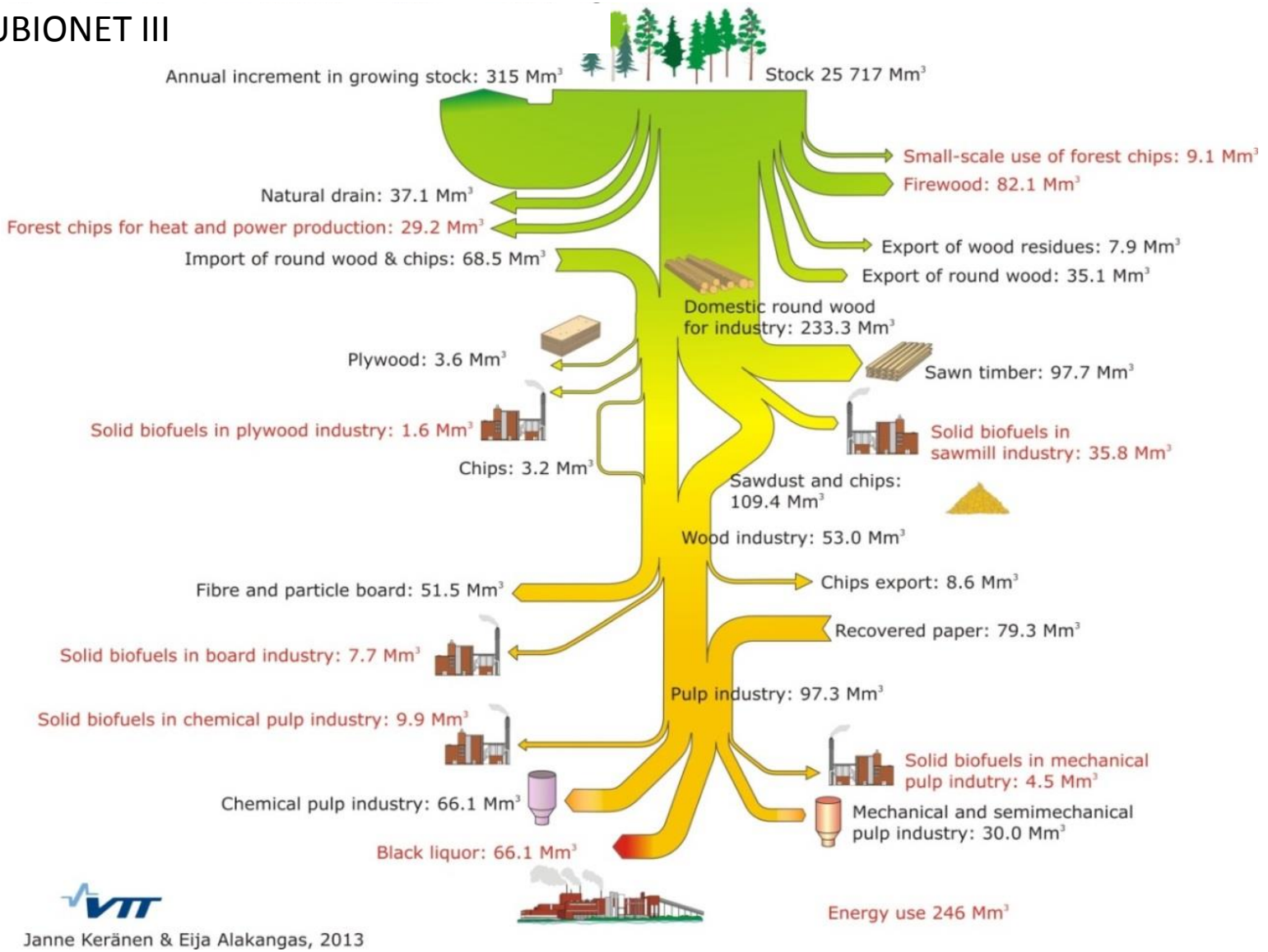
- **Currently the most important source of renewable energy**
- **Accounts for around 1/2 of the EU's total renewable energy consumption**
  - 92.5 million toe or 3,850 PJ (2012)
- **Expected in 2020 (according to NREAPs), biomass (mainly woody) used for heating, cooling and electricity:**
  - ~ 42% of the 20% RES target for 2020

Present use of forest biomass

- **Forests and wooded land (EUROSTAT, 2010):**
  - covers 180 million ha
  - 42.4% of EU land area
  - between 2000-2010, the forest area in EU increased by 2%
- **The growing stock of forests in EU (2010):**
  - 24.4 billion m^3,
  - 22 billion m^3 are available for wood supply (~90%)
- **The primary energy production from forestry in the EU-27 (2010):**
  - 9.8% of the total primary energy (80.8 million toe or 3,400 PJ)
  - 48.5% of the total renewable energy

Wood use flow in EU-28 (2012)

