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Making bioeconomy happen

European policies and how to assess supply and demand

Summary

- European forests and the bioeconomy
- The forest biomass issue
- How to assess forest biomass
- Voluntary Payments for Carbon: a case study

Commission Communication COM(2012) 60

Accompanying Staff Working Document SWD(2012) 11

«Innovating for Sustainable Growth: A Bioeconomy for Europe»

Bioeconomy Strategy and Action Plan (available in all EU languages)

- Background to the Bioeconomy Strategy and Detailed Action Plan
- Estimating the impact of EU level research funding and better policy interaction in Bioeconomy

The Bioeconomy...

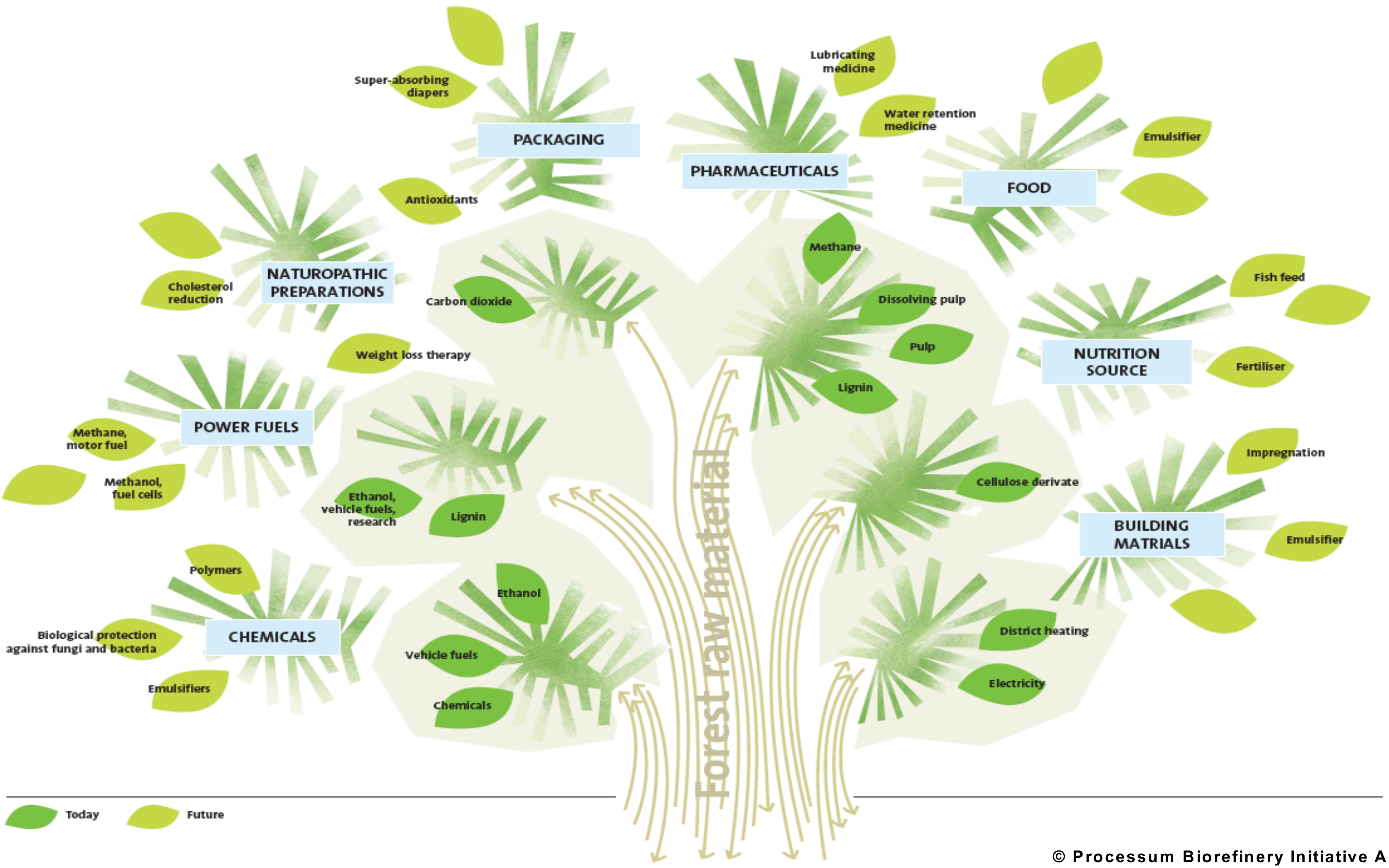
- Promotes sustainable production of renewable resources from land and sea and their conversion into food, bio-based products, biofuels and bioenergy.

- Encompasses the sectors of agriculture, forestry, fisheries, aquaculture, food and pulp and paper, as well as parts of the chemical, biotechnological and energy industries.

- Provides and protects public goods, such as clean air and water, fertile and functioning soils, landscapes, sustainable marine ecosystems and biodiversity, and addresses social needs.

Substituting fossil by renewable resources

A wide range of applications with a strong growth potential



Example wood construction: key part of urban bioeconomy

Prefabricated wood modules & elements, *e.g. cross laminated timber (CLT)*

- rapid construction
- less primary energy
- less carbon emissions

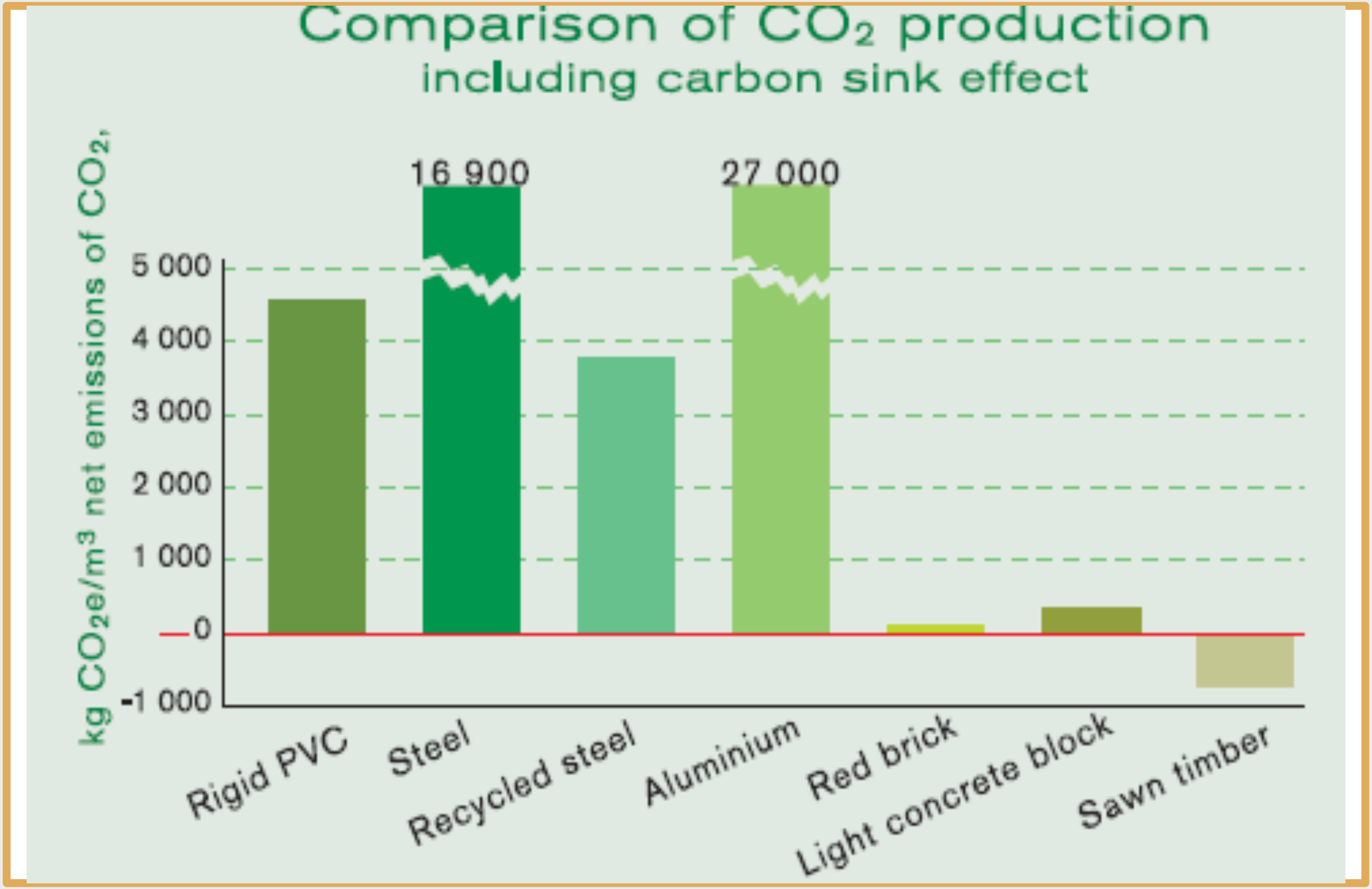
- For a **1 ton of wood products** replacing Portland cement, estimated average of **2 tons of CO_2 avoided**

Helsinki City new wooden library to be opened 2018

Image: Keskustakirjasto arkkitehtuurikilpailu

7 storey office building in Zurich

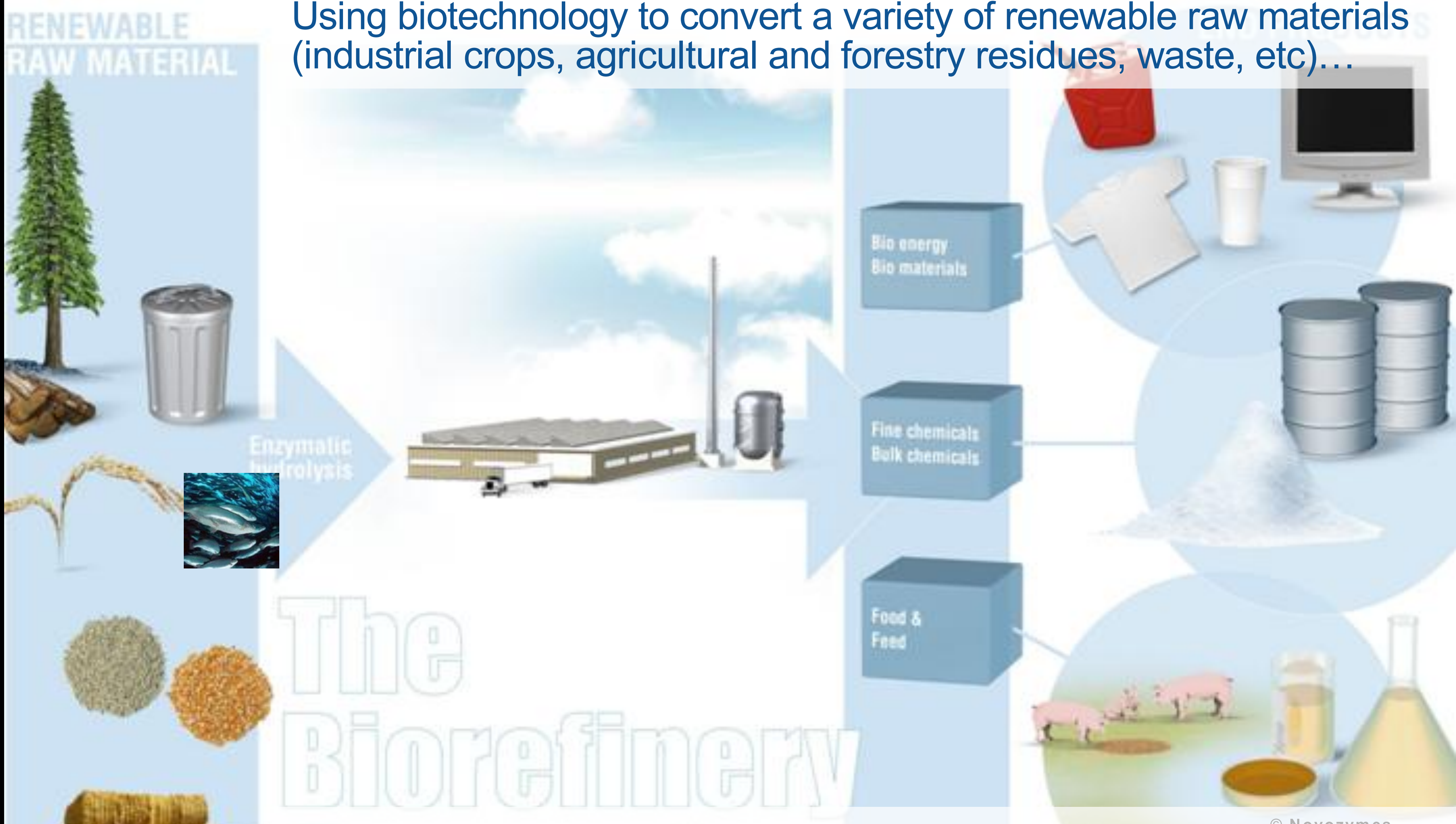
Photo: © Blumer-Lehmann AG



Comparison of CO_2 production
including carbon sink effect
kg CO_2e/m^3 net emissions of CO_2,
5 000
4 000
3 000
2 000
1 000
0
-1 000
16 900
27 000
Rigid PVC
Steel
Recycled steel
Aluminium
Red brick
Light concrete block
Sawn timber

The Biorefinery Concept

Using biotechnology to convert a variety of renewable raw materials (industrial crops, agricultural and forestry residues, waste, etc)…



…into a wide range of value added products.

Application of the “cascading approach“.

Wood-based textile fibres for growing population

- The textile market to triple by 2050: **from 80 Mt to 250 Mt.** China & India key markets

- Only 5% of world textiles are wood-based (viscose etc.), but expected to grow 10% /year

- Polyester (60%) and cotton (30%) are less environmentally friendly than viscose *(dissolving pulp based)*

Enocell Mill in Finland produces dissolving pulp for Chinese textile industry

High value materials for the automotive, packaging and agricultural industry…

www.forbioplast.eu

…**produced from forestry resources and industry by-products** using industrial biotechnology

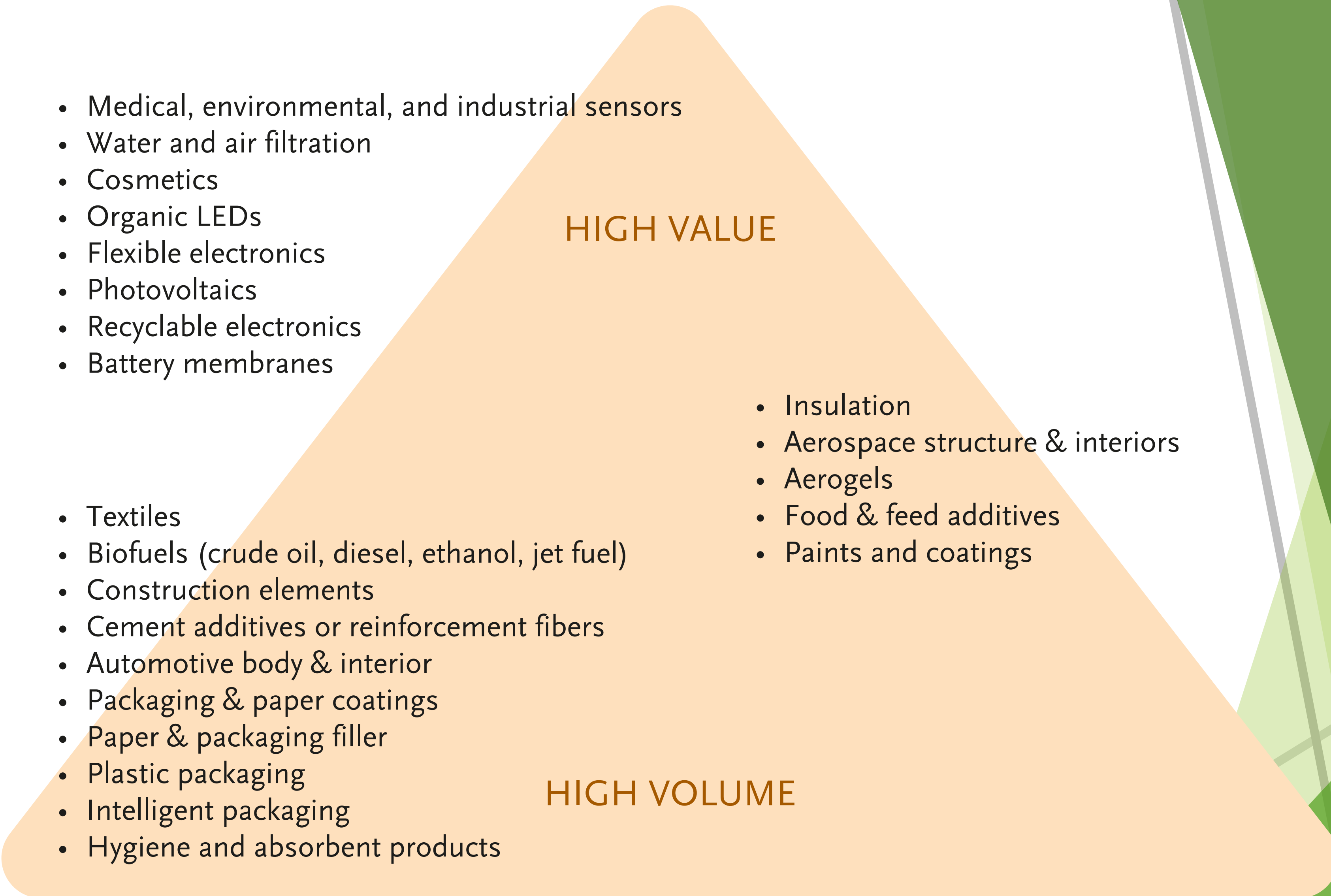


Figure 16. Examples of the possible end uses of new wood-based products (Cowie et al, 2014; Pöyry, 2016).

Relevance of *traditional* EU forest products industry

- Turnover equal to sum of French company giants *GDF Suez* + *EDF* + *Airbus*
- Empolyment 3 x bigger than the three above companies
- Including further forest-based processing industries + forestry + logistics + services could easily double the numbers

EU forest products industries turnover & employment

Data source: EUROSTAT	Paper and Paperboard	Wood Products	Total
Turnover value *(2014, in billion euros)*	179	123	**302**
Employment *(2013, number of workers)*	621 700	823 000	**1.45 million**

The Bioeconomy's growth potential

In 2010, the Bioeconomy represented about:

- *2 trillion € annual turnover*
- *1 trillion € value added, ±9 % GDP*
- *22 million jobs, ± 9% of the EU's workforce*

By 2025, funding associated to the Bioeconomy Strategy could generate about:

- *130 000 new jobs*
- *45 billion in value added in bioeconomy sectors*

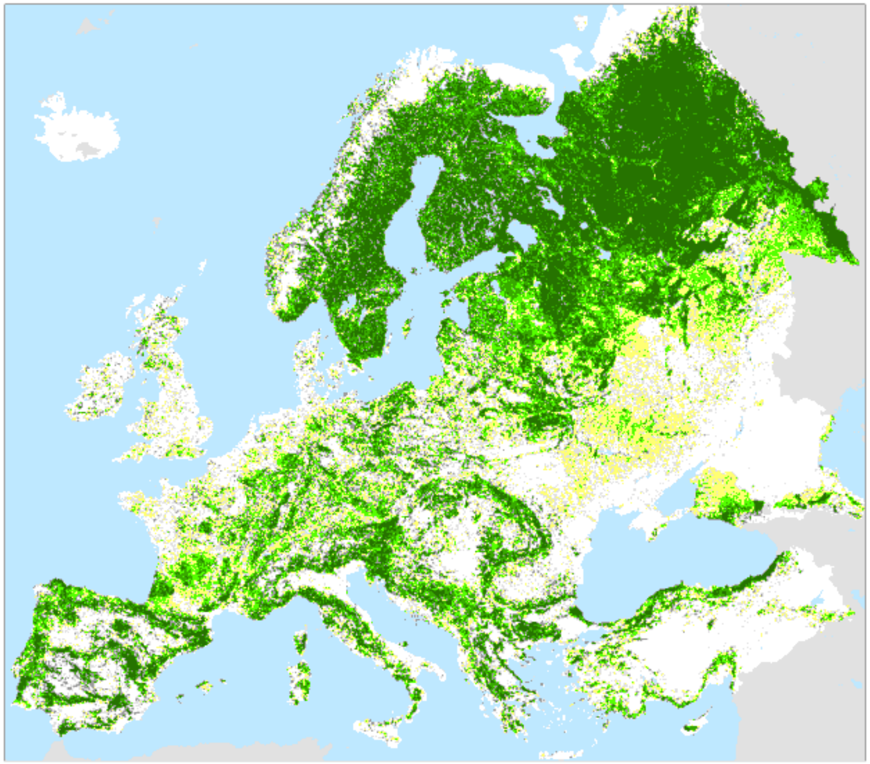
Further growth is expected from other – direct and indirect – public and private investments in all parts of the bioeconomy.