Source: EUBIONET III



Sustainable potential supply of forest biomass

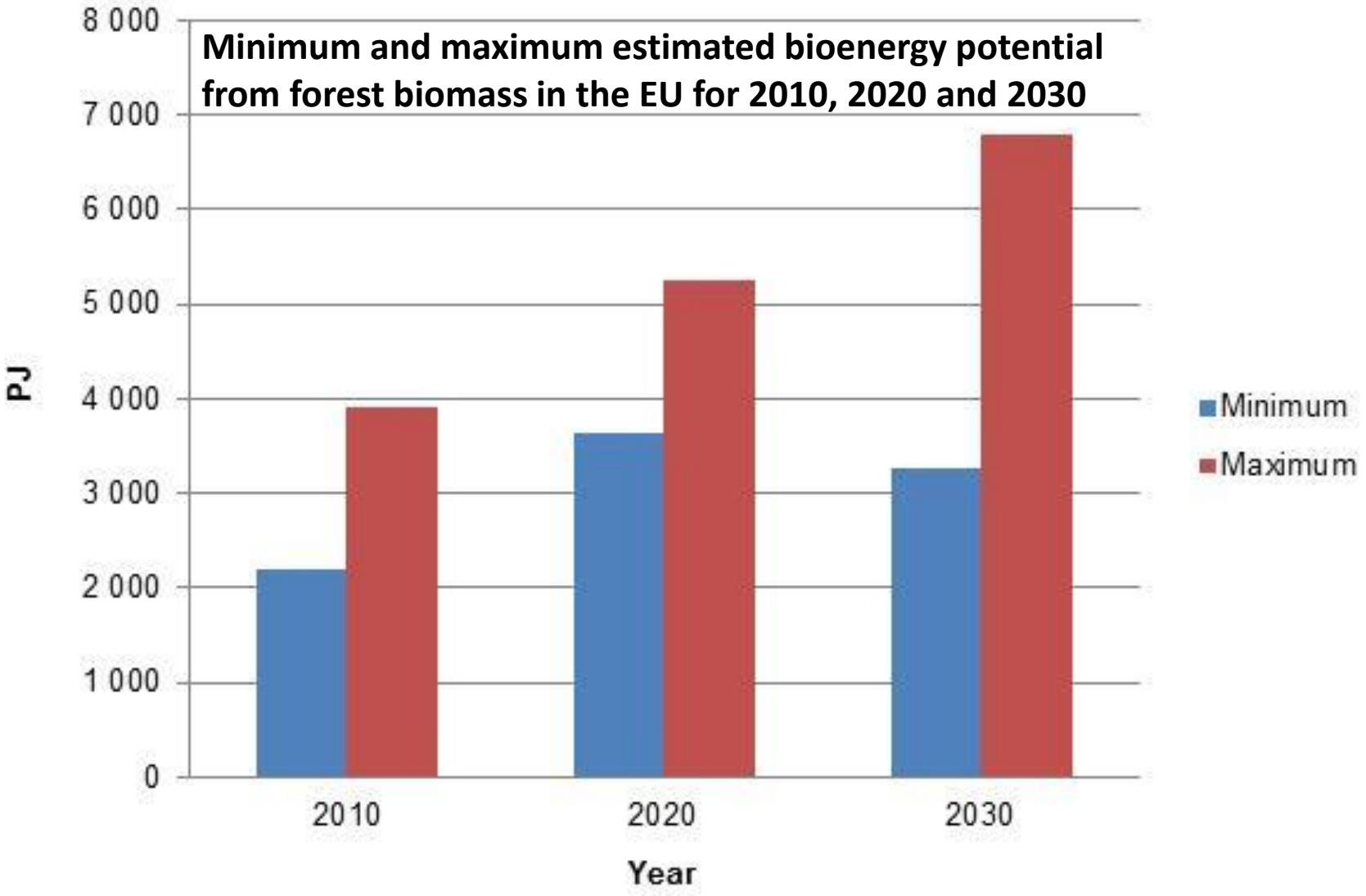
- **Several studies have been reviewed:**
  - The European Forest Sector Outlook Study (EFSOS) II prepared by UNECE (United Nations Economic Commission for Europe) and FAO in 2011
  - Study from the International Institute for Sustainability Analysis and Strategy (IINAS) in cooperation with the European Forest Institute (EFI) and Joanneum Research (JR) on behalf of several NGOs
  - Biomass Futures project estimates on the supply of wood for energy use in EU-27 for 2010, 2020 and 2030 based on the EUWOOD project
- **Different estimations, assumptions and policy scenarios used in studies provide large differences between obtained projections**

Sustainable potential supply of forest biomass

Studies estimating wood supply from forest for bioenergy use	2010	2020	2030
	Energy potential (PJ)		
EFSOS II	2,434		
EFSOS II - Reference scenario			3,274
EFSOS II – biodiversity			3,274
EFSOS II - Promoting wood energy			4,084
EFSOS II - biomass carbon			3,274
Biomass Futures	3,909	5,239	5,123
EUWOOD	2,200	5,000	6,800
IINAS	3,000	3,650*	4,300

* This value is linearly extrapolated from the values of 2010 and 2030

Sustainable potential supply of forest biomass



EU policies for sustainable supply of forest biomass

- Sustainable forest management issues are addressed by **several EU policy strategies**
- Guidelines, criteria and indicators for sustainable forest management developed by **FOREST EUROPE**
- **EU forest strategy** (revised in 2013)
- **EU Renewable Energy Directive** – sustainability criteria
- **Report on the state of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU** (2014)
- **Sustainability certification schemes**, including voluntary schemes
- **Sustainable Biomass Partnership** (formed by industry in 2013)
- **Biomass Assurance Framework -** statement of principles, standards and processes necessary to demonstrate compliance with legal, regulatory and sustainability requirements relating to woody biomass (developed by SBP)

Non-food lignocellulosic crops in EU-28

- **Non-food lignocellulosic crops:**
  - unsuitable for human or animal food consumption
  - grown for the purpose of producing biomass for energy and/or material purposes in an agricultural rather than a forestry context
- Nearly all of the crops considered within this definition are **perennial in nature**:
  - they can be cut and harvested for biomass over successive years without re-cultivation or sowing
  - The whole crop can be harvested and used for energy production
- Two broad types of **energy crops**:
  - **perennial herbaceous crops** (Miscanthus, switchgrass, reed canary grass, giant reed, perennial rye grass)
  - **woody crops** known as short rotation coppice (SRC) (e.g. willow, poplar, eucalyptus, paulownia).

Present use of non-food lignocellulosic crops

- **Bioenergy cropping area:**
  - 5.5 million ha of agricultural land
  - 3.2% of the total cropping area
- **Cultivation shares:**
  - 82% oil crops for biodiesel production
  - 11% sugar and starch crops for bioethanol production
  - 7% crops grown as feedstock for biogas production
- **Minor use for electricity and heat generation (1% or only 50,000 – 60,000 ha of land)**
  - Largest areas in the UK, Sweden, Finland, Germany, Spain and Italy
  - Statistics of non-food lignocellulosic crops plantations are almost inexistent in many European countries

Sustainable potential supply of non-food lignocellulosic crops

- **Several potential studies include areas of:**
  - fallow land in agriculture
  - other unutilised land within the current agricultural land area
  - recently abandoned agricultural land
  - recently abandoned arable land
  - contaminated land
- **Different opinions on including arable land**
- **Lack of data - significant challenge to the accurate identification of land areas with potential for non-food lignocellulosic crop cultivation**

Sustainable potential supply of non-food lignocellulosic crops

Institute for European Environmental Policy (IEEP): A hypothetical area of land that could be investigated further for growing non-food lignocellulosic crops

Agricultural land	Area (ha)
Recently abandoned cropland (<5 years old)	200,000
(Recently abandoned) Grassland moving out of agricultural use since 2009, most likely out of production, includes transitions to urban land	600,000
Fallow land in agricultural rotation, most of which is needed for agronomic purposes	200,000
Other underutilised land within the current UAA but not permanent grassland	300,000
Non-agricultural land	
Suitable contaminated sites (excluding areas suited only for afforestation)	50,000
Total potentially available land based on optimistic assessments of area	**1,350,000**
This corresponds to: **7.7 - 16.7 million dry tonnes of biomass or 3.3-7.2 million toe (140 - 300 PJ) of energy**	

Sustainable potential supply of non-food lignocellulosic crops

- **EEA-ETC/SIA assessment for 2020:**
  - Available land for dedicated perennial biomass crops: 6.8-12 million ha
  - Estimated biomass production: 86 -118 million dry tonnes
  - 33 - 45 million toe (1,400 - 1,900 PJ)
- **Biomass Futures project study on primary energy potential for non-food lingocellulosic crops:**
  - In 2020: 51.6 - 70 million toe (2,150 - 2,950 PJ)
  - In 2030: 36.8 - 60.8 million toe (1,550 - 2,550 PJ)
- **Study of Nielsen et al. assessed opportunities to use arable land:**
  - 10% of arable land used: 49 million toe (2,050 PJ)
  - 20% of arable land used: 98 million toe (4,100 PJ)
  - 30% of arable land used: 146 million toe (6,100 PJ)

Sustainable potential supply of non-food lignocellulosic crops

Summary of the non-food lignocellulosic crop potential (including arable land):

	Min		Max	
	Million toe	PJ	Million toe	PJ
Present	~52	2,200	153	6,400
2020	82	3,450	217	9,100
2030	86	3,600	208	8,700

EU policies for sustainable supply of non-food lignocellulosic crops

- **CAP cross compliance rules – water, soil, air**
- **Non-food lignocellulosic crops can undergo two lines of energy conversion pathways:**
  - production of 2nd generation transport biofuels (RED sustainability criteria)
  - production of heat and power (no sustainability criteria applied, e.g. like for forest biomass)
- **Impact of land use change:**
  - crops are grown on agricultural land
  - crops grown on marginal land
- **Reformed CAP (2014-2020):**
  - Direct payments: there will be no direct incentives supporting the production of bioenergy from energy crops
  - Greening payment: significant share of the subsidy will in future be linked to rewarding farmers for the provision of environmental public goods
  - Rural development measures: encourages the supply of bioenergy from agriculture and forestry and the use of bioenergy on farms and in rural areas
- **Policy beyond 2020: no support for biofuels from food-based feedstock, no targets for RES in transport sector**