FOREST IN EUROPE

The EU’s forest industries provide employment for over 3 million

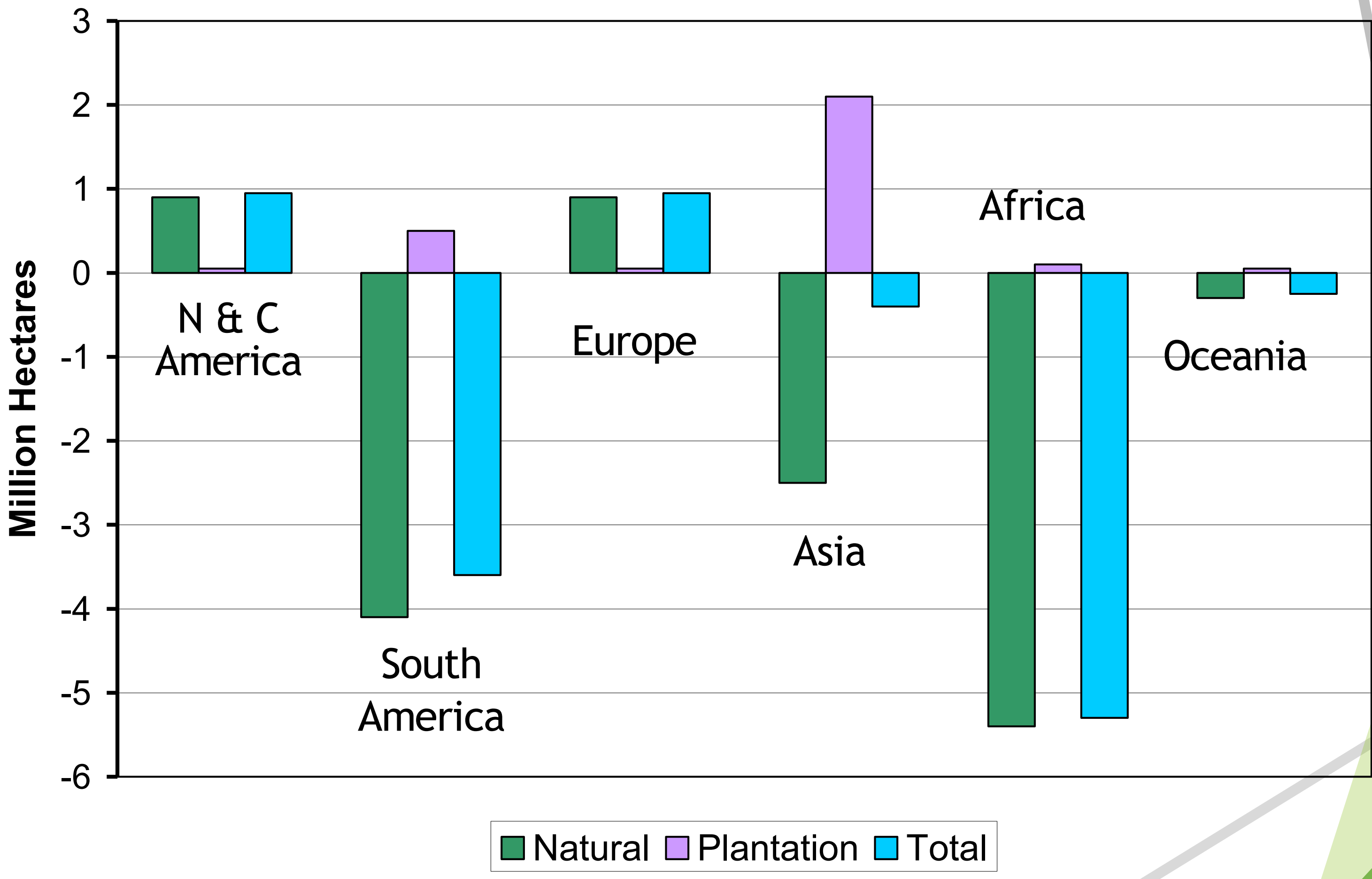
The EU’s **bioeconomy** employs over 22 million, 9% of the workforce

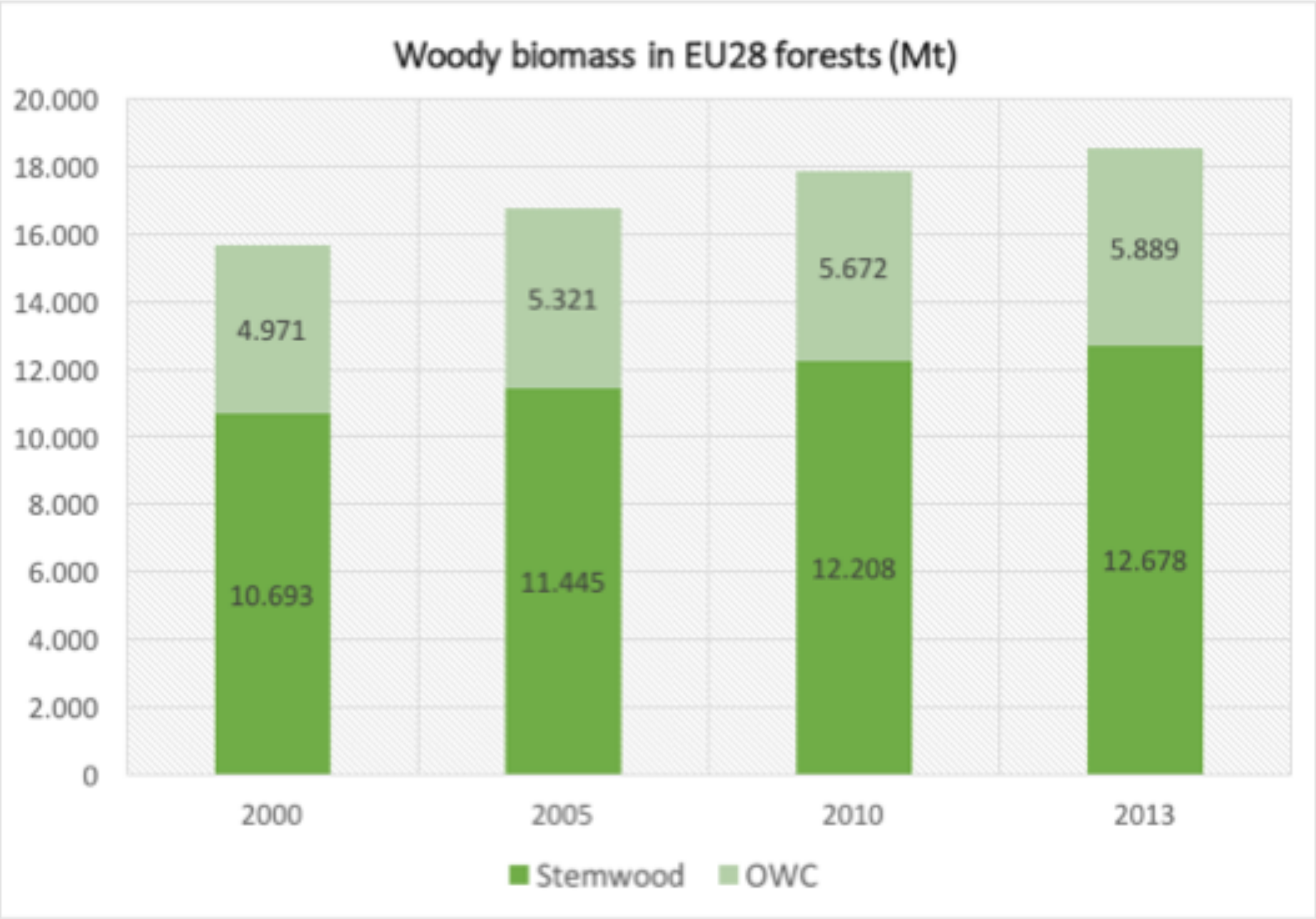
European forests: key for Europe's circular bioeconomy

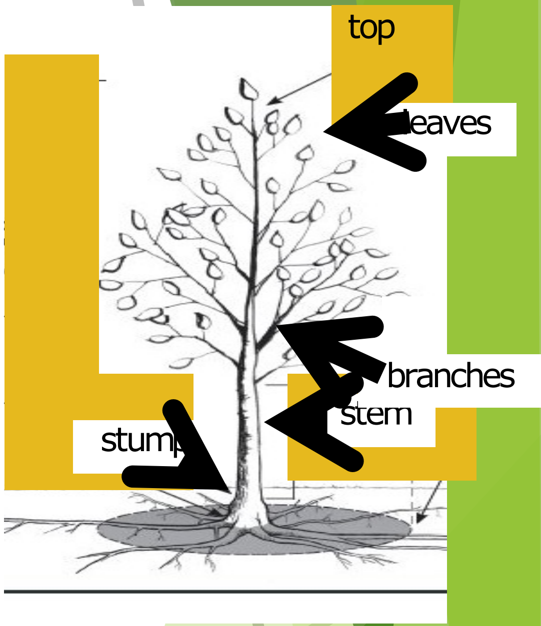


- Covering **37% of EU** land
- Capturing **13% of CO_2 emissions**
- Renewable resources for
  - **25% of EU Bioeconomy**
  - **44% of renewable energy**
- Key for the sustainability of: **biodiversity, water and soil**

Annual change in forest area, 1990-2000




Woody biomass in EU28 forests (Mt)
20.000
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0
4.971
10.693
5.321
11.445
5.672
12.208
5.889
12.678
2000
2005
2010
2013
Stemwood
OWC


top
leaves
branches
stem
stump


Forest and other wooded land
182 Mha
Forest
161 Mha
134 Mha
Forest Available for Wood Supply (FAWS)
Trees outside forest

Forest-based sectors as part of the Bioeconomy

The EU is **one of the few regions in the world where forest areas are growing**.

The potential biomass production in Europe of 1,28 billion m^3 biomass is reduced to 750 million m^3 due to environmental, technical and social constraints. ⇒ **Less than 60% of the forestry biomass production potential is exploited**.

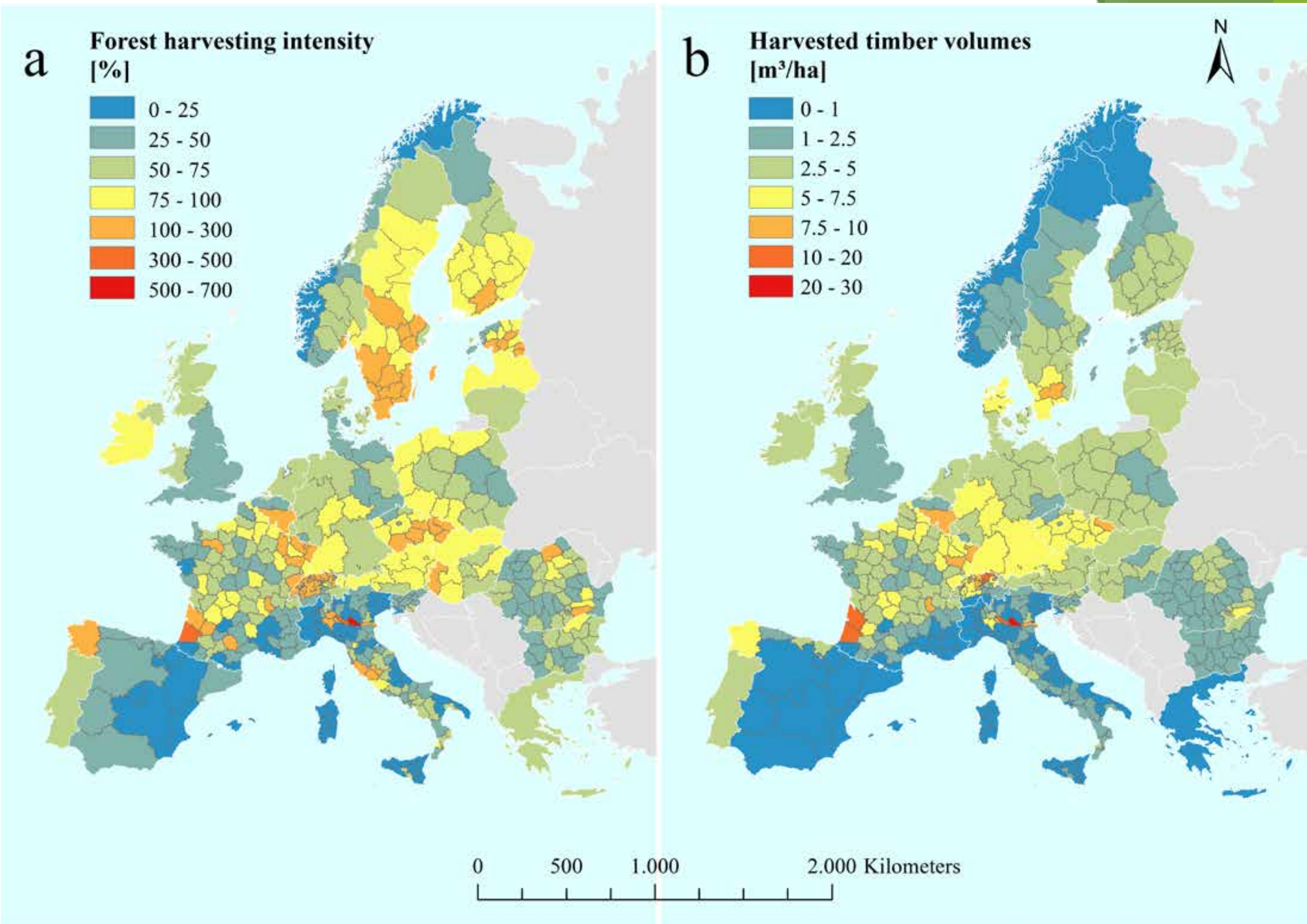
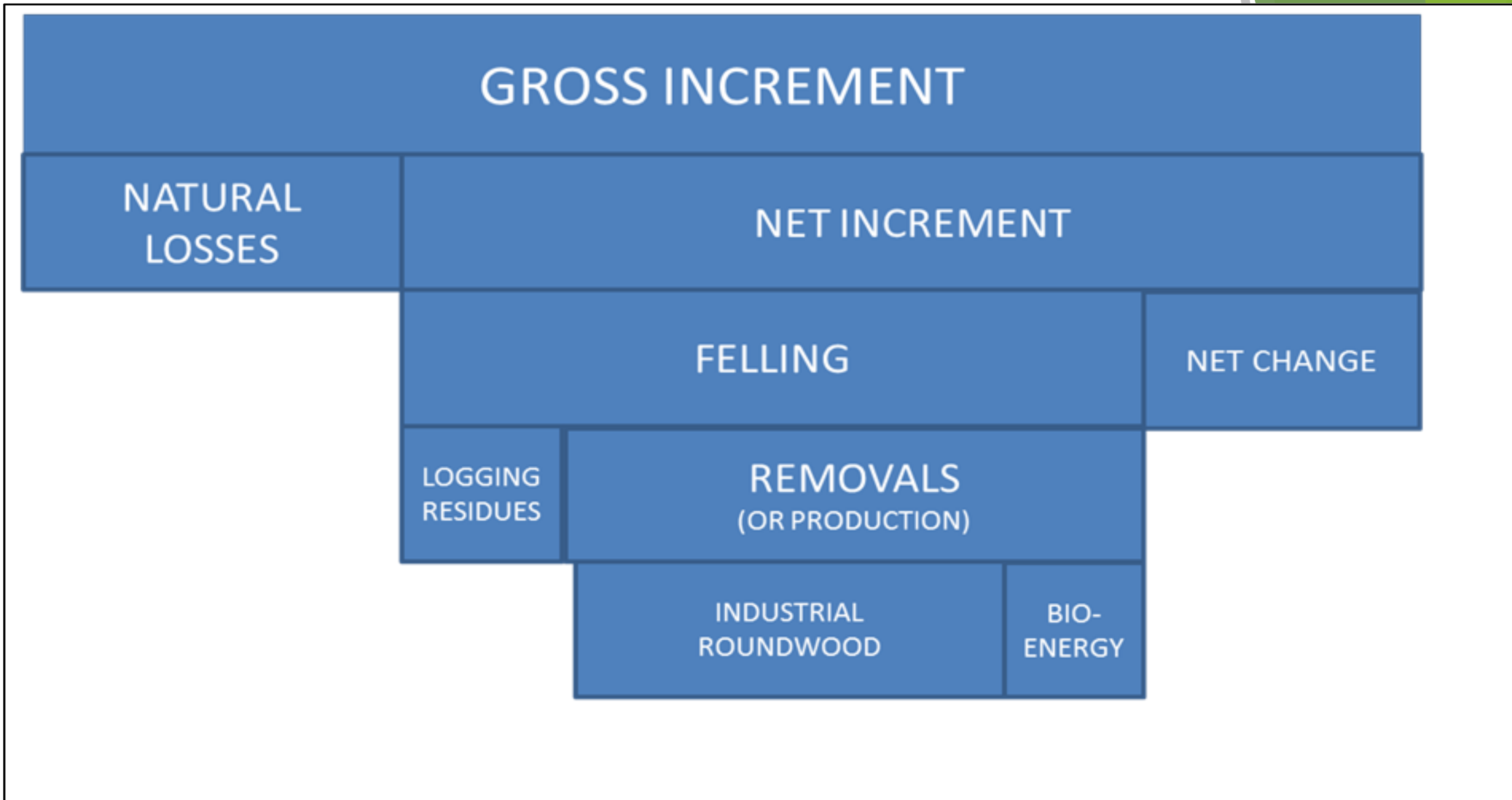
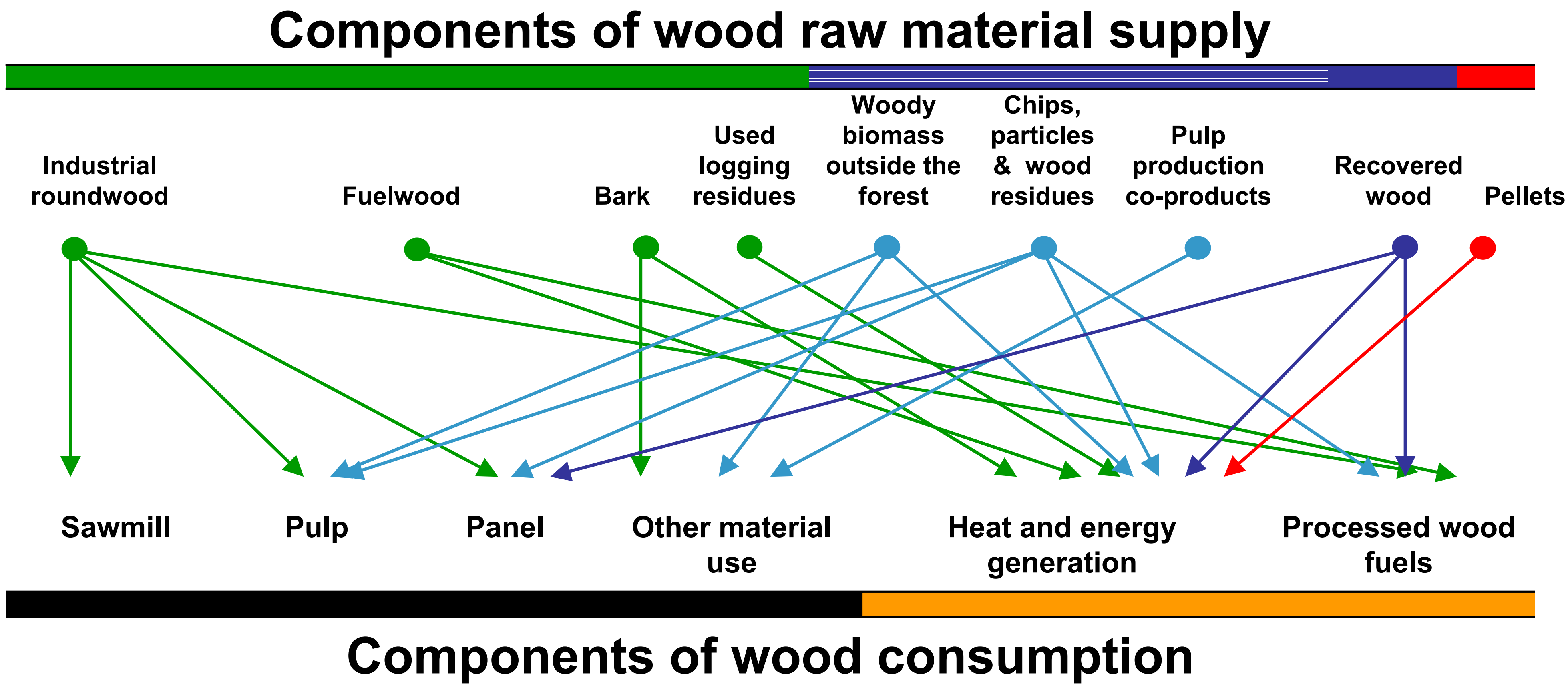


Figure 2. Average harvesting intensity (A; %) and harvested timber volumes (B; m^3/ha) for the period 2000–2010. Source: Levers et al, 2014.