Agricultural residues in EU-28

- **Classification of agricultural residues:**
  - **Primary** - resulting from primary agricultural operations (e.g. straw, manure)
  - **Secondary** - produced during the processing of crops into food or other products (e.g. bagasse)
- **The use of agricultural residues for energy productions depends on their properties and characteristics, e.g.:**
  - Moisture content:
    - Dry residues -> combustion, gasification
    - Wet residues -> anaerobic digestion
  - Ligno-cellulose content
- **Alternative markets and uses should be considered**
- **Competition for land use and resources is highly avoided**

Present use of agricultural residues

- **Primary renewable energy production from agriculture in the EU-27 (EUROSTAT, 2010):**
  - 2.1% of the total primary energy produced
    (17.6 million toe or 750 PJ)
  - 10.6% of the total renewable energy production
- **Most of this share comes from energy crops**
- **No data on the share from agricultural residues for bioenergy production on EU level**

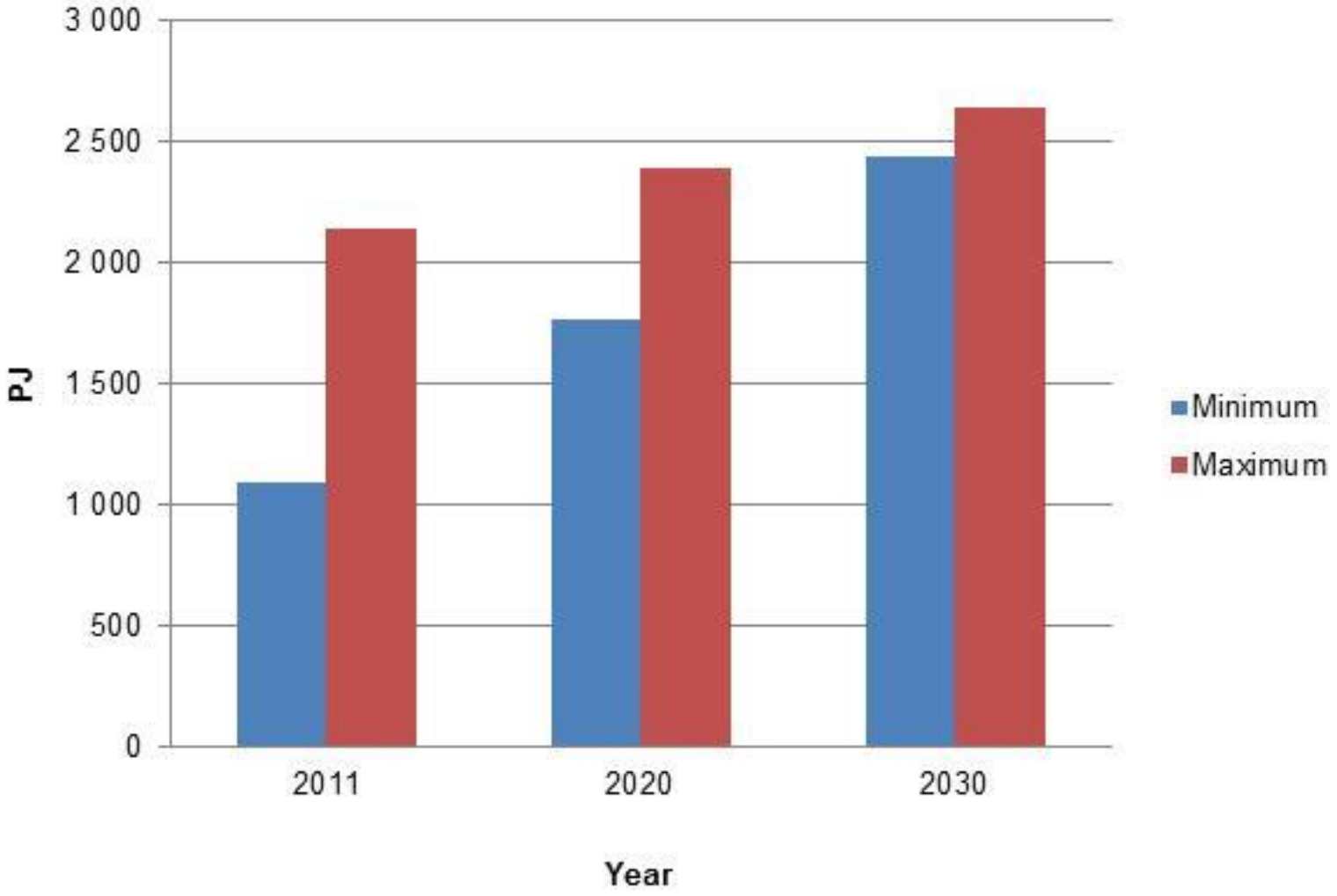
Sustainable potential supply of agricultural residues

Primary agricultural residues – crop residues

- **Crop residues are parts of the crop that are not harvested during standard agricultural operations**
- **Large differences in EU – cultivated area, types of crops and yields (different climate conditions, specific soil condition, farming practices)**
- **Crop residue yields are very variable and depend on:**
  - plant variety
  - crop yield
  - climate and soil conditions
  - irrigation rate
  - farming practices, harvesting techniques and the cutting height
  - amount that can be removed keeping land fertility
  - land fertility maintained
  - competitive use for agricultural or industrial purposes

Sustainable potential supply of agricultural residues

Summary of bioenergy potential from crop residues in EU



Sustainable potential supply of agricultural residues

Primary agricultural residues – pruning residues

- Woody material from pruning and cutting from plantations of soft fruit, citrus, olives and vineyards
- Harvest ratios (derived from several publications):

Land use category	Residue yields tonnes dry matter / ha / year
Fruit and berry plantations - total	2.15
Temperate climate fruit and berry plantations	
Subtropical climate fruit and berry plantations	
Nuts fruit and berry plantations	2.15
Citrus plantations	2.75
Olive plantations - table olives	1.77
Olive plantations - oil production	
Vineyards - quality wine	2.81
Vineyards - other wines	
Vineyards - table grapes	
Vineyards – raisins	

Sustainable potential supply of agricultural residues

Primary agricultural residues – pruning residues

- **Largest potential is delivered by vineyards and olives**

- **Potential supply of pruning residues (source: Biomass Futures project):**
  - In 2020: 10 million toe (423 PJ)
  - In 2030: 9 million toe (370 PJ)

- **Constraints for applications for bioenergy production:**
  - relatively high ash content (resulting from the high share of bark)
  - presence of agrochemicals on the biomass surface (impact on flue-gas emissions in combustion)
  - used for combustion technologies aimed for low quality fuels

Sustainable potential supply of agricultural residues

Primary agricultural residues – livestock residues

- **Manure production in the EU (EC, 2011) - 1.4 billion tonnes (wet)**
- **Largest production – France and Germany**
- **Currently 7.8% of the livestock manure in the EU is being processed (~108 million tonnes), including processing in biogas plants**
- **Estimations of energy potential from manure in EU-27 (Biomass Futures project):**
  - In 2004: 57 million toe (2,400 PJ)
  - For 2020: 47 million toe (1,950 PJ)
  - For 2030: 50 million toe (2,100 PJ)
- **The total potential of residues from livestock production in Europe (BioBoost project):**
  - Theoretical: ~ 1,450 PJ
  - Technical: only 21 PJ (due to the need of soil conservation)

Sustainable potential supply of agricultural residues

Other primary agricultural residues

- **Mowing from permanent grasslands (agricultural land, recreational, nature conservation areas and abandoned grasslands)**
- **Roadside verge grass**
- **Potential from abandoned grassland cuttings in EU (Biomass Futures project):**
  - In 2020: 3.65 million toe (153 PJ)
  - In 2030: 0.26 million toe (11 PJ) – due to conversion of land
  - Potential from non-agricultural lands is excluded from the study!
- **Potential of roadside verge cuttings in EU (Biomass Futures project):**
  - In 2010: 1.09 million toe (46 PJ)
  - In 2020: 1.14 million toe (48 PJ)
  - In 2030: 1.16 million toe (49 PJ)

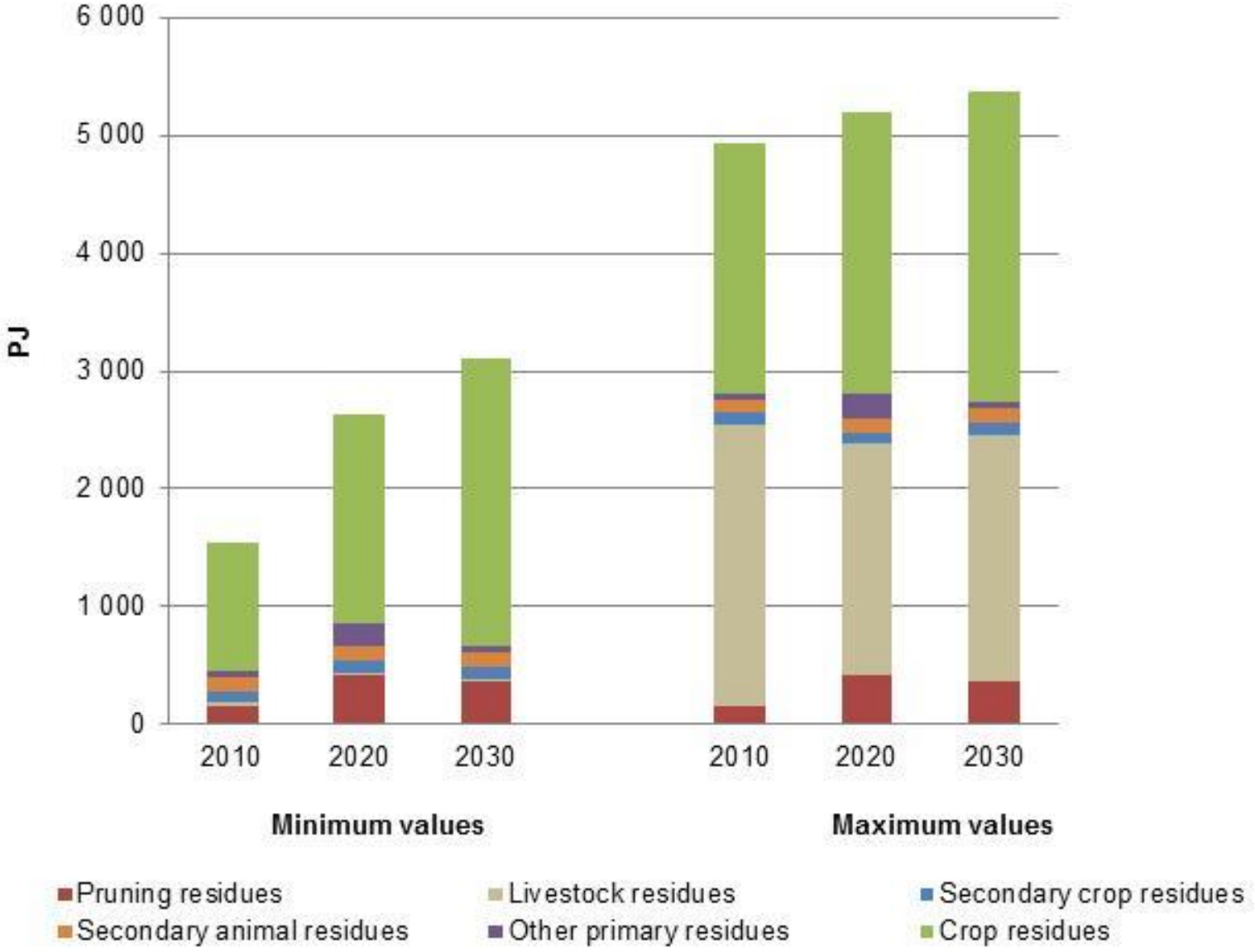
Sustainable potential supply of agricultural residues