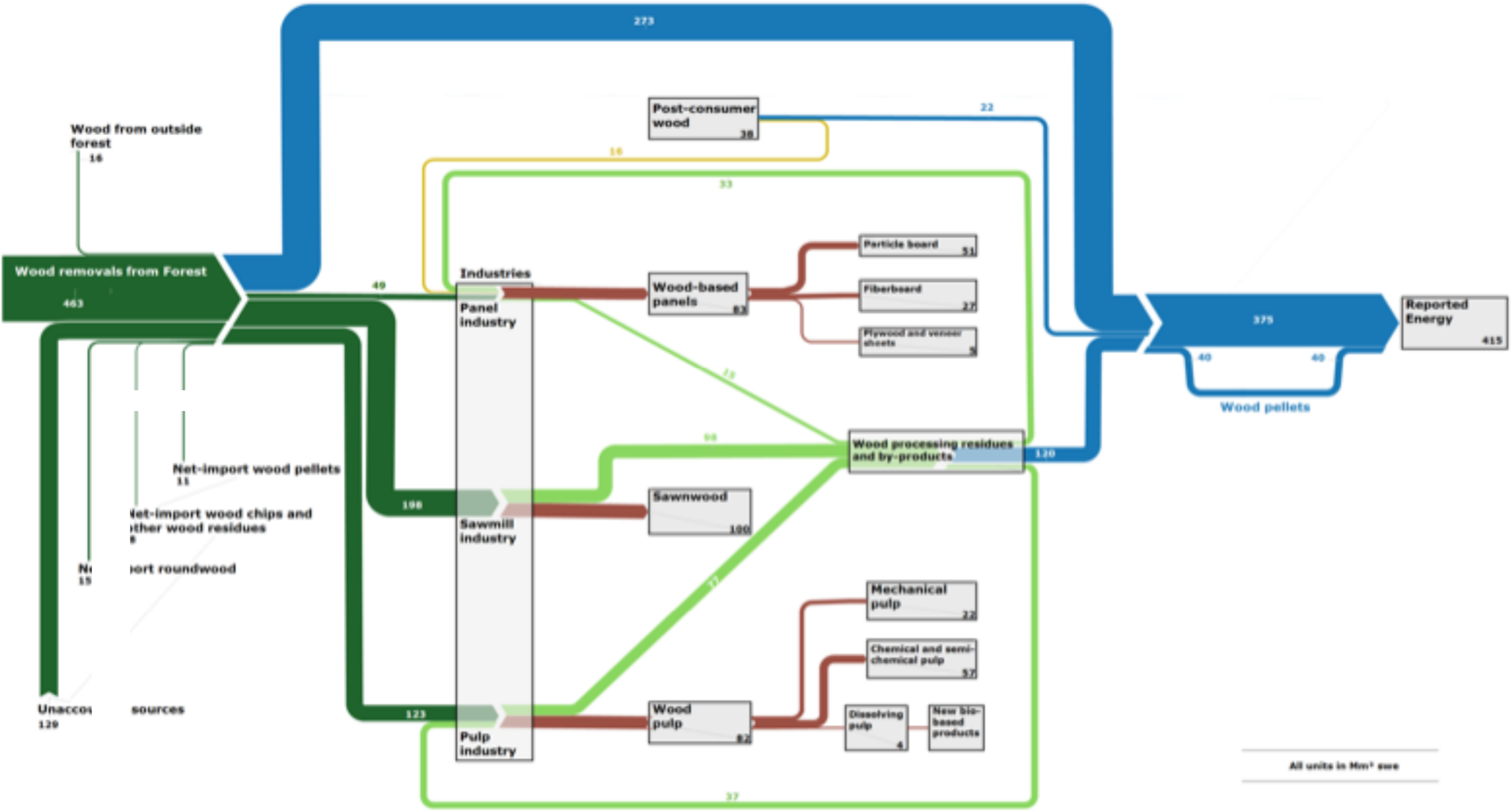


Source: State of Europe's Forests 2011

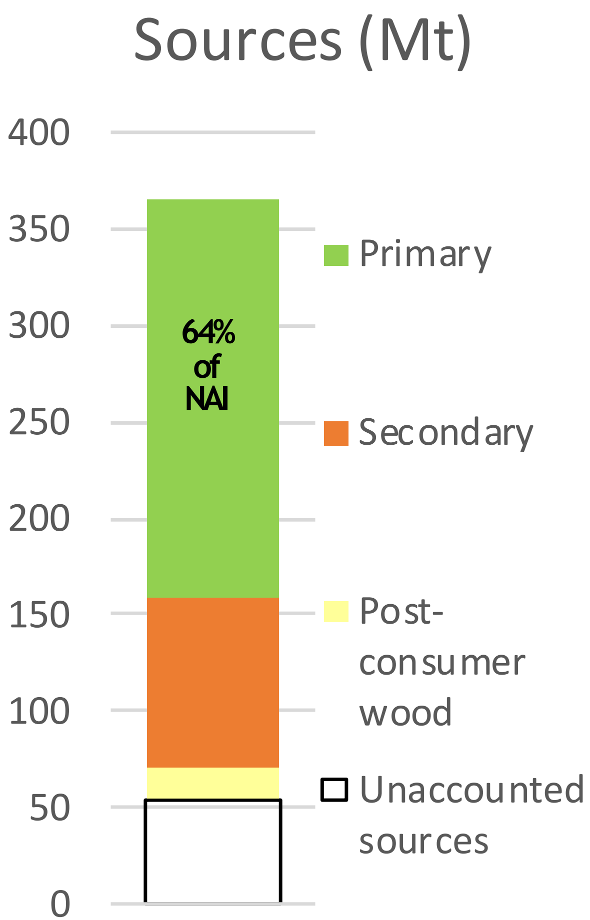
Wood sources and use



Wood resource flow charts/ EU28 (2013)



EU28 Wood Resource Balance of 2013 (in Mt/Solid Wood Equivalent)



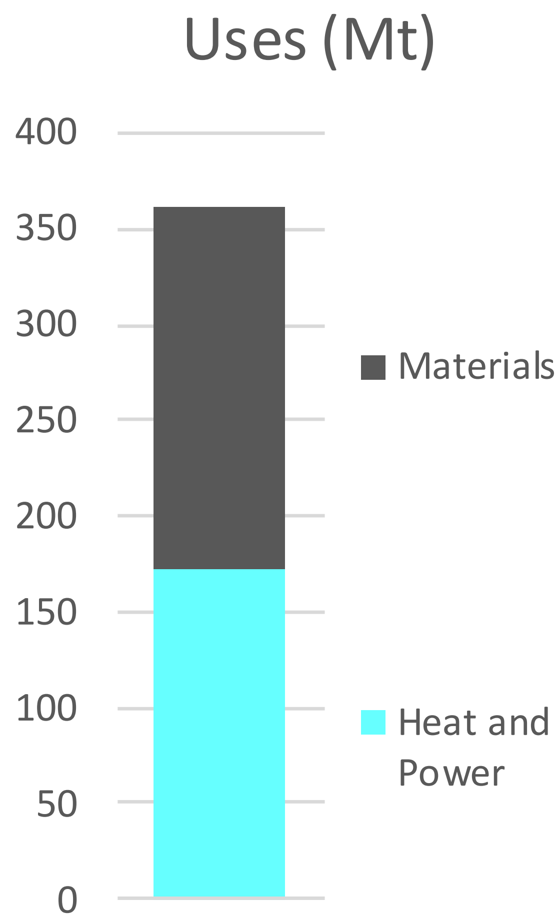
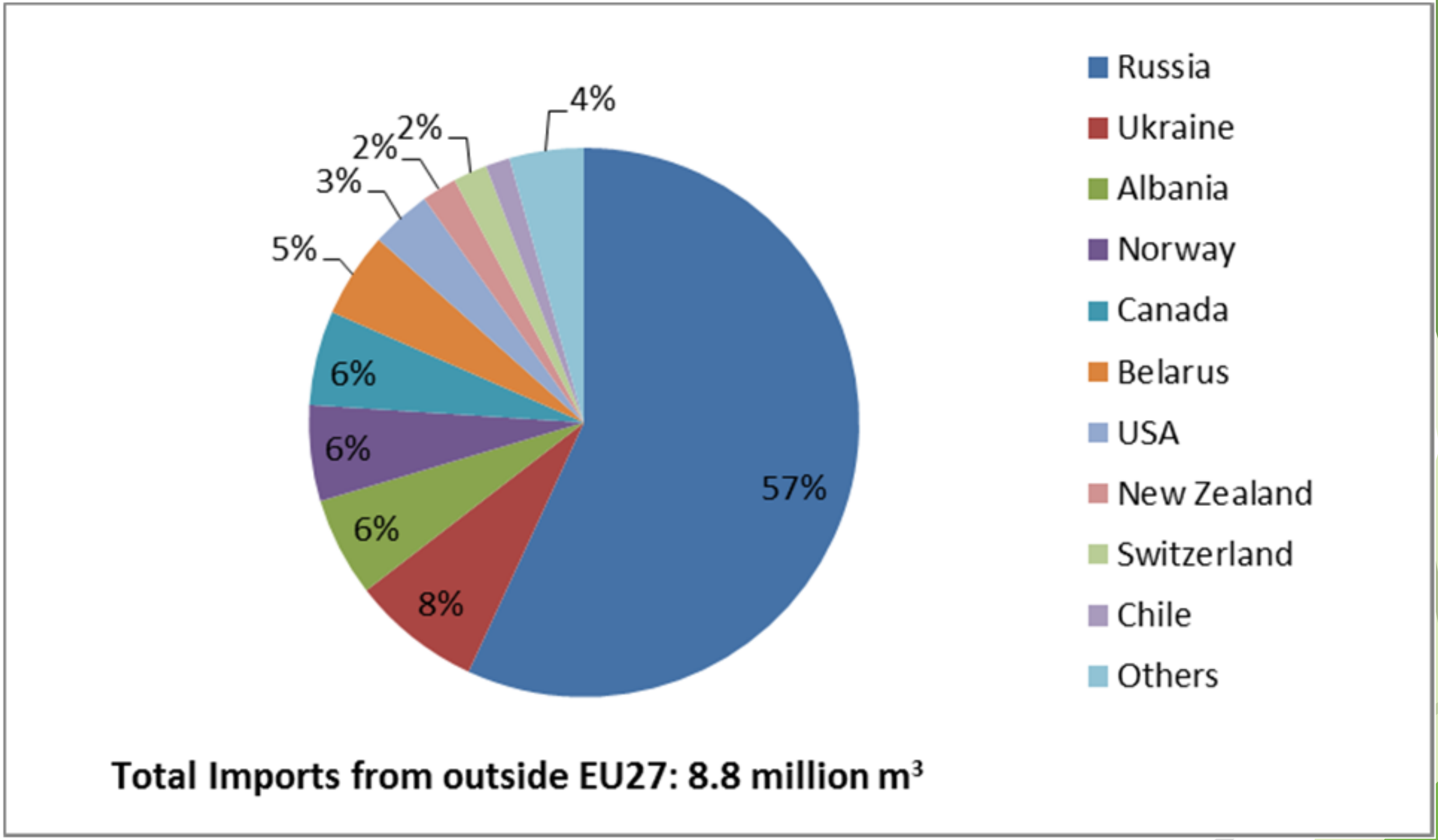
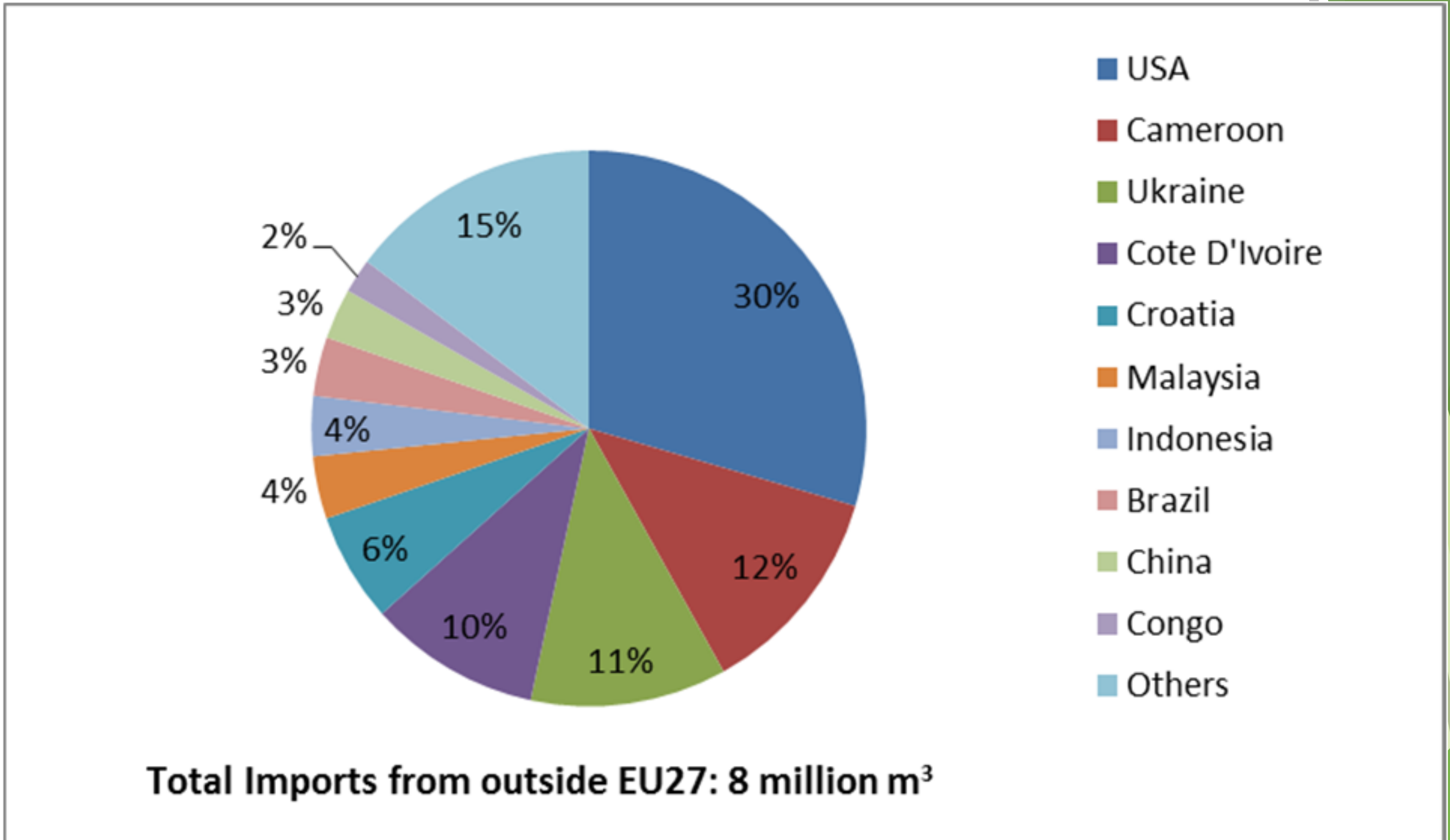


Figure 3.10 International sources of softwood sawnwood imported by the EU-27 (2011)



Source: Eurostat, External Trade database, 2012

Figure 3.11 International sources of hardwood sawnwood imported by the EU-27 (2011)



Source: Eurostat, External Trade database, 2012

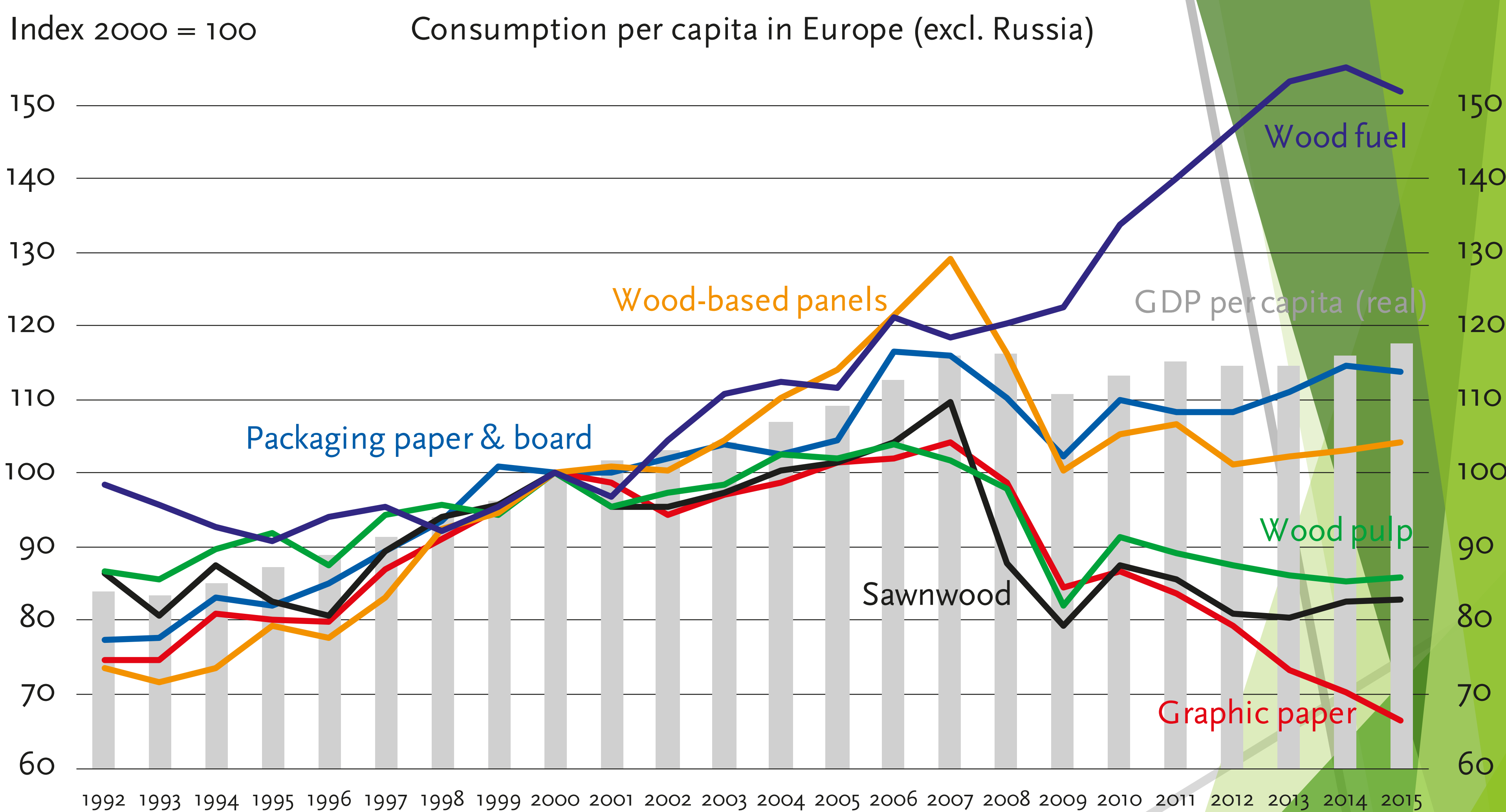
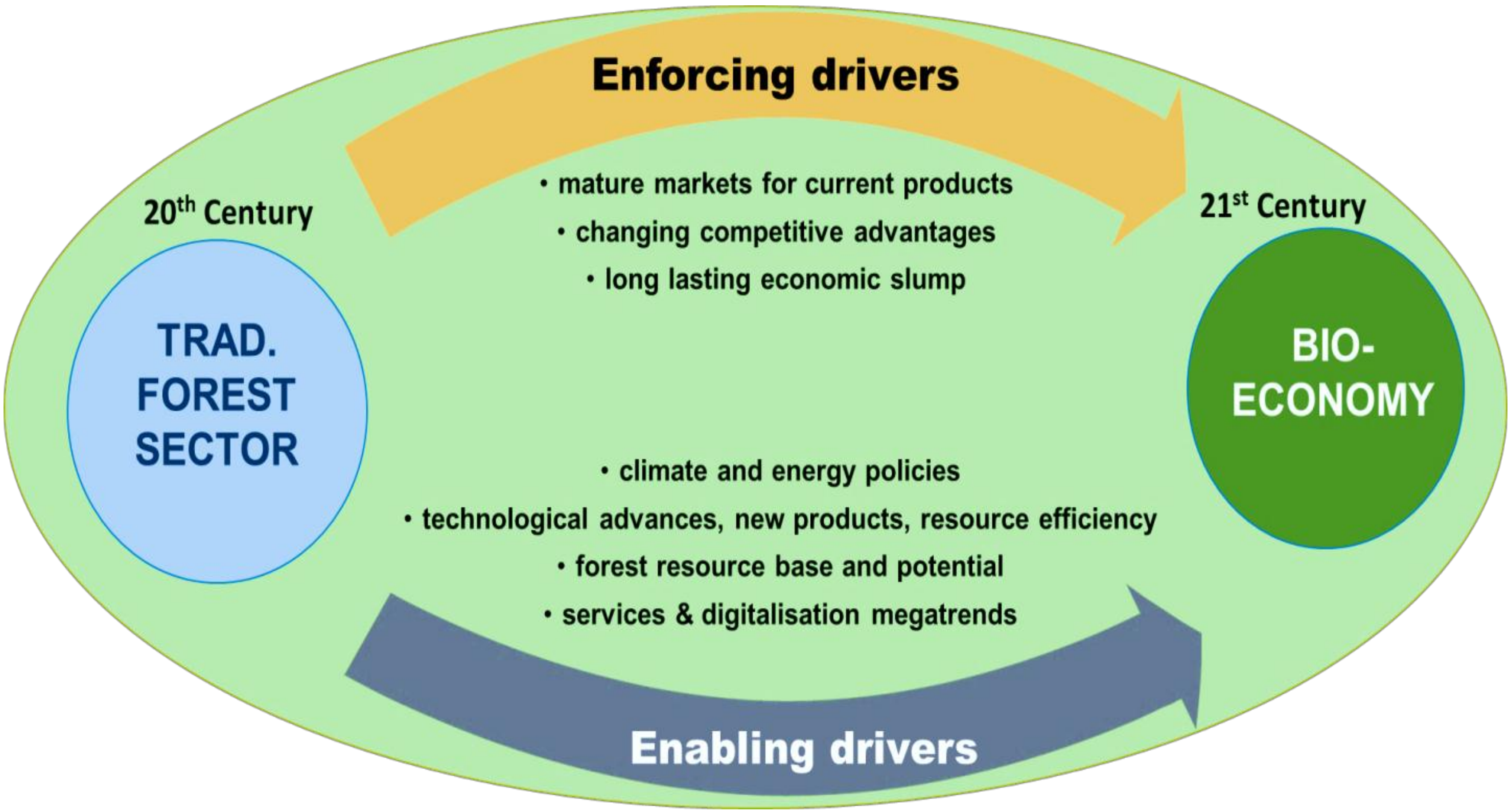


Figure 15. Consumption per capita of forest-based products and GDP growth in Europe (excluding Russia) (Data: FAOSTAT, World Bank).