Secondary agricultural residues (agro-industrial residues)

- **Easy to collect at the processing site**
- **Their logistics are greatly simplified**

- **Unexploited energy potential of secondary crop residues in 17 EU countries (EUBIONET III project):**
  - 2.4 million toe (100 PJ)
- **Secondary animal residues – animal waste of food preparation and products – estimated energy potential in EU-27 (Biomass Futures project):**
  - Current: 2.8 million toe (115 PJ)
  - In 2020 and 2030: 2.9 million toe (120 PJ)
  - Not clear if this potential is completely available for bioenergy production, since other uses exist

Total potential supply from agricultural residues



Residual biomass from waste in EU-28

- **According to the definition of the EU Waste Framework Directive waste is a material which an entity wishes to dispose of**
- **In the context of biomass, waste will occur in the forestry and agricultural businesses (covered before) as well as in biodegradable municipal waste – bio-waste and sludge**
- **Bio-waste :**
  - Green waste from parks and gardens (MC: 50-60%, lignocellulose)
  - Kitchen waste (MC up to 80%, no lignocellulose)
- **Bio-waste management options:**
  - Apart to prevention at source, collection (separate or mixed)
  - Anaerobic digestion (energy recovery) and composting
  - Incineration (with and without energy recovery)
  - Landfilling

Present use of residual biomass from waste

- **The overall potential for separately collected bio-waste in EU-27:**
  - up to 150kg/inhabitant/year (including kitchen and garden waste from households, park and garden waste from public estates, and waste from the food industry)
  - 80 million tonnes
  - ~30% (24 million tonnes) is collected separately and treated biologically
- **Total Municipal Solid Waste (MSW) in the EU (2012):**
  - 33% landfilled, 24% incinerated, 27% recycled and 14% composted
  - Contains between 30 and 40% bio-waste (ranges from 18-60%)
  - EUROSTAT (EU-28, 2012): gross energy consumption of the renewable part of MSW - 8.84 million toe (370 PJ)

Sustainable potential supply of residual biomass from waste

Biodegradable Municipal Waste

- **Any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard (Council Directive (1999/31/EC)72)**
- **Biodegradable Municipal Waste energy potential (EEA study, 2006):**
  - In 2010: 19 million toe (795 PJ)
  - In 2020: 17 million toe (715 PJ)
  - In 2030: 16 million toe (670 PJ)
- **Results from a study of Siemons et al. (2004) regarding energy recovered from landfill gas and from incineration:**
  - In 2010: 24 million toe (1,000 PJ)
  - In 2020: 36 million toe (1,500 PJ)

Sustainable potential supply of residual biomass from waste

Used oils and fats

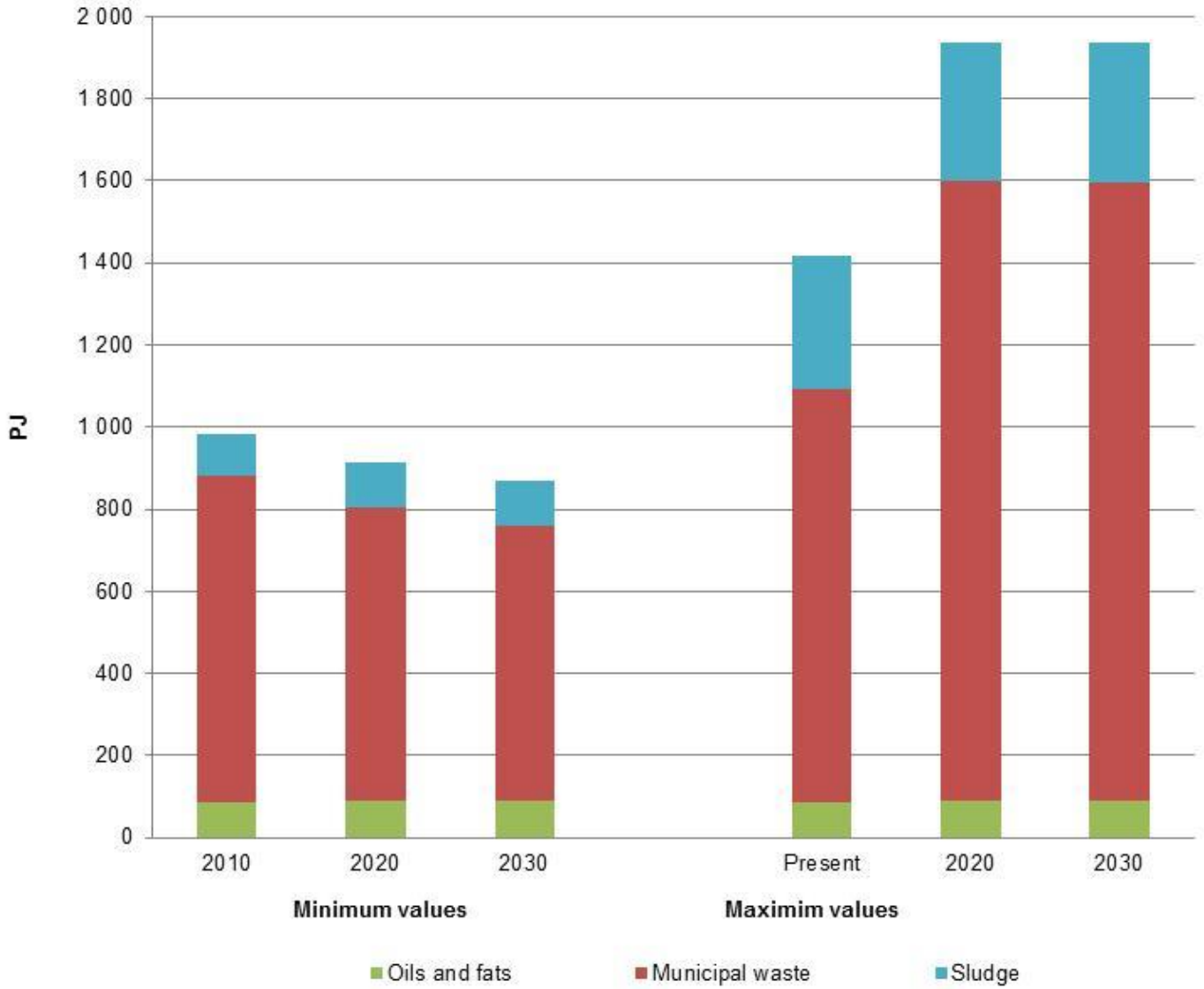
- **Energy potential from used oils and fats (Biomass Futures project):**
  - In 2010: 2.10 million toe (88 PJ)
  - In 2020: 2.17 million toe (91 PJ)
  - In 2030: 2.16 million toe (90 PJ)

Sustainable potential supply of residual biomass from waste

Common sludge

- **Common sludge (industrial effluent sludge) includes all kinds of sludge originating from wastes, waste water treatment and water preparation**
- **Energy potential from sludge in Europe (Biomass Futures project):**
  - Current: 7.8 million toe (325 PJ)
  - In 2020: 8.1 million toe (340 PJ)
  - In 2030: 8.2 million toe (345 PJ)
- **Estimations of the study of Siemons et al.:**
  - In 2010: 2.4 million toe (100 PJ)
  - In 2020: 2.6 million toe (110 PJ)
- **Today most of the sludge is incinerated and/or deposited on the land (e.g. agriculture) and only a small part is already used for energy recovery (e.g. biogas production)**