Traditional European forest sector is moving to innovative bioeconomy



The Bioeconomy Strategy and Action Plan

Investments in research, innovation and skills

Reinforced policy interaction and stakeholder engagement

Enhancement of markets and competitiveness in bioeconomy sectors

EU Institutions

Member States

Stakeholders

International Organisations

Information on the Bioeconomy

- Bioeconomy Website http://ec.europa.eu/research/bioeconomy/index_en.htm

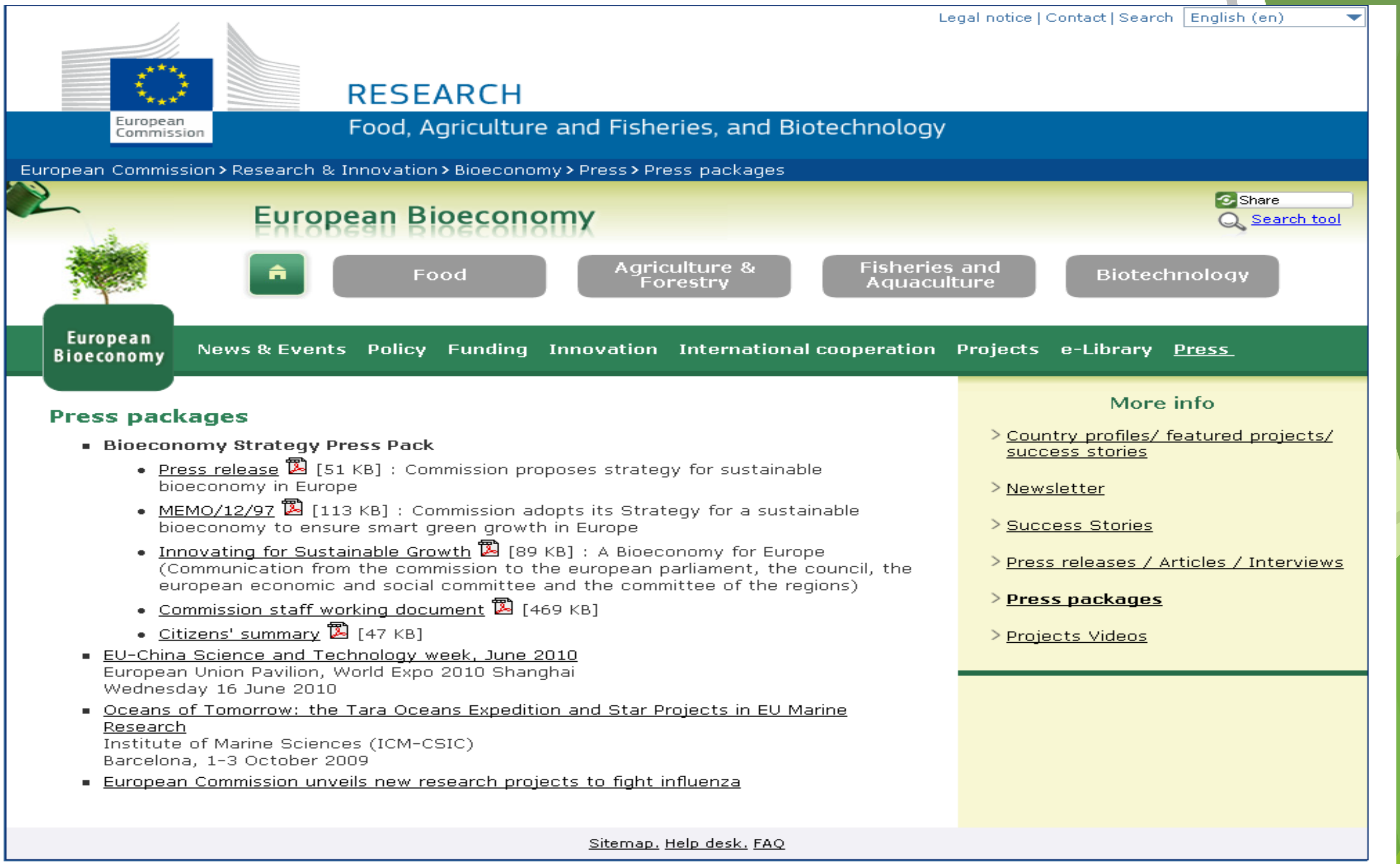


Table 1. Selected bioeconomy strategies in chronological order.

Country	Strategy	Year
OECD-countries	The Bioeconomy to 2030 – Designing a policy agenda	2009
EU	Innovating for Sustainable Growth – A Bioeconomy for Europe	2012
The Netherlands	Framework Memorandum on the Bio-Based Economy	2012
Sweden	Swedish Research and Innovation – Strategy for a Bio-Based Economy	2012
USA	National Bioeconomy Blueprint	2012
Malaysia	Bioeconomy Transformation Program – Enriching the Nation, Securing the Future	2013
South Africa	The Bio-economy Strategy	2013
Germany	National Policy Strategy on Bioeconomy	2014
Finland	Sustainable Growth from Bioeconomy – The Finnish Bioeconomy Strategy	2014
West Nordic countries*	Future Opportunities for Bioeconomy in the West Nordic Countries	2014
France	A Bioeconomy Strategy for France	2016
Italy	BIT – Bioeconomy in Italy	2016
Spain	Spanish Strategy on Bioeconomy Horizon 2030	2016
Norway	Familiar Resources – Undreamt of Possibilities	2016

* West Nordic countries comprise Greenland, Faroe Islands and Iceland. Source: Priefer et al. 2017. The strategies of Italy, Spain and Norway have been added by the authors to the table provided by Priefer.

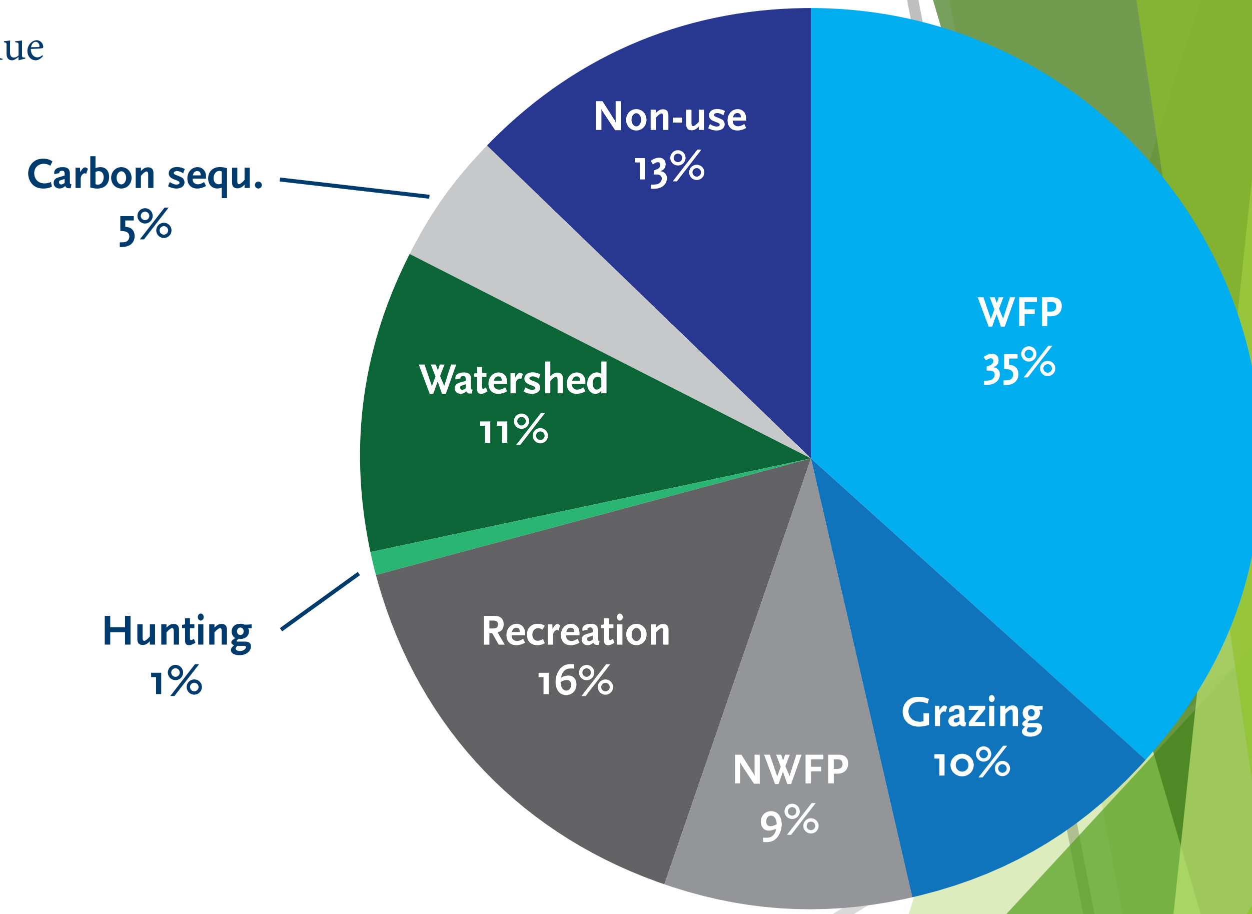
Gaps in existing bioeconomy strategies

1. Take sustainability as given (biodiversity, social sustainability, etc.)
2. Lack of connection to climate and environmental policies
3. Do not link the bioeconomy to the circular economy
4. Agricultural and food sector dominates, at the cost of failing to acknowledge the potential of the forest-based sector
5. Many of the ecosystem services forgotten
6. Policies to maximize synergies and minimize trade-offs
7. New global agreements

WHAT IS FOREST GROWN FOR?

- Carbon sink
- Maximising roundwood production
- Maximising energy production
- To maintain biodiversity
- To prevent erosion, floods, desertification
- As investments

Fig. 9. Composition of the total economic value of Mediterranean forests
NWFP: non-wood forest products
WFP: wood forest products;
Non-use: bequest and existence value



Source: Merlo and Croitoru (2005)

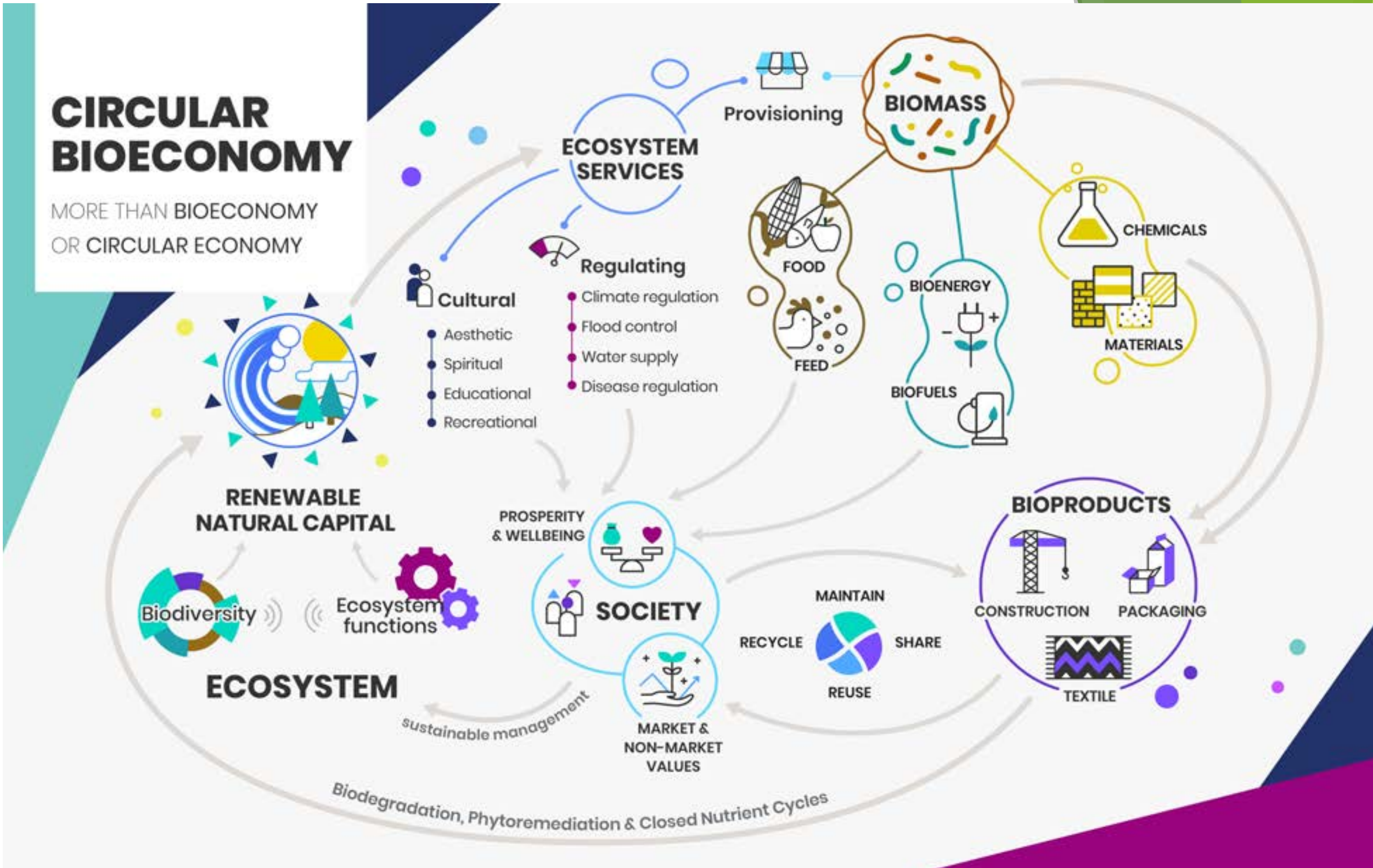


Figure 1. Illustration of circular bioeconomy flows, based on Hetemaki *et al.* 2017

Example: forest bioenergy

- Bioenergy largest renewable energy source in EU: 44% of renewable energy production in 2014

- Forest bioenergy integral part of forest management, forestry, forest-based products & energy-industry system > *not helpful to look at it as a separate entity*

- Bioenergy contributes significantly to energy supply in most scenarios that meet ambitious climate targets*

**Berndes et al. 2016*. Forest biomass, carbon neutrality and climate change mitigation. *From Science to Policy 3, European Forest Institute, 2016*

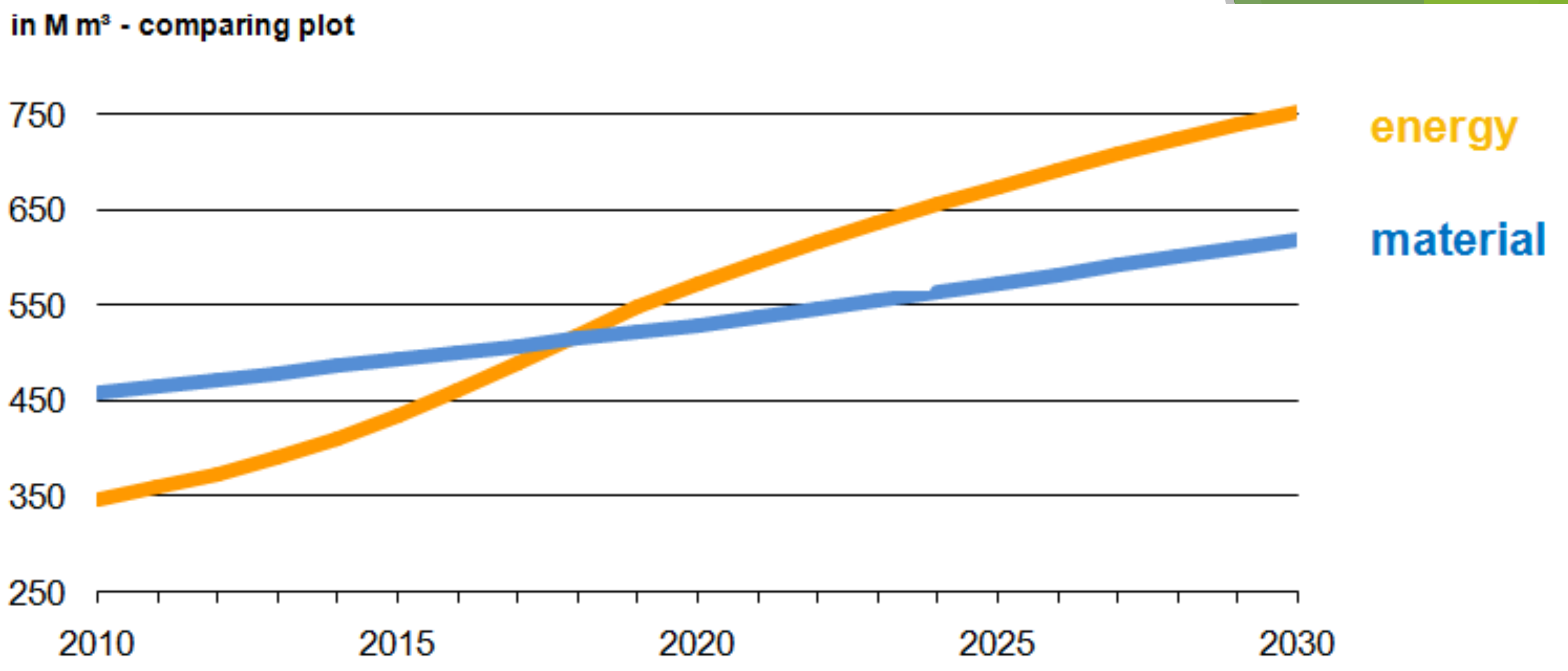
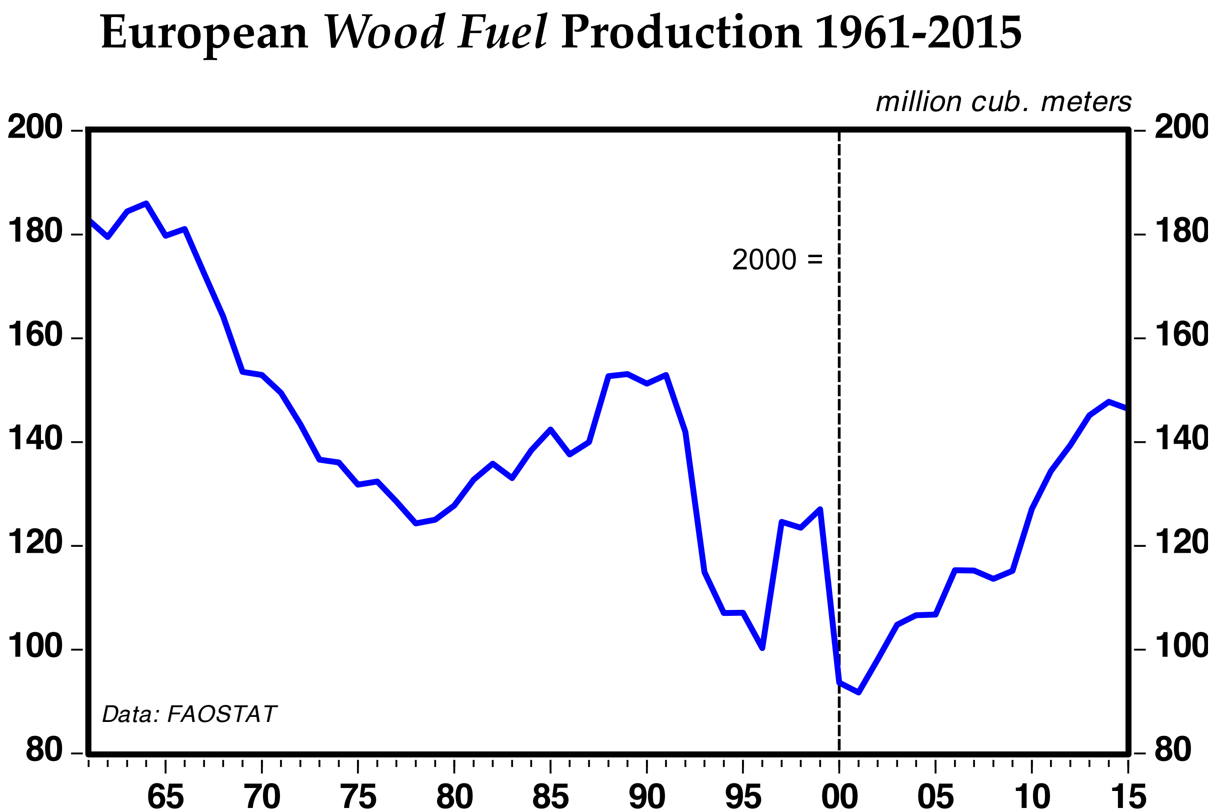


Figure 1-6: Development of material and energy uses of wood (A1)

Source: EUwood 2010

European energy wood production again increasing



50% of *wood fuel* comes from *wood residues*, and most of the rest form *logging residues, thinnings and coppice*

Growing wood residues consumption implies increasing resource-efficiency and cascading use

Wood fuels *is the concept used by FAO and is basically energy wood. It is defined as all types of biofuels originating from woody biomass, e.g., firewood, log wood, wood chips, wood pellets, wood briquettes (FAO def.). These come from forests, plantations (coppice), urban forests, by-products (chips, bark, etc.), post-consumer wood.*

Sources of biomass products

Traditional

In Future?

Split logs (fire wood)

Wood-pellets

Miscanthus

Wood-chips

Straw Grains

Wood-Plantation

Physical States of Biomass products

Solid Biomass

wood, forest residues, wood pellets

⇩

Heat and electricity

liquid

rape, sunflower

⇩

Mobility

gaseous

Energy crops, slurry organic waste

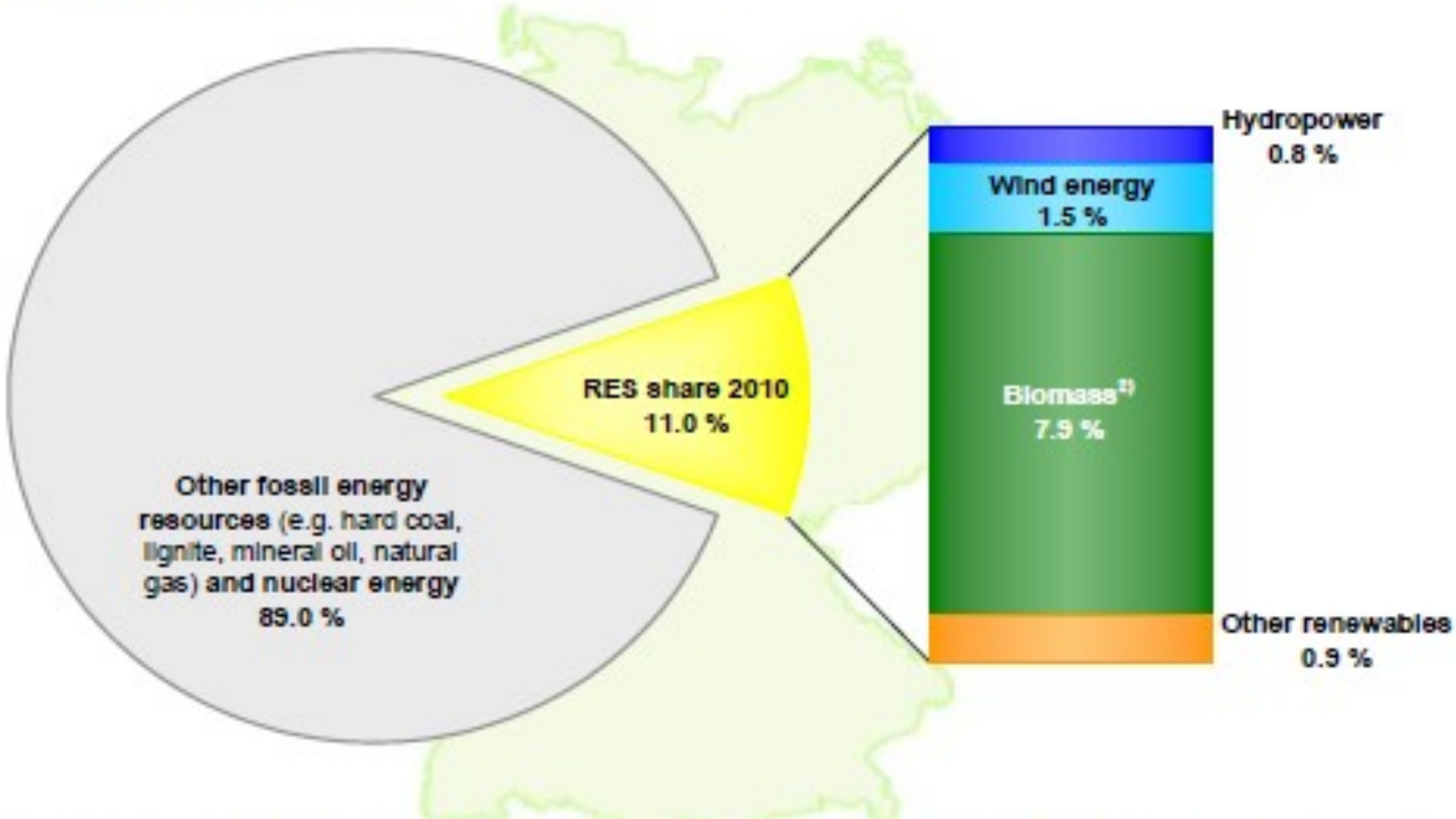
⇩

Electricity and heat

Example:
second generation forest-based diesel

- UPM 's biorefinery: 100,000 tonnes of 2nd generation biodiesel for transport from tall oil *(sidestream of pulping)*
- Decreasing transport emissions up to 80% compare to fossil fuels
- Finland's new biofuel target: 30% biofuels by 2030 of

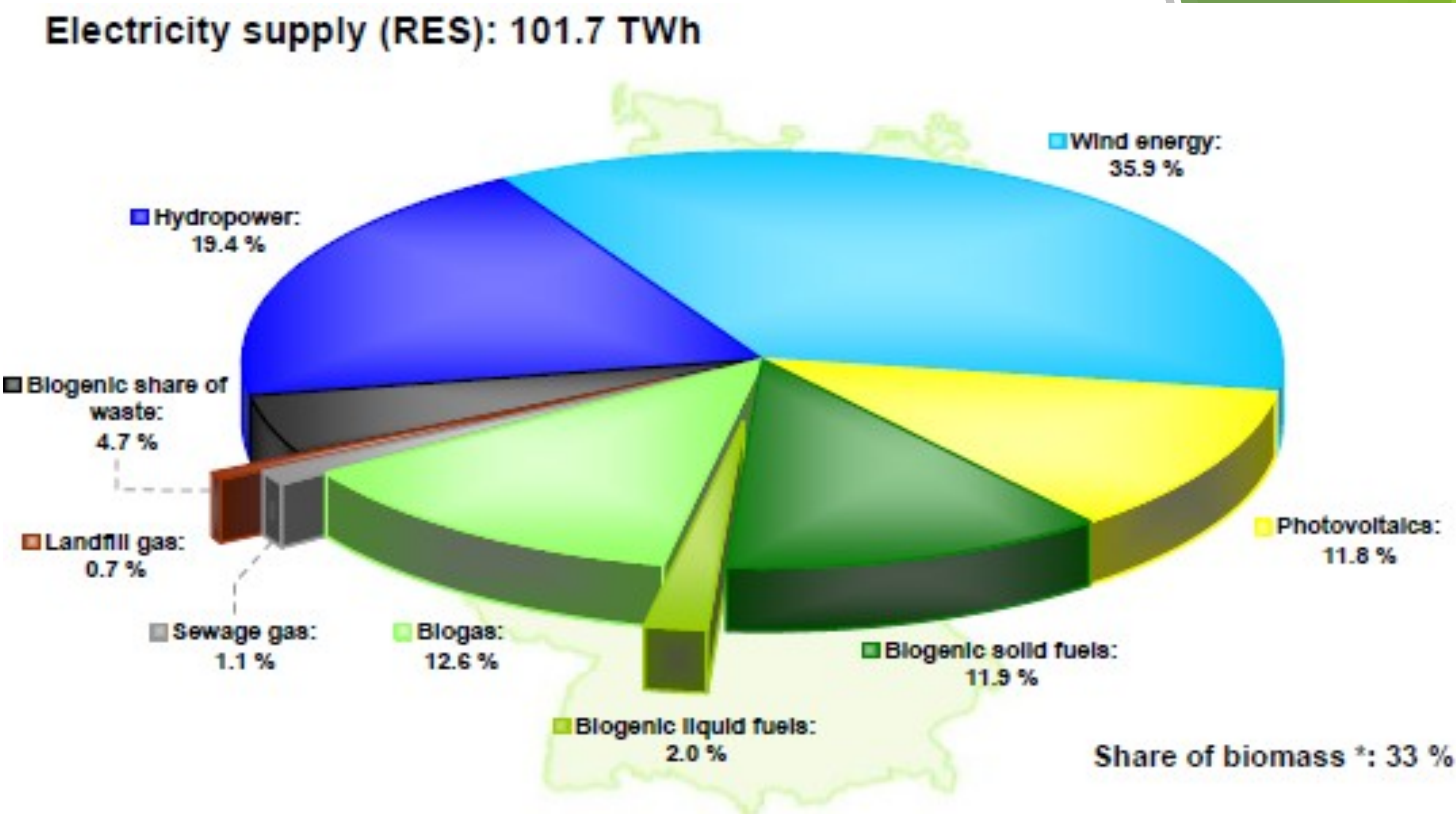
Final energy (RES): 8,984 PJ[1)]



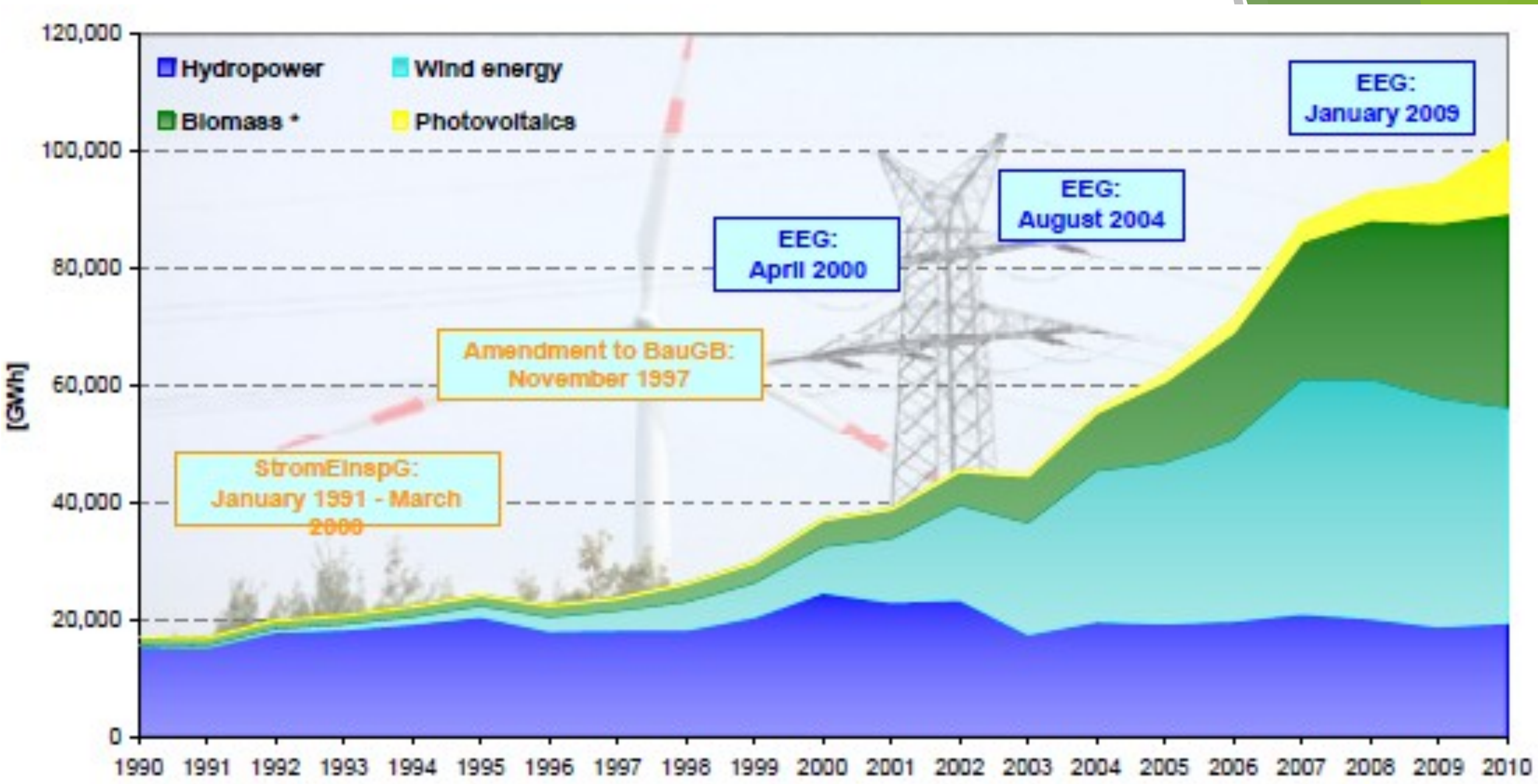
1) Energy Environment Forecast Analysis (EEFA) GmbH & Co KG; 2) Solid and liquid biomass, biogas, sewage and landfill gas, biogenic share of waste, biogenic fuels;
Source: BMU-KI III 1 based on Working Group on Renewable Energy Sources-Statistics (AGEE-Stat) and the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), according to Working Group on Energy Balances e.V. (AGEB); RES: Renewable Energy Sources; deviations in the totals are due to rounding; 1 PJ = 10^{15} Joule; as at: March 2011; all figures provisional

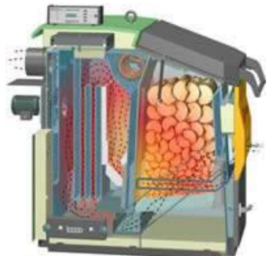
Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Contribution of renewable energy sources to electricity generation in Germany



Contribution of renewable energy sources to electricity generation in Germany

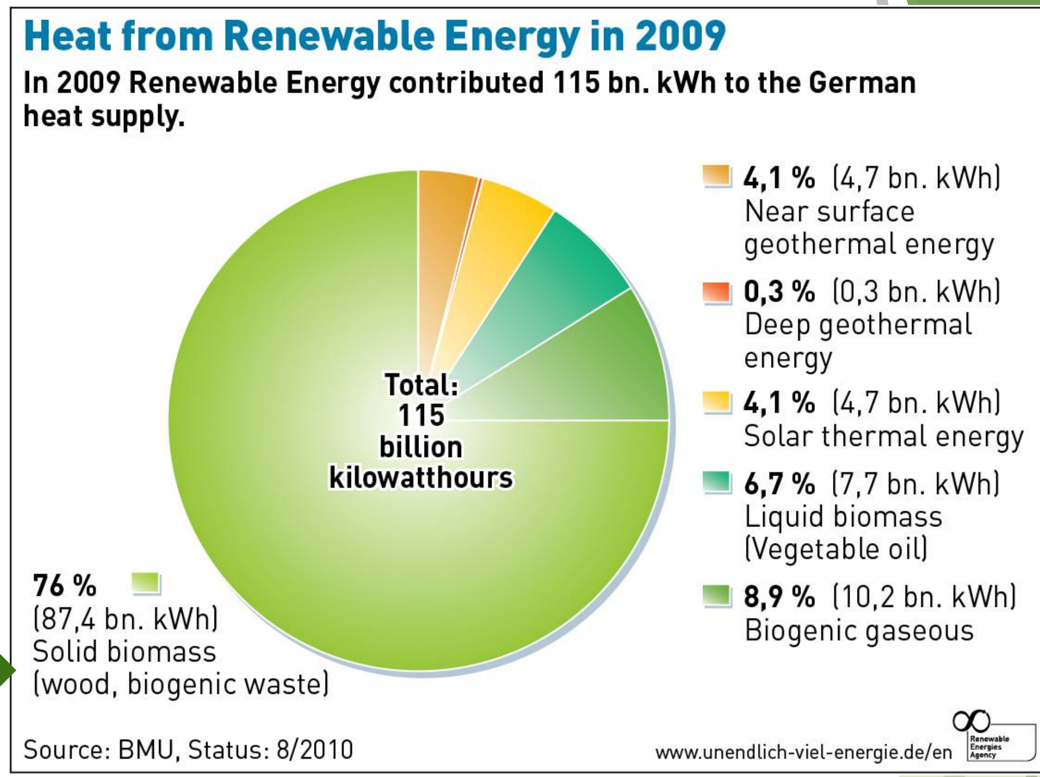




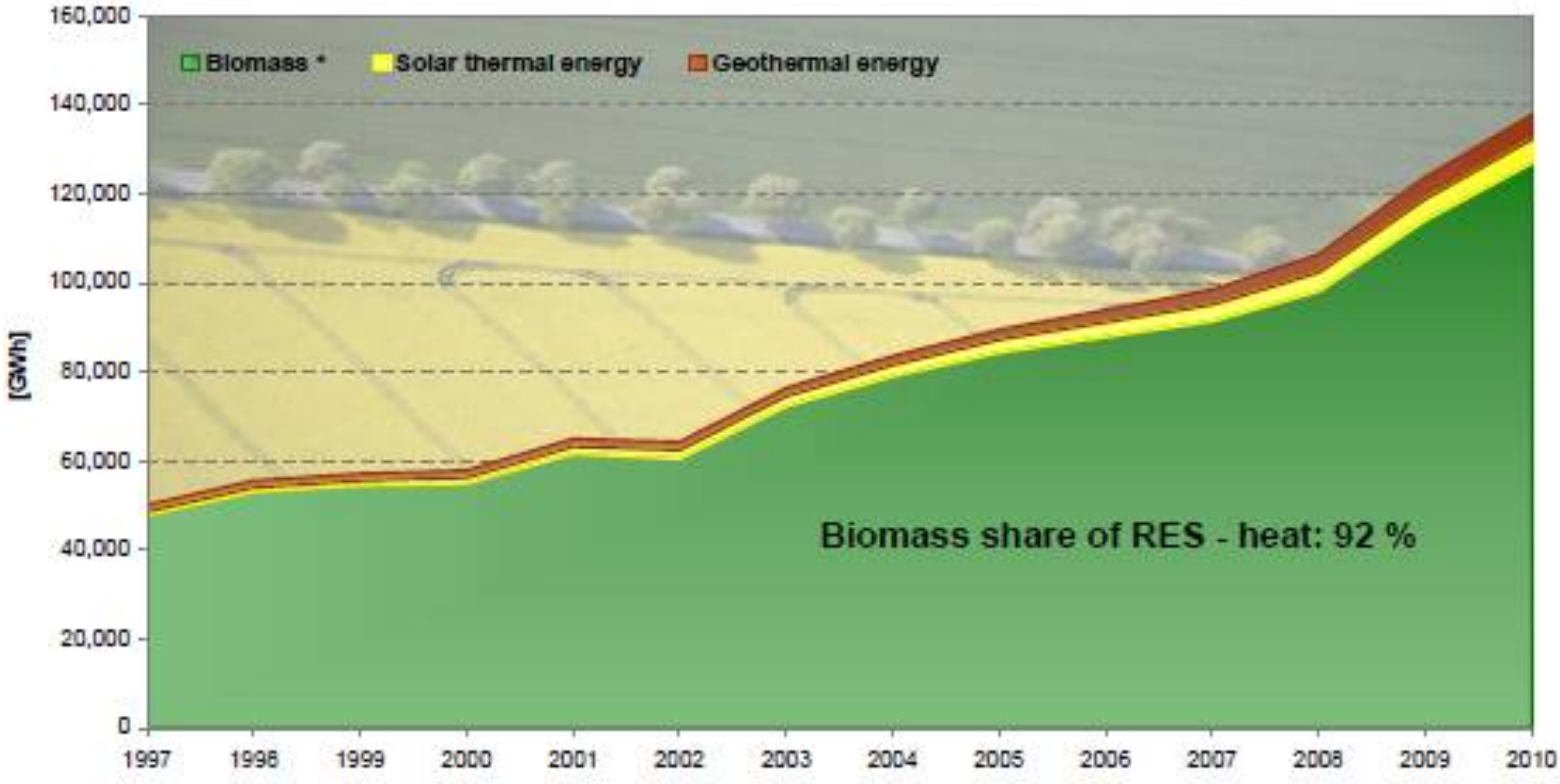
Source: HDG Bavaria

58 bn. kWh from split logs (fire wood) in private households (= 2/3 of solid biomass)

= 20 Mio. tons/a !



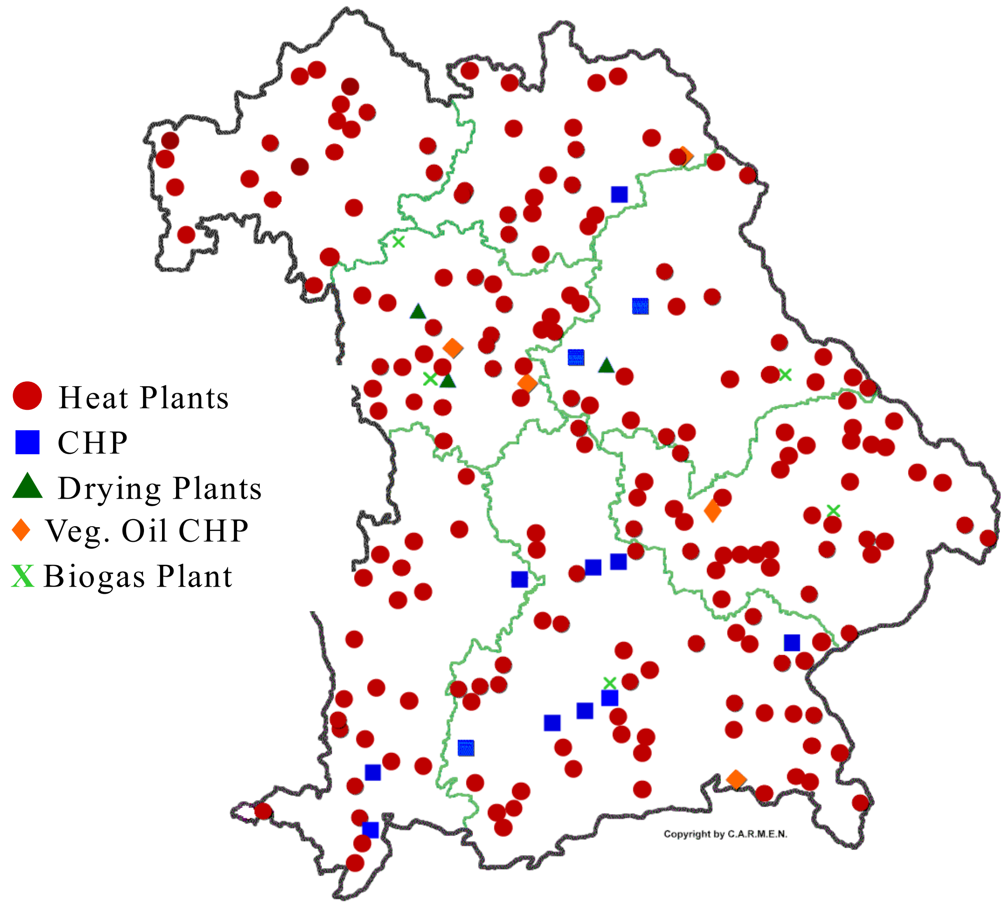
Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety



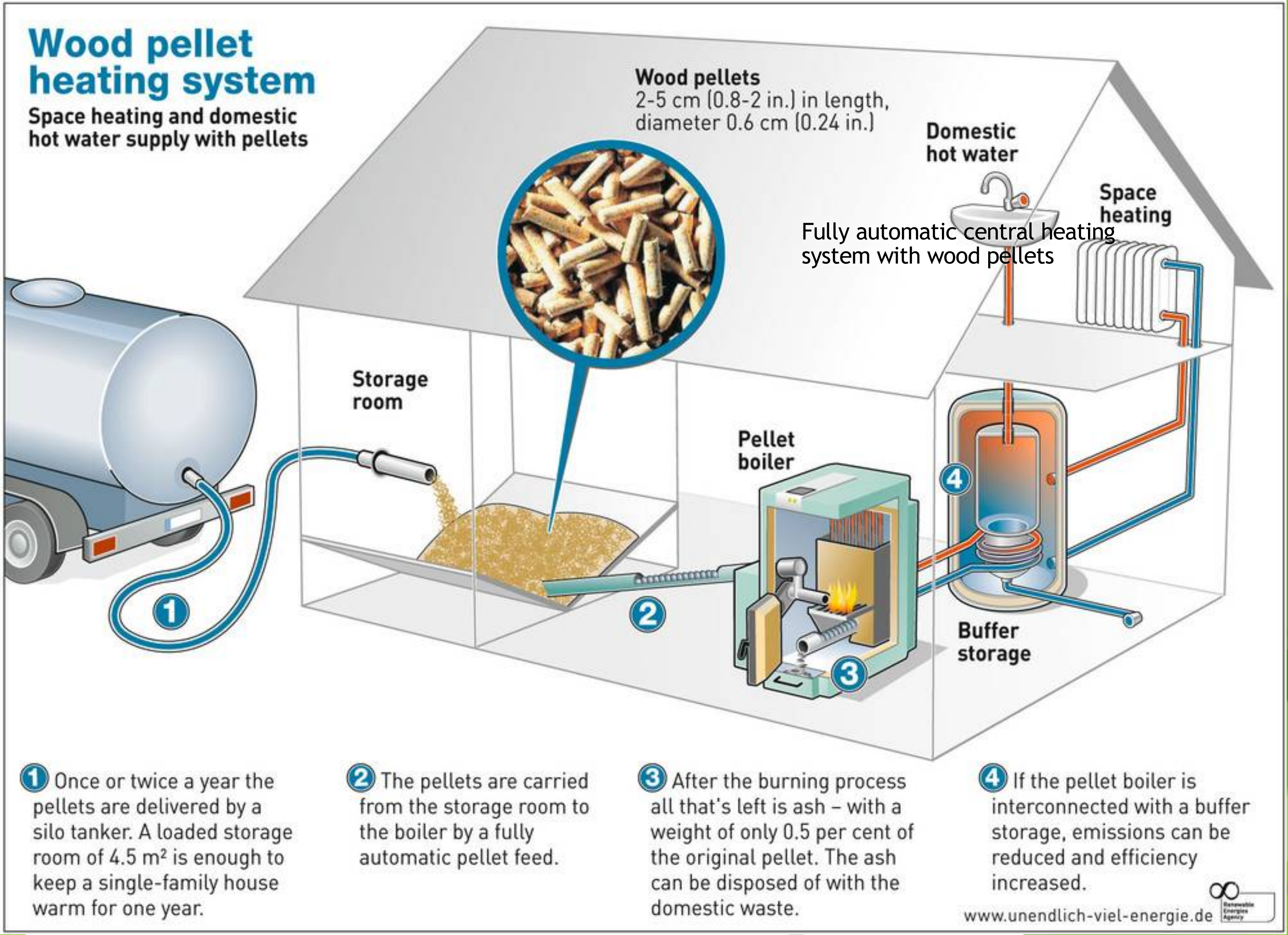
Biomass *
Solar thermal energy
Geothermal energy
[GWh]
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Biomass share of RES - heat: 92 %

Sponsored BioEnergy-Projects

- Approx. 350 heat plants
  500 $kW_{th.}$ to 13 $MW_{th.}$
- 13 wood-Combined Heat and Power Plants
  40 $kW_{el.}$ to 10 $MW_{el.}$
- 6 vegetable oil - CHPs
  5 $kW_{el.}$ to 200 $kW_{el.}$
- 6 Biogas - CHPs
  15 $kW_{el.}$ to 250 $kW_{el.}$
- 3 drying plants for animal food



Fully automatic central heating system with wood pellets

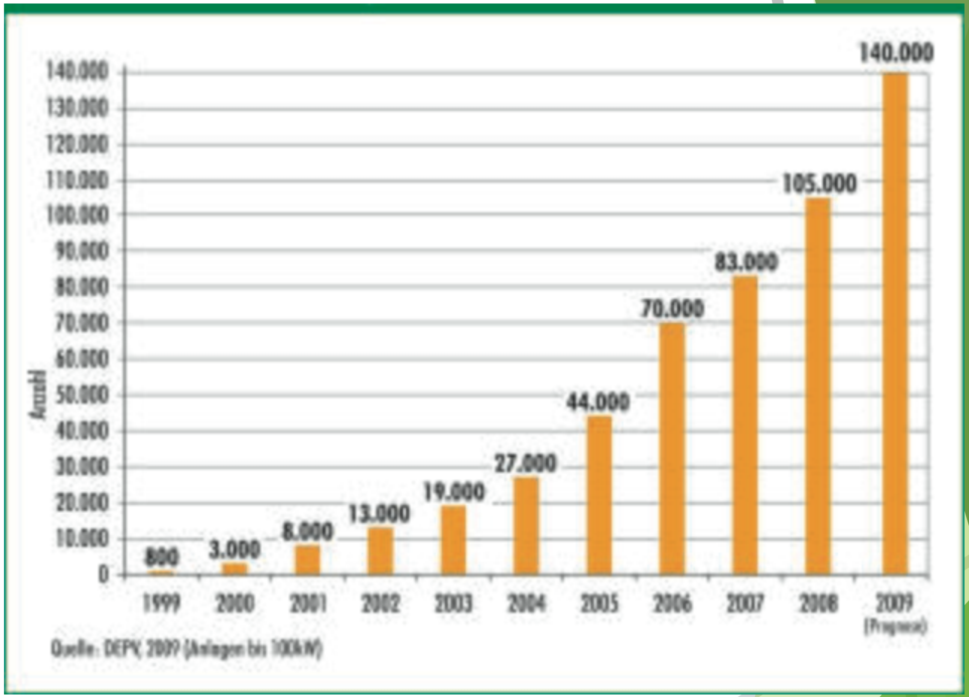


Wood Pellets; Number of installed Pellet Boilers < 100kW

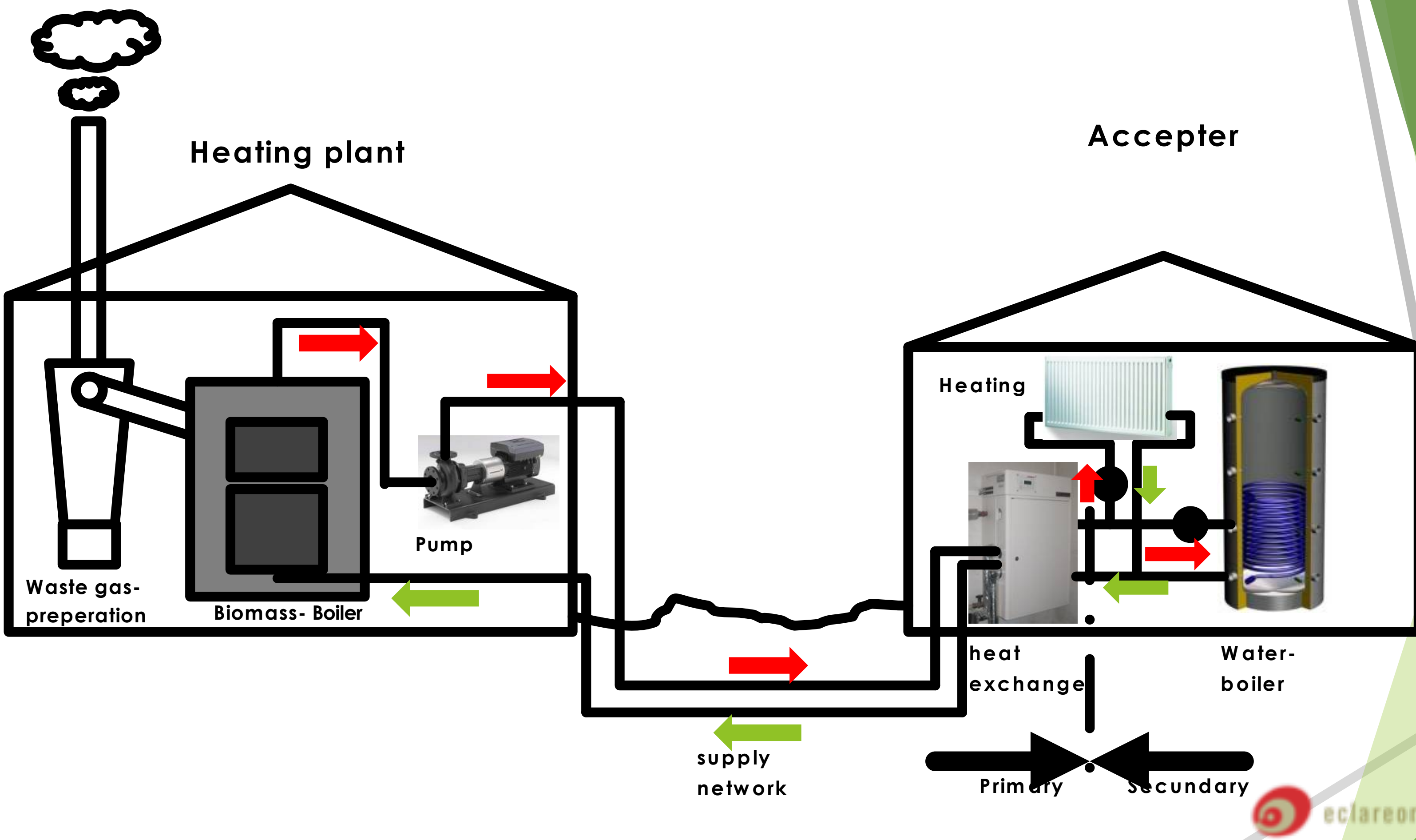
Wood Pellets

- **Characteristics :**

  Diameter : 6 or 8 mm
  Length : 10 to 40 mm
  Cal. value : 5 kWh / kg
  Density : 650 kg/m^3
  Ash content :< 0,5 %

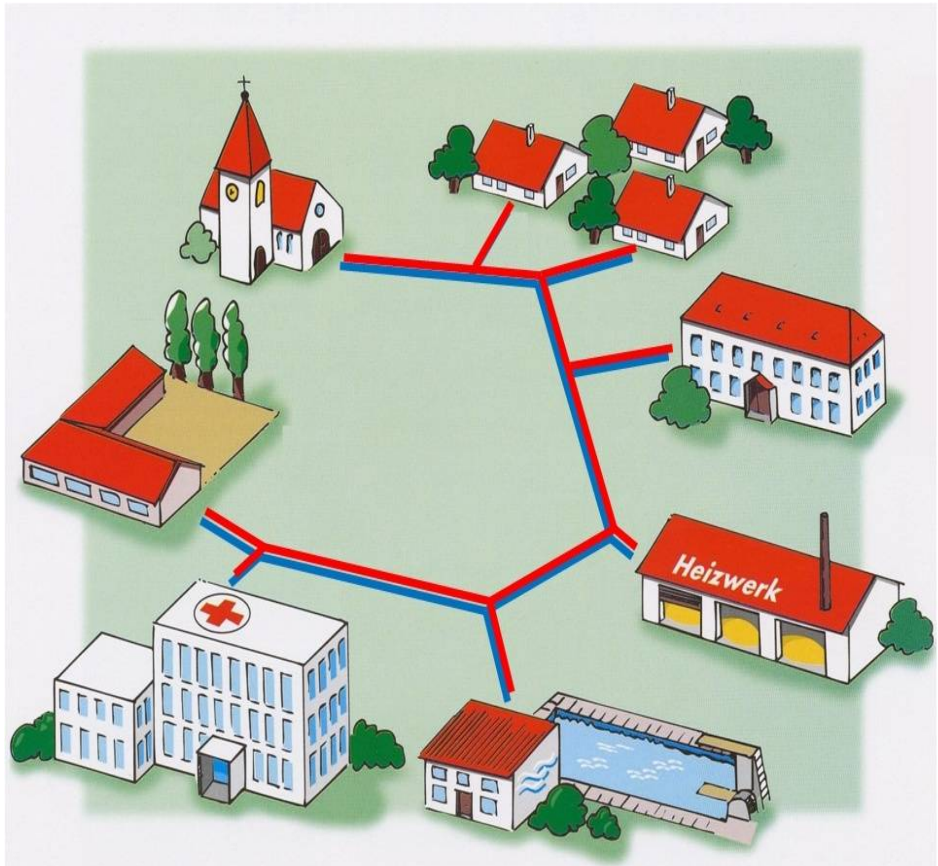


Biomass Heat Plant



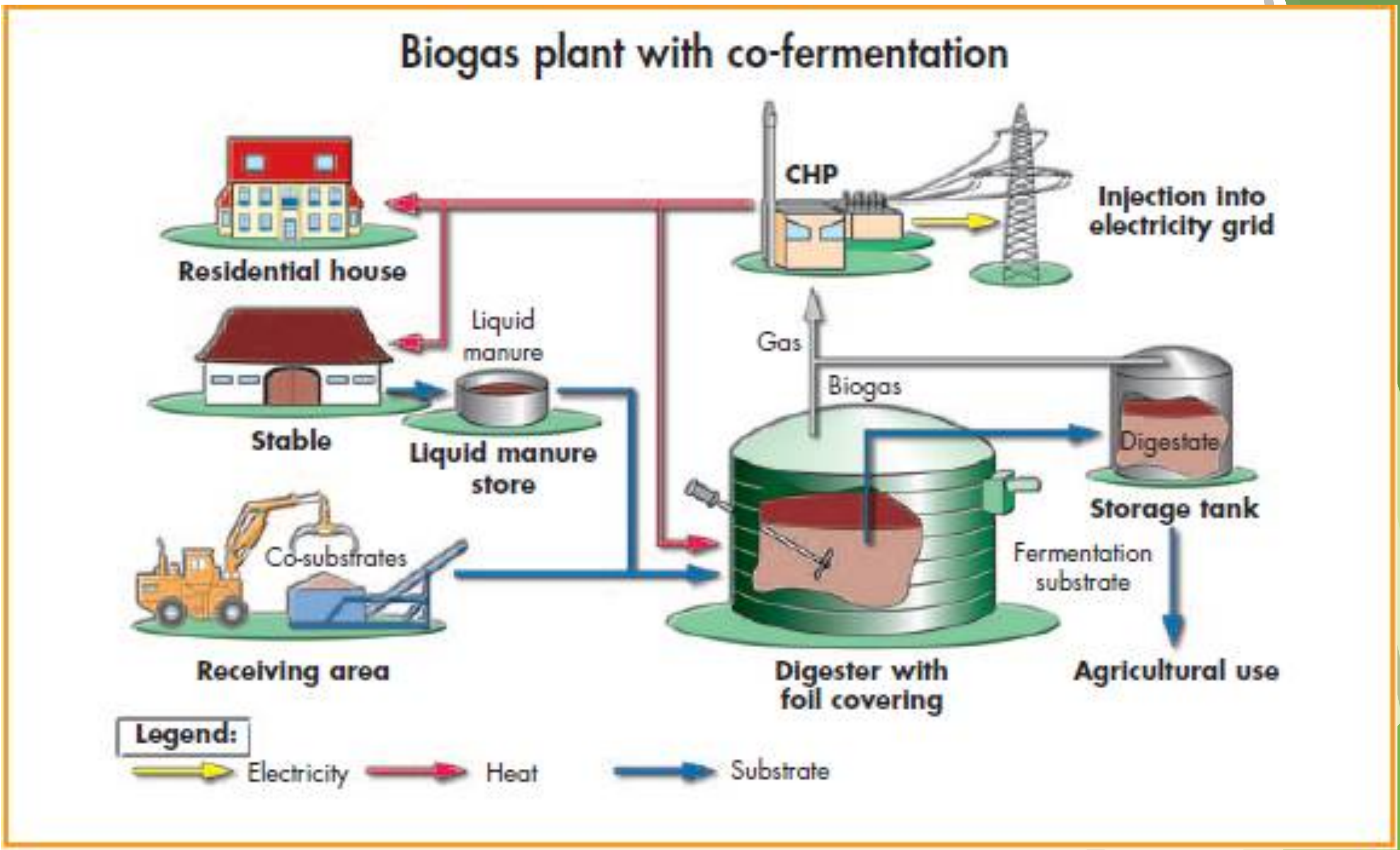
Biomass Heat Plant

Different heat sinks with different annual curve and peak load



Biomass plant with wood chip bunker

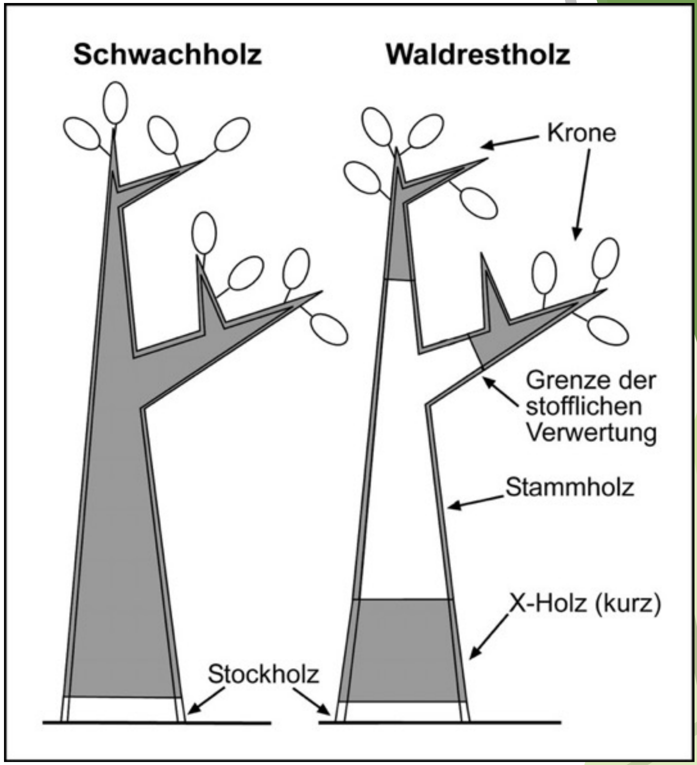
Biogas Plant



Source: Biogas - an Introduction; FNR

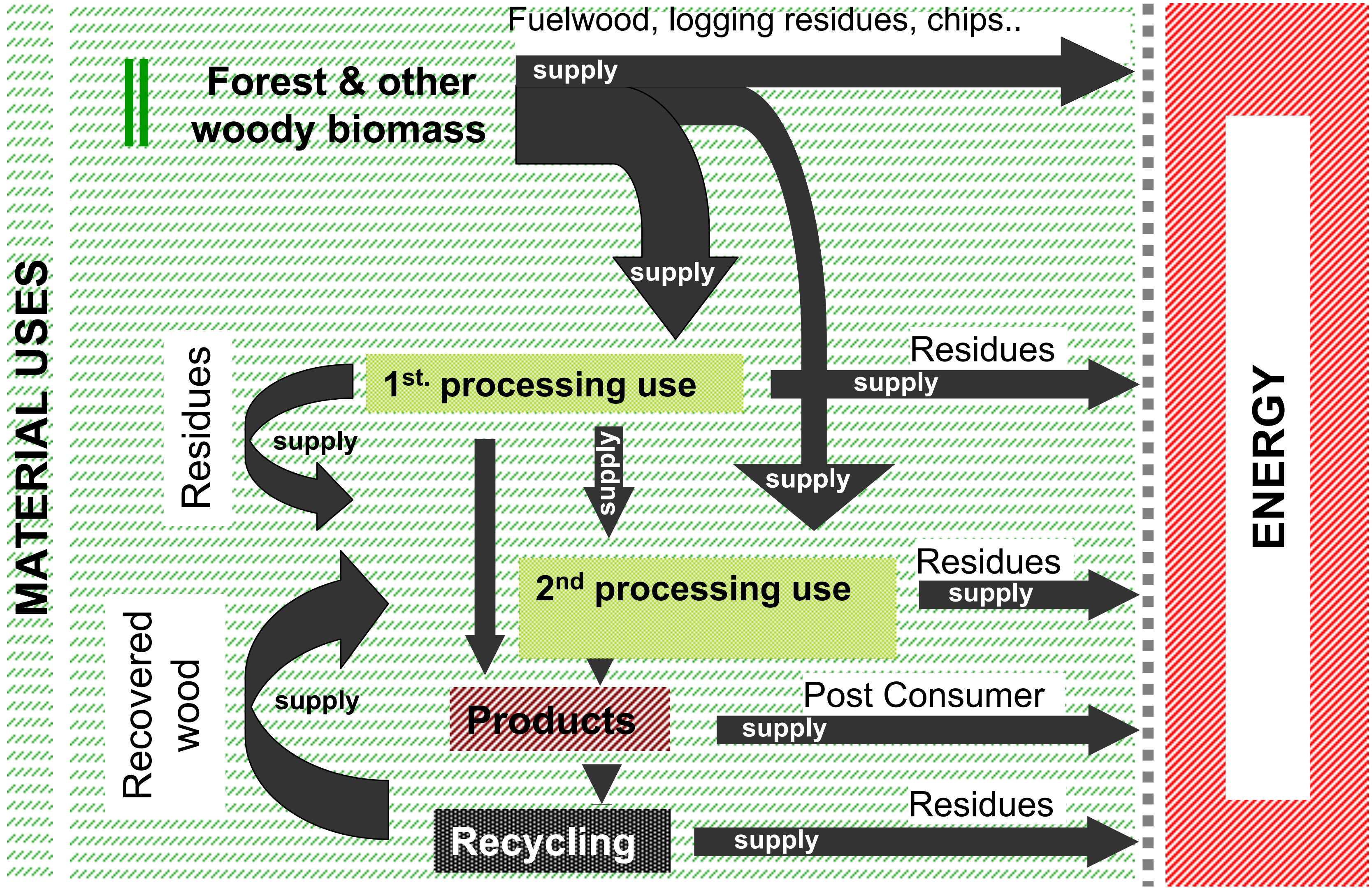
- From forestry residues in the Forest
  - Smaller entire trees or
  - Smaller parts (treetops) of larger trees

Source: www.haeckselzug.de



Source: IPF, Univ. of Karlsruhe TH

Multiple use of wood fibers



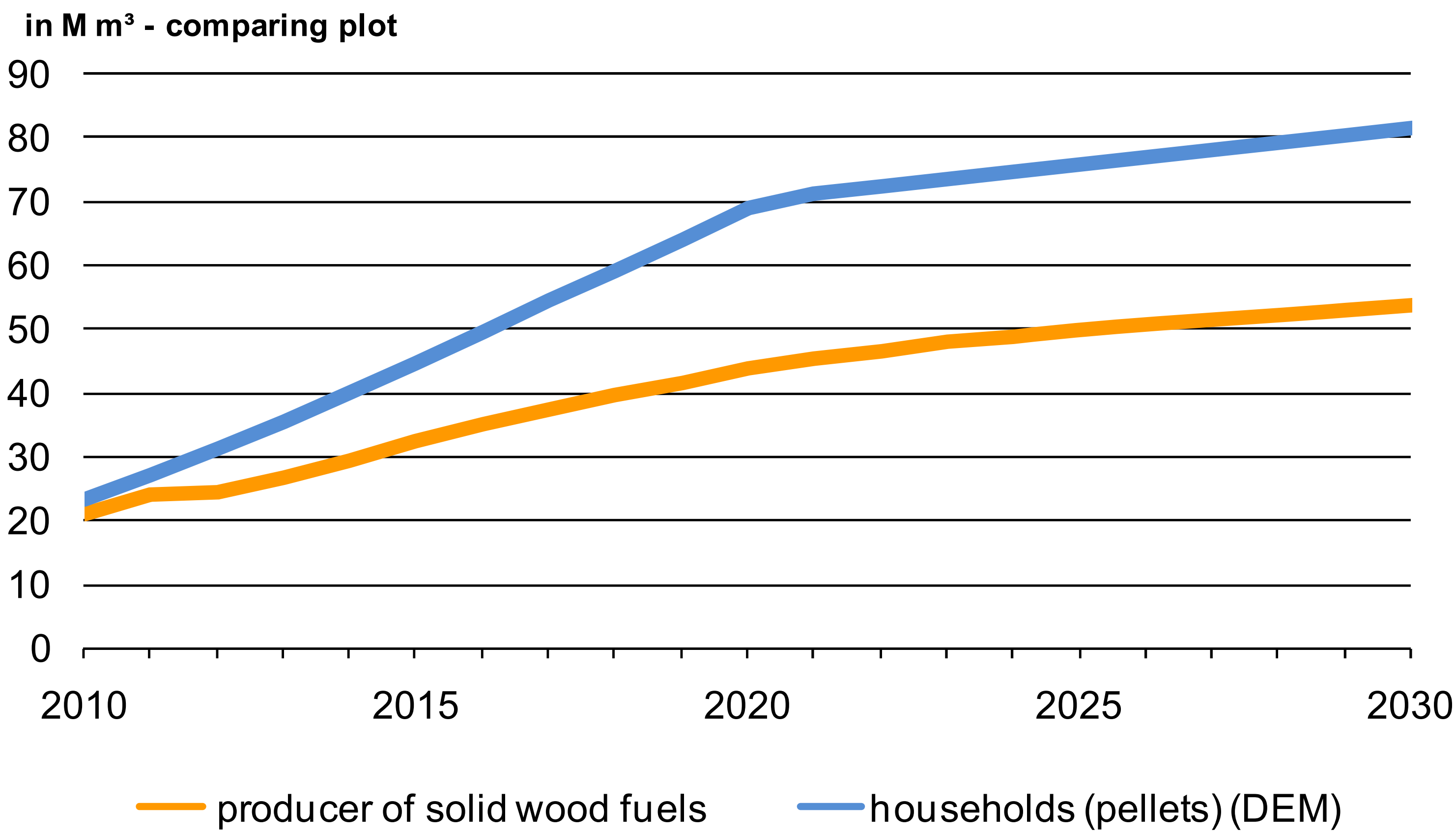
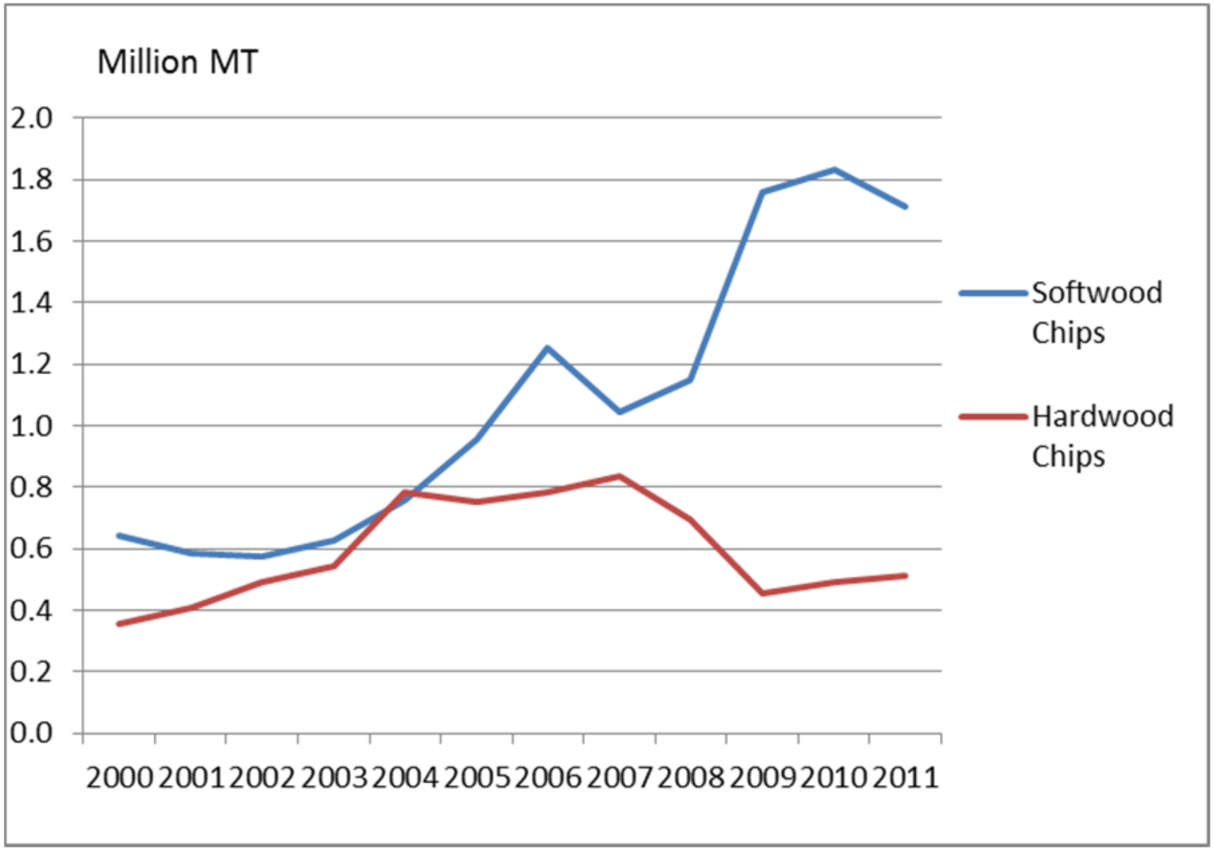


Figure 3-9: Wood based pellets production and consumption (EU 27)

Source: EUwood

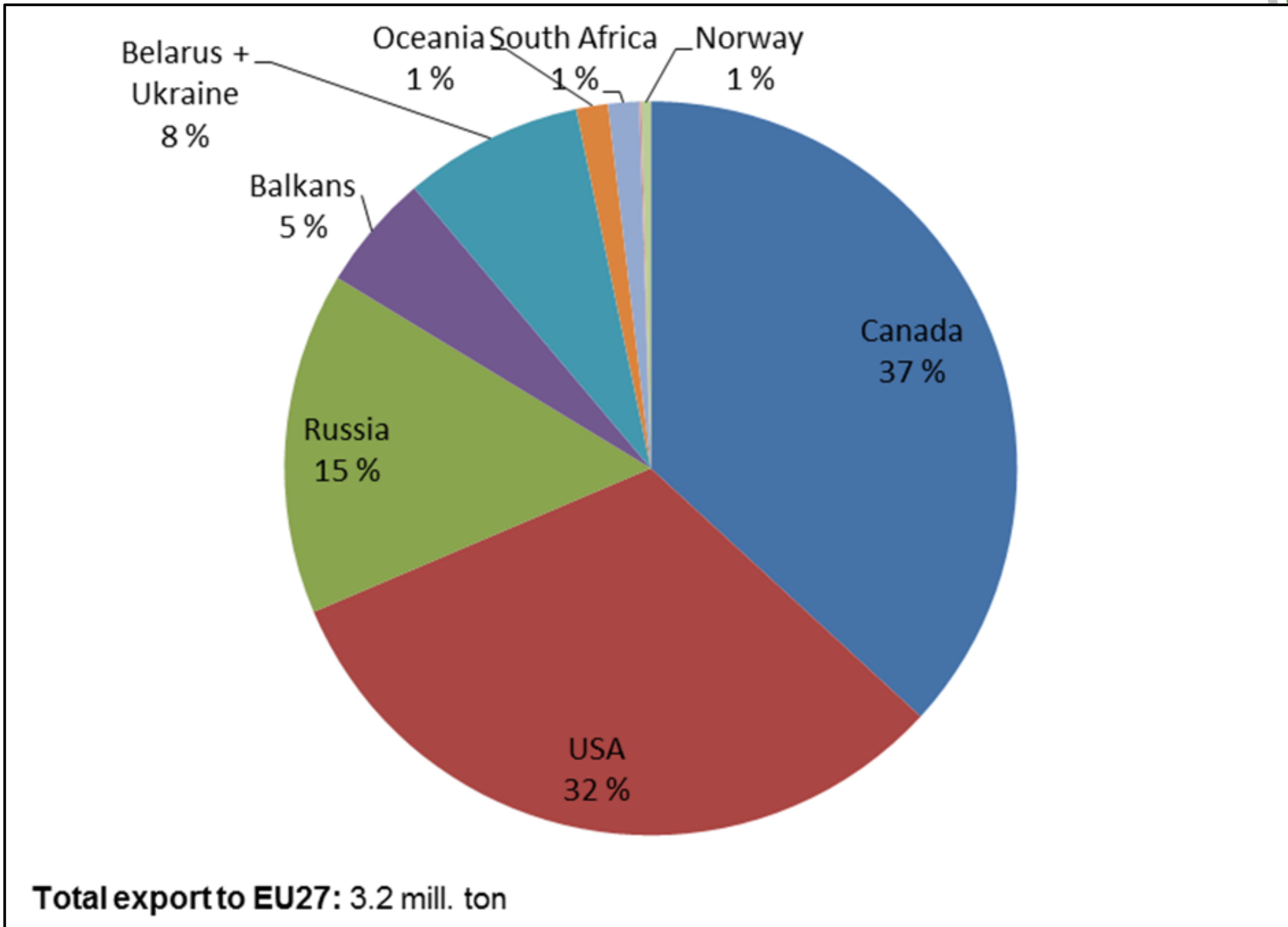
Figure 2.32 EU-27 imports of wood chips (2000-2011)



Source: Eurostat, External Trade database, 2012

EUwood calculated that 43 million m³ of the pellets consumption in 2020 might be produced from domestic sources whereas 22 million m³ might come from imports. In 2030 54 million m³ of the total consumption might be produced within the EU 27. Thus, the EU 27 will be an important net importer of wood based pellets and briquettes.

Figure 3.49 Wood pellet exports to the EU-27 from outside EU (2011)



Source: AEBIOM 2012

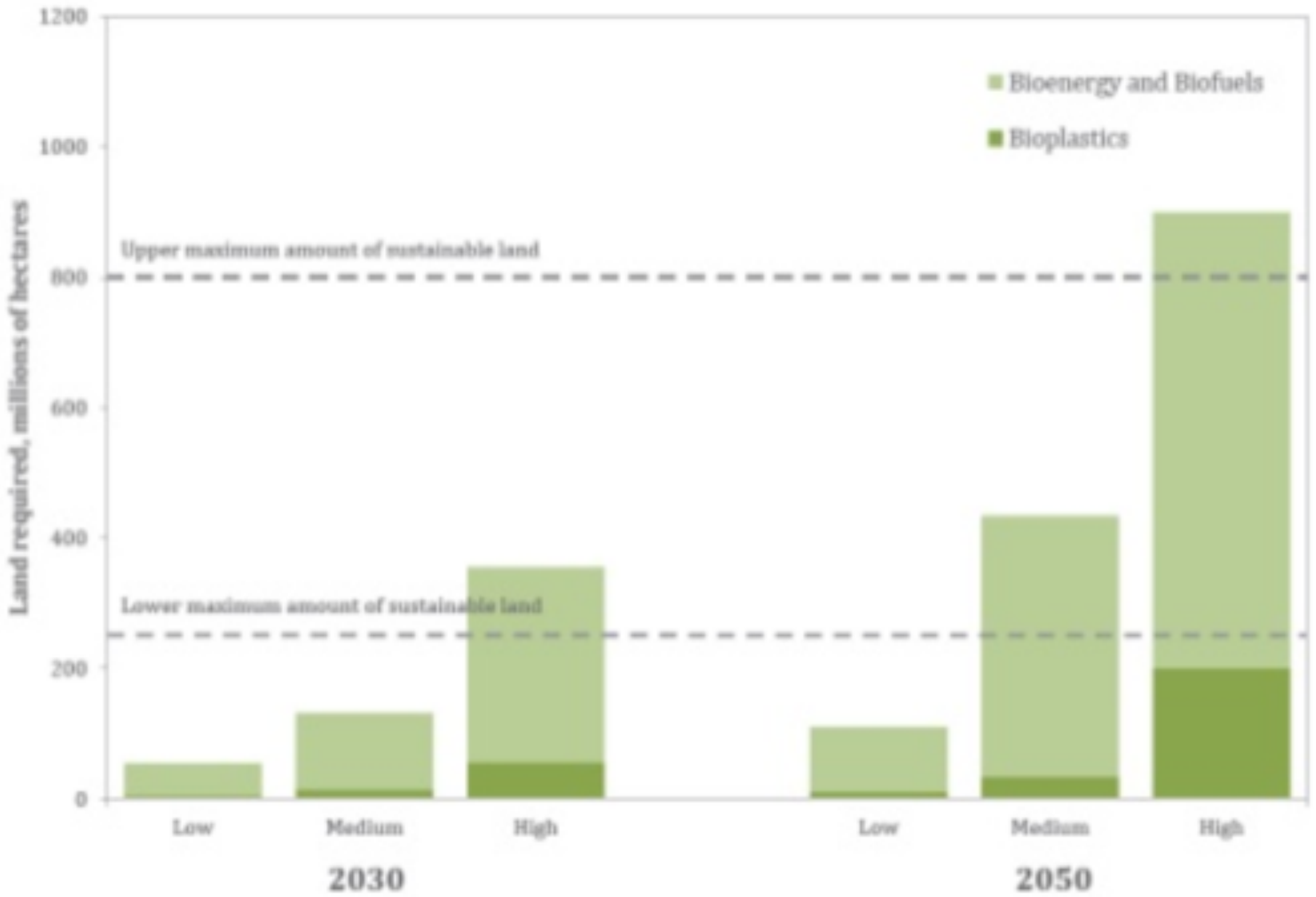
The current EU Policy for bioenergy

- Fuel Quality Directive (FQD)
  - 6% greenhouse gas reduction target in carbon intensity of road transport fuels in 2020
- Renewable Energy Directive (RED)
  - 20% share of renewable energy by 2020 (**32% by 2030**)
  - 10% renewable energy in transport by 2020

Significant contribution to both targets expected to come from biofuels (mainly 1G, food and feed crop-based)

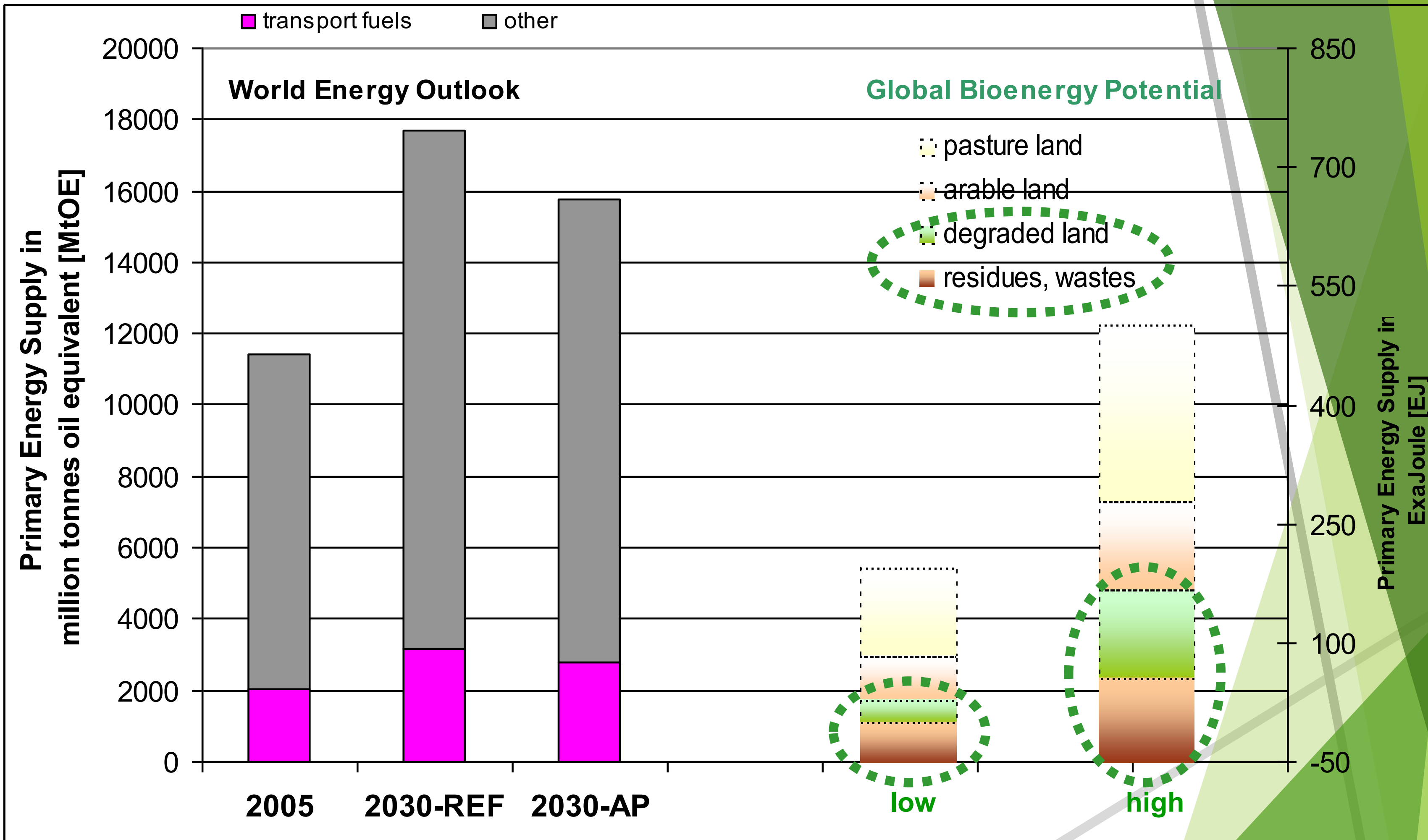
Do we have enough land to feed the planet *and* produce the low carbon energy, fuels and materials needed by a population expected to reach 9 billion by 2050?

Land requirements – the bigger picture



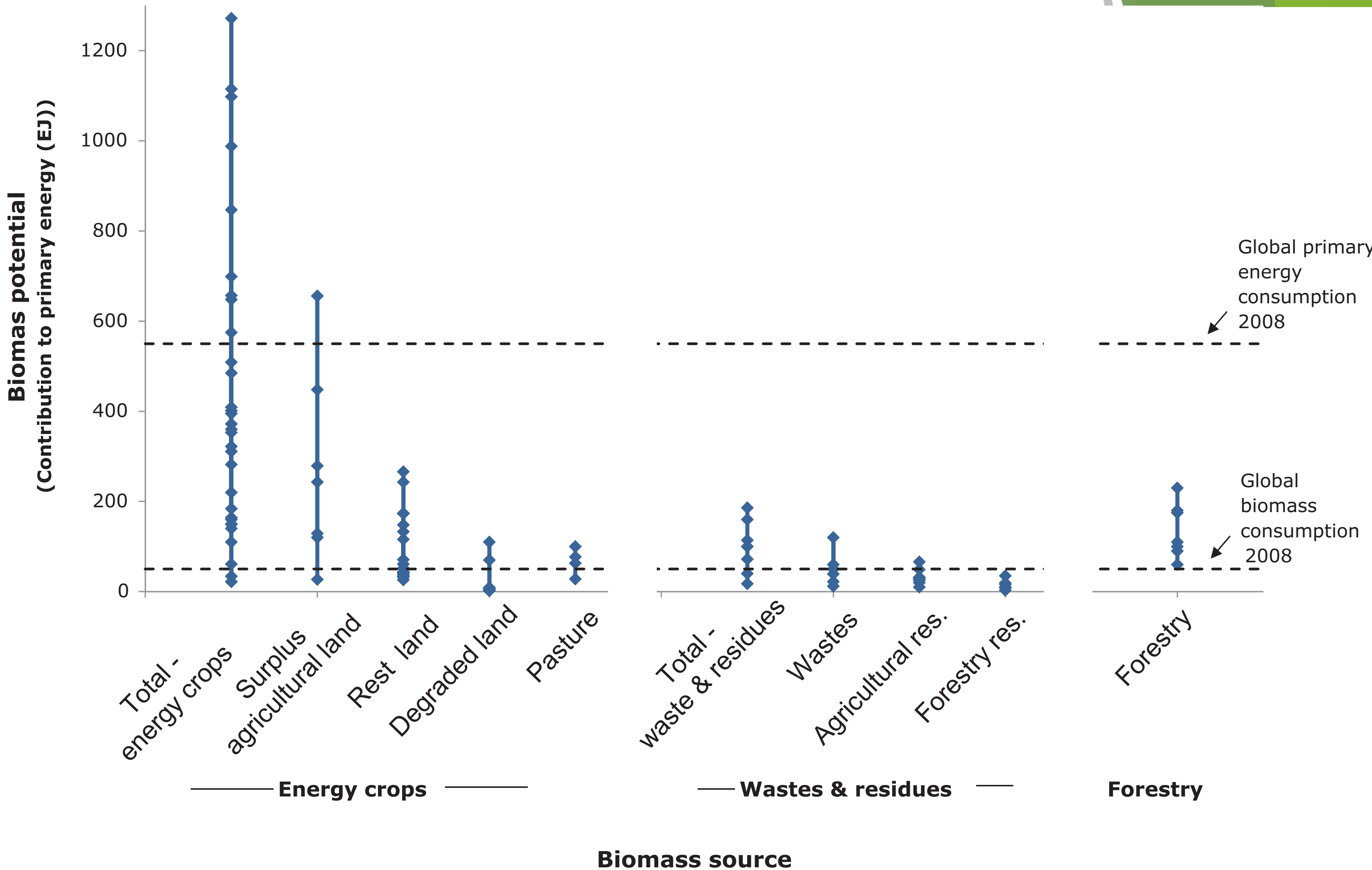
Predicted biomass demand scenarios versus land availability in 2030 and 2050.

Sustainable Bioenergy



Source: IEA (2007), and Best et al. (2008)

Figure 4.2: Indicative contributions to global biomass potential estimates from different biomass sources and land classes



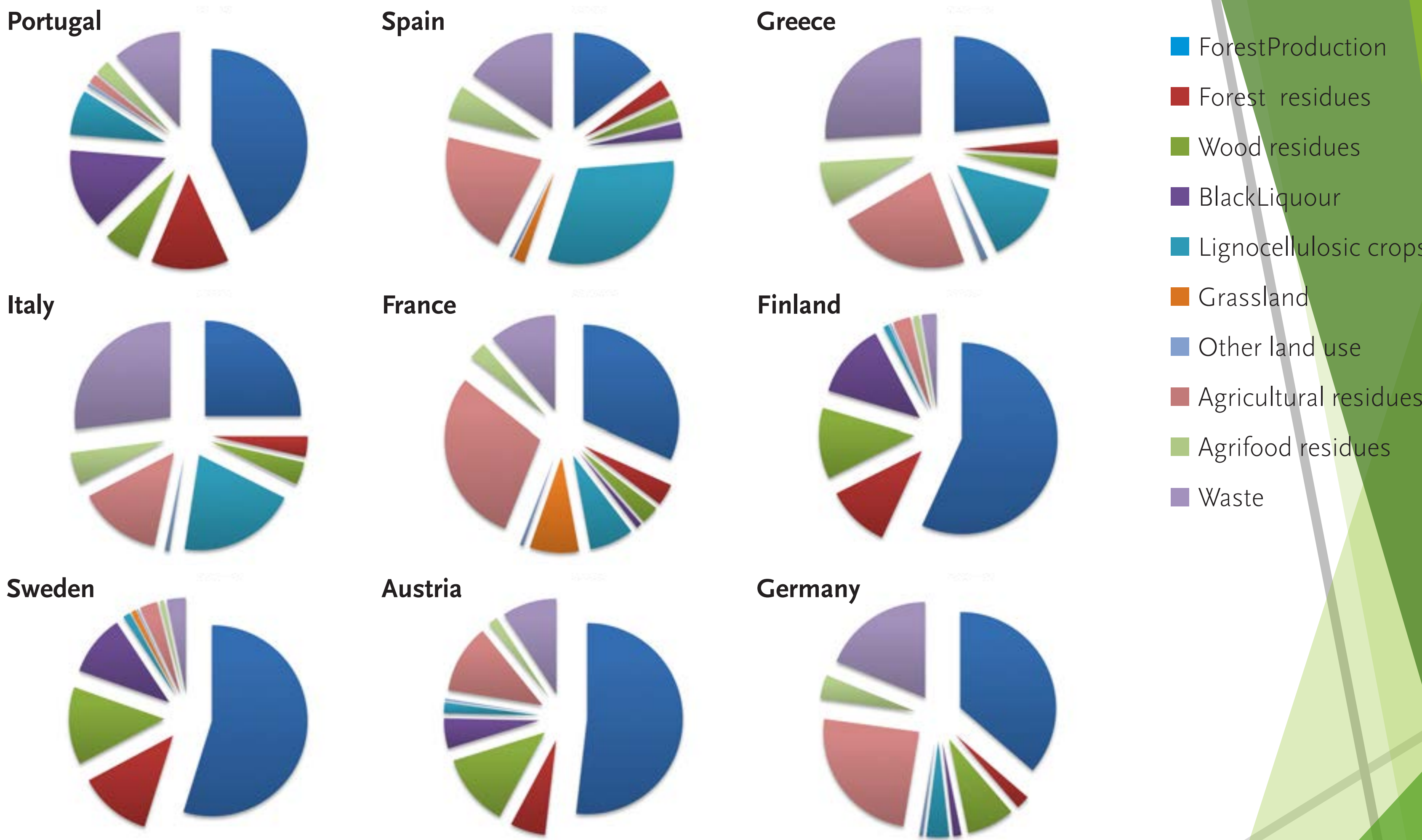
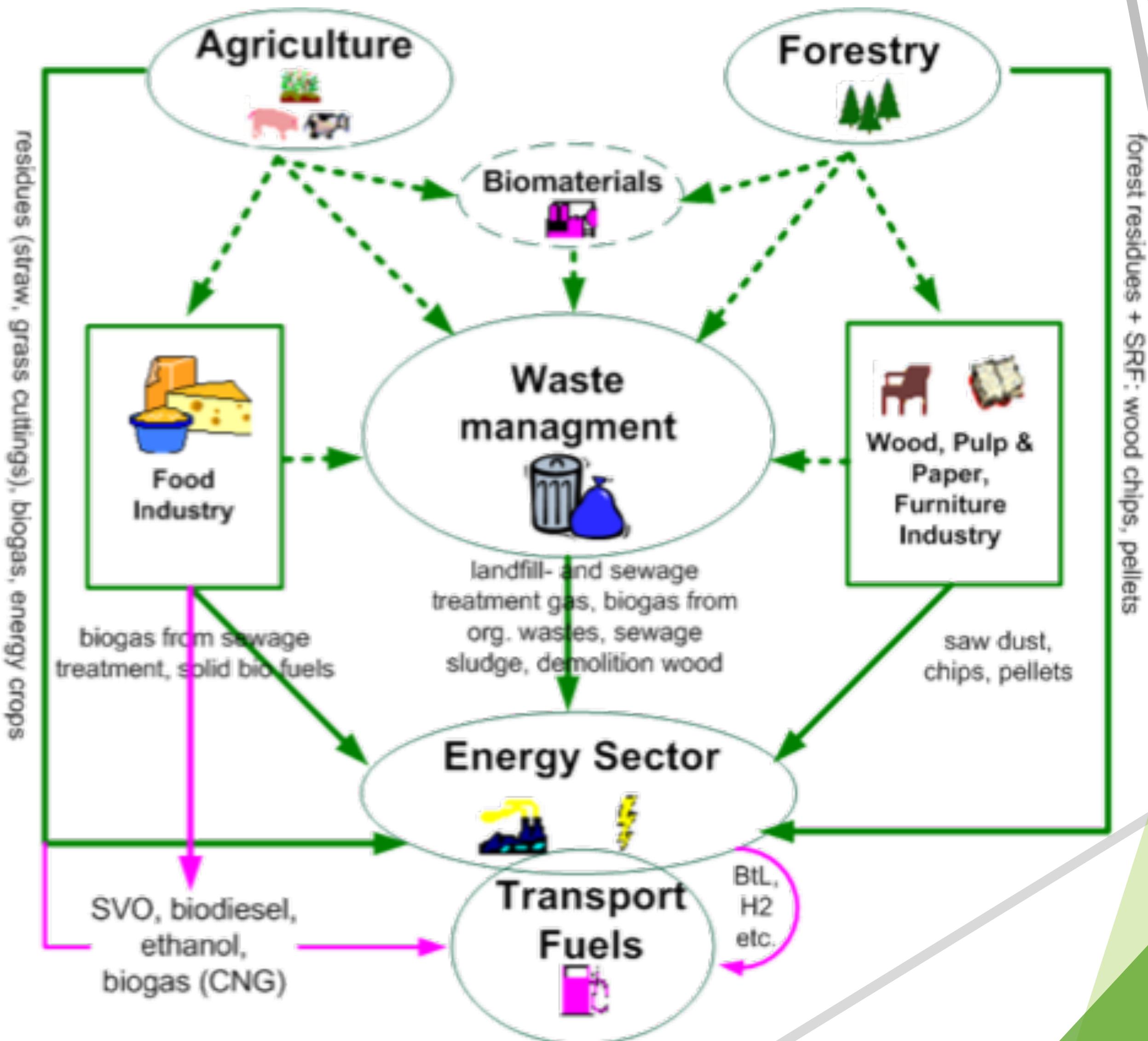


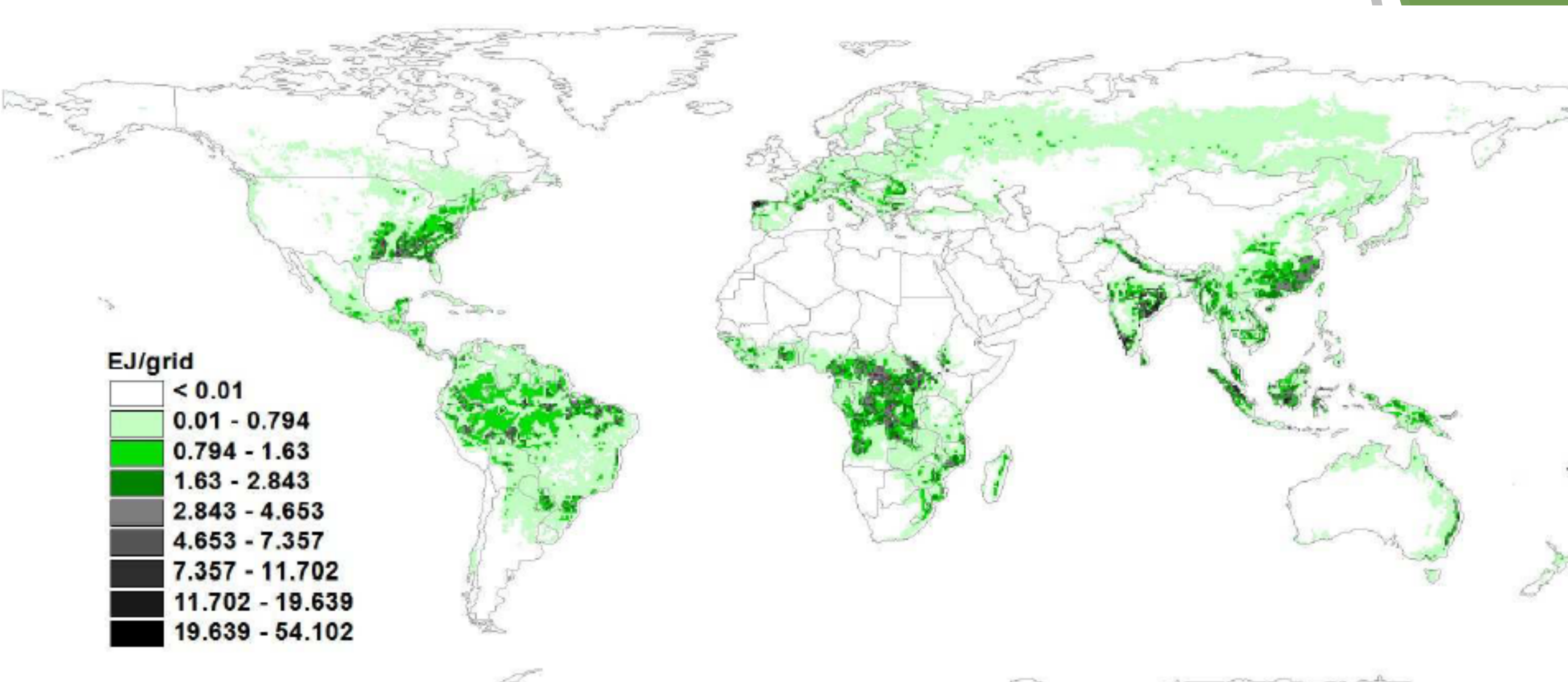
Figure 6. Relative availability of biomass types.

Source: S2Biom project[4]

Consider all Bioenergy Flows

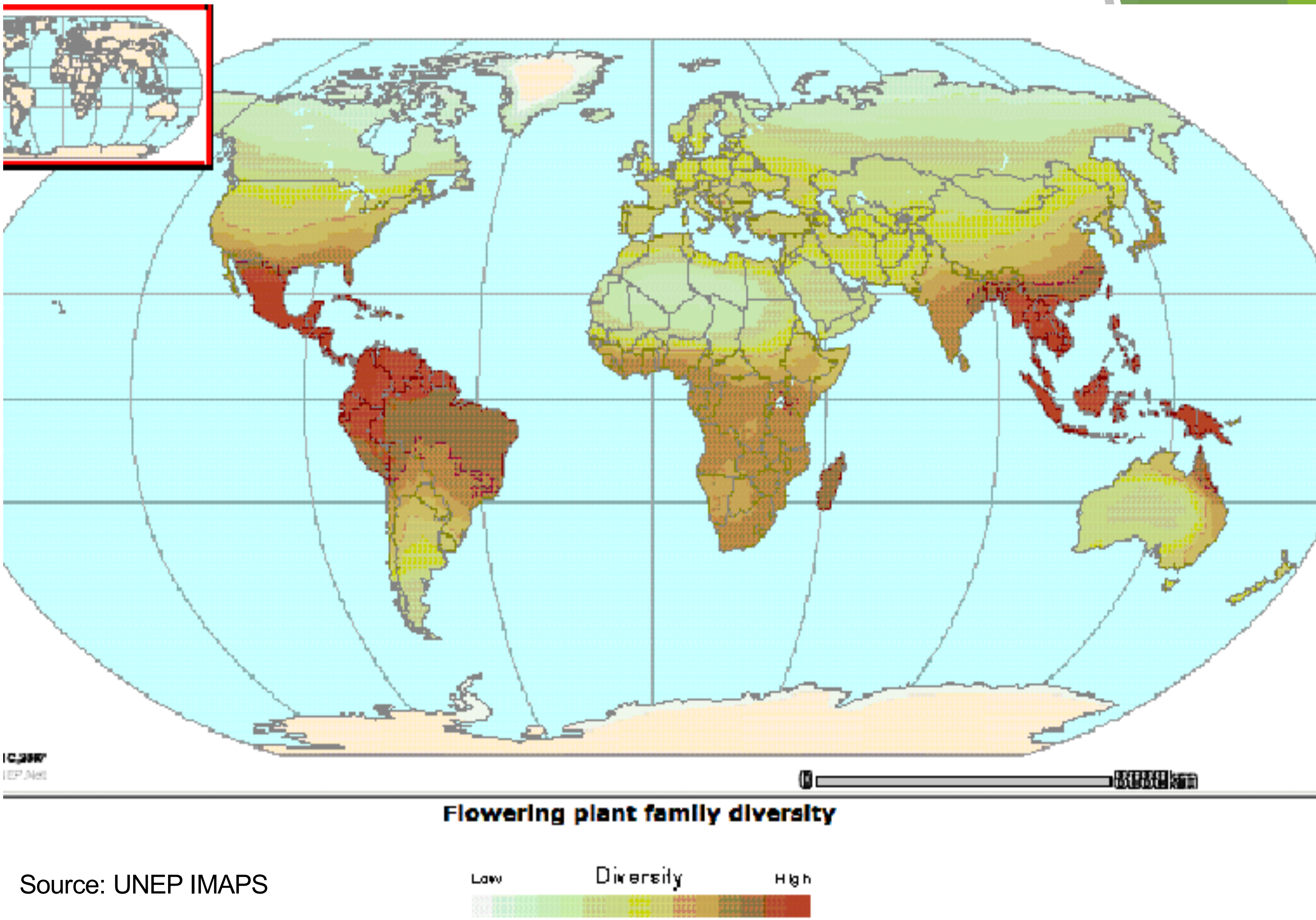


Global Biomass Potential



Source: IIASA, Kraxner 2007, Rokiyanskiy et al. 2006

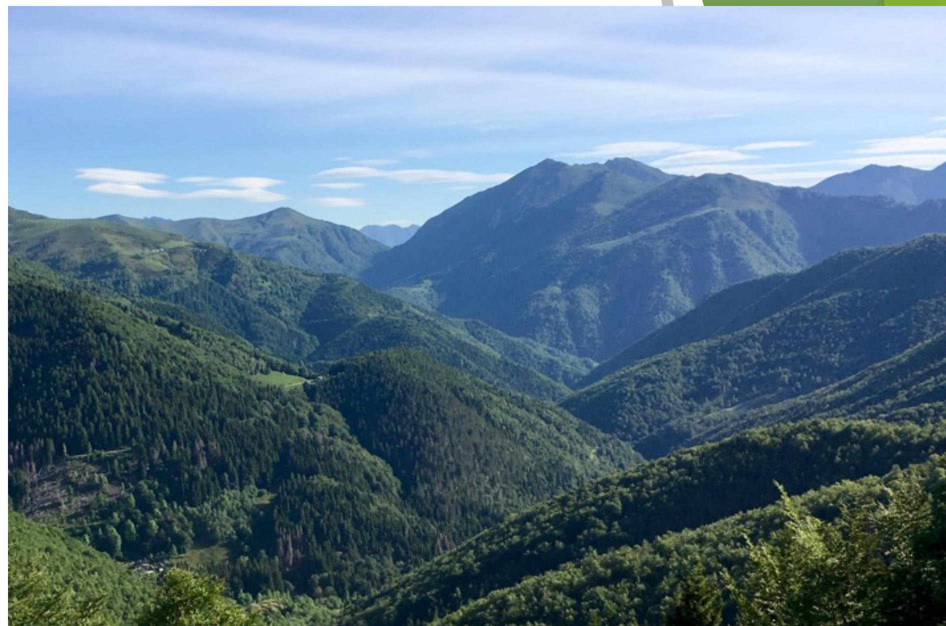
Global Biodiversity



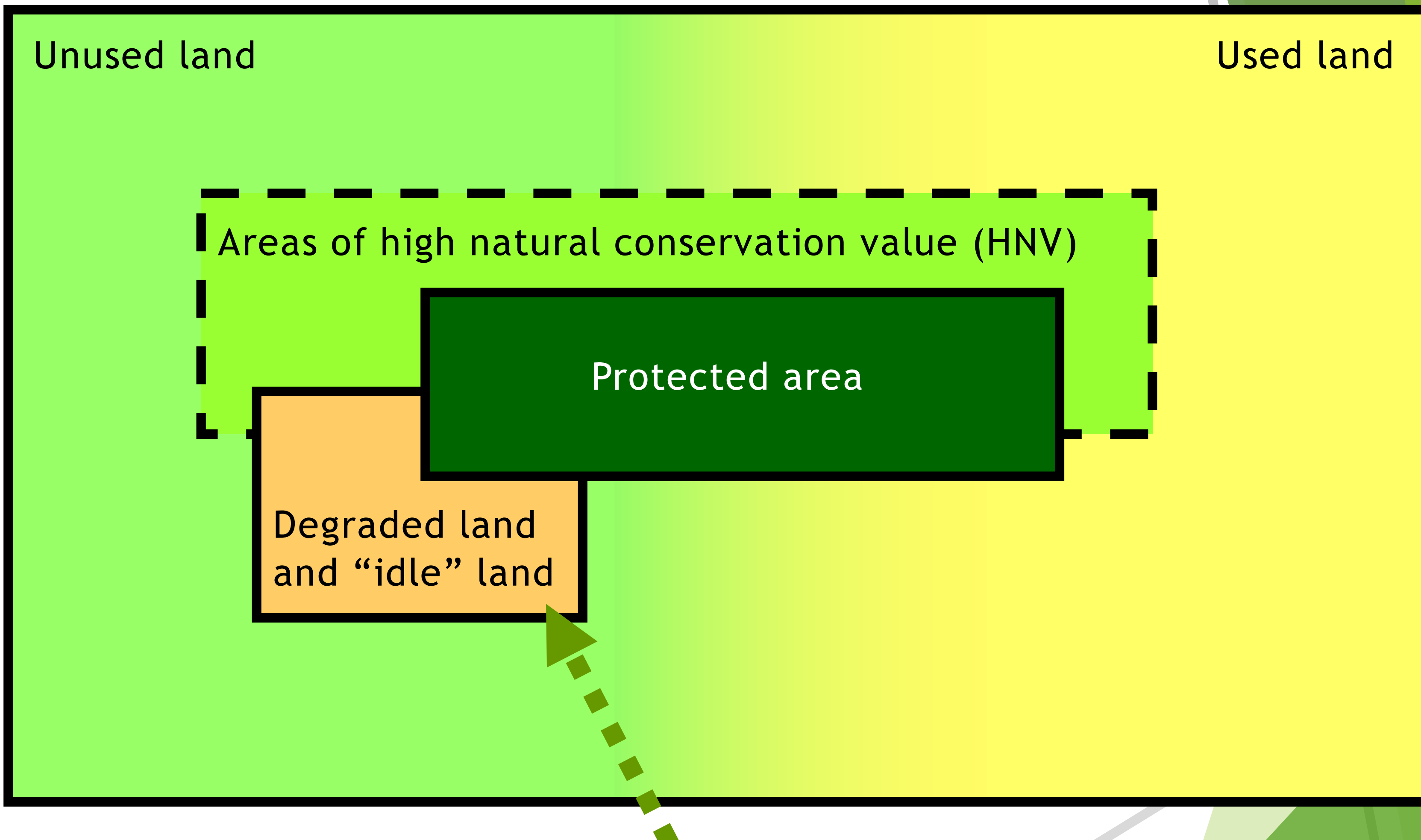
Source: UNEP IMAPS

Biodiversity is the basis for the goods and services that forests may provide. Thus the choice is not between biodiversity and bioeconomy, but rather on developing principles of a bioeconomy that also maintain biodiversity.

More intensive biomass harvesting should be applied where it benefits biodiversity, for example through maintenance of **traditionally