Summary of the residual waste potential

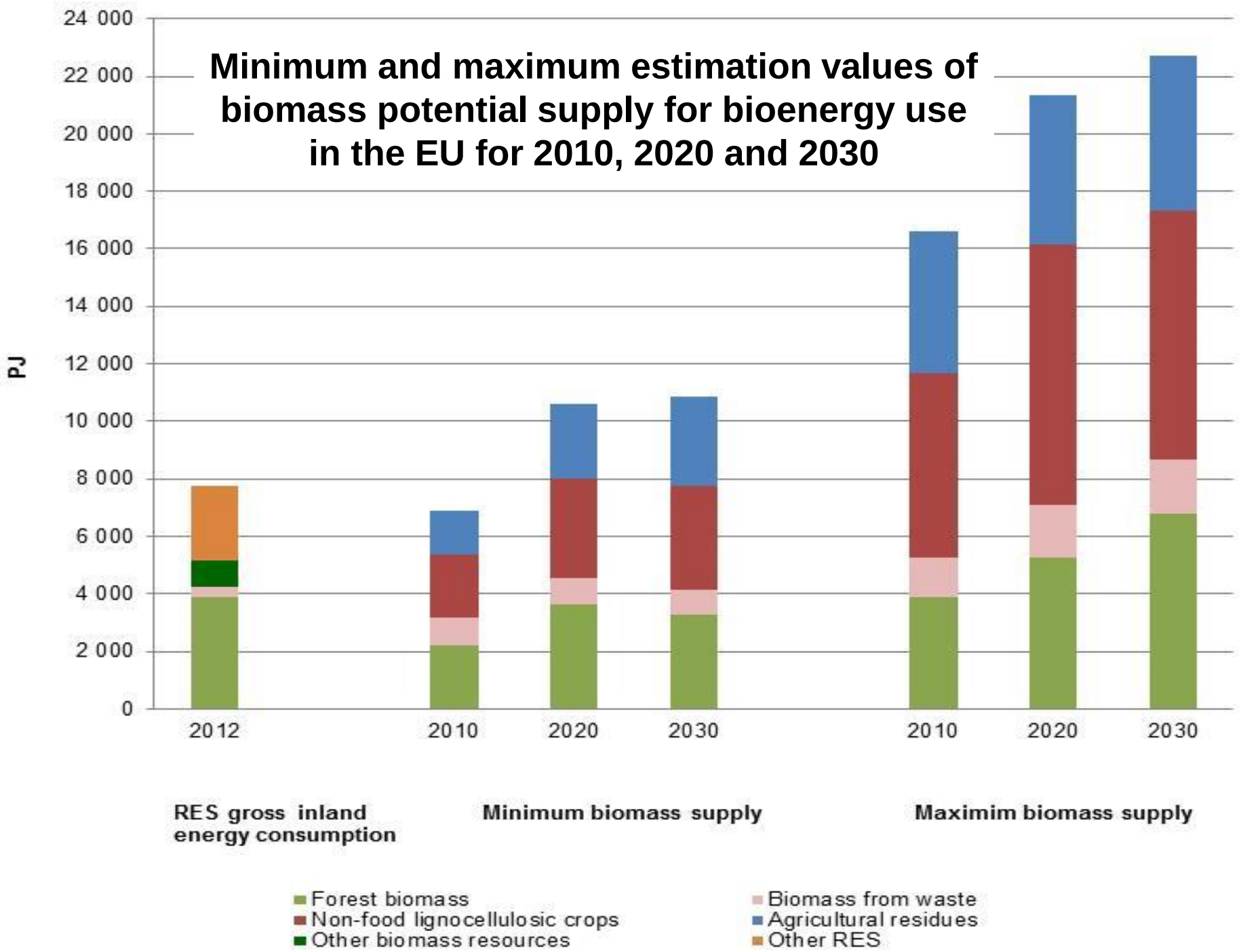


EU policies for sustainable supply of biomass from waste

- **European Landfill Directive 1999/31/EC - limits the landfilling of biodegradable waste**
- **Waste Framework Directive 2008/98/EC – provides measures to promote recycling and separate collection of waste**
- **End-of-waste criteria – will affect the handling and fate of bio-waste:**
  - End-of-waste material should be hygienised and stabilized compost
  - digestate materials should be obtained through a biological waste treatment process using strictly defined input materials (limitations regarding use of mixed MSW, sludge and animal by-products)
  - input materials must not be contaminated
- **Industrial emissions directive (2010/75/EC) – covers management and emissions from large composting and digestion plants dealing with waste**

Conclusions

- **Currently biomass is providing more than 60% of renewable energies in the EU and is expected to provide more in terms of toe for 2020 and 2030**
- **Sustainable biomass is a limited resource**
- **EU has a potential to provide between 6,900 PJ and 16,600 PJ from biomass for its energy consumption today**
- **These estimates could increase to:**
  - 10,600 - 21,350 PJ in 2020
  - 10,850 - 22,700 PJ in 2030
- **The current supply of biomass for energy is not exhausted and biomass can supply more in the future**


Minimum and maximum estimation values of biomass potential supply for bioenergy use in the EU for 2010, 2020 and 2030
PJ
24 000
22 000
20 000
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
0
2012
2010
2020
2030
2010
2020
2030
RES gross inland energy consumption
Minimum biomass supply
Maximim biomass supply
Forest biomass
Non-food lignocellulosic crops
Other biomass resources
Biomass from waste
Agricultural residues
Other RES

Conclusions

- Biomass potentials from forestry and waste are relatively stable over time
- Waste and agricultural residues has a potential that is currently barely exploited for energy generation
- Large uncertainty exists on how much biomass from agriculture can be supplied
- For the future, non-food lignocellulosic crops and agricultural residues seem to be the key for a genuine expansion of biomass supply once biomass from forestry and waste are stable
- The S2Biom project aims at filling the gaps of uncertainties by providing updated harmonized datasets on the sustainable delivery of non-food lignocellulosic biomass at local, regional and pan-European level for energy and material use

References & further reading

- Khawaja C., Janssen R. (2014). Sustainable supply of non-food biomass for a resource efficient bioeconomy: A review paper on the state-of-the-art. WIP-Renewable Energies, S2Biom project
- EU Energy Policy 2050: https://ec.europa.eu/energy/en/topics/energy-strategy/2050-energy-strategy
- Resource efficiency: http://ec.europa.eu/environment/resource_efficiency/
- Reformed CAP: http://ec.europa.eu/agriculture/cap-post-2013/

Thank you for your attention !!

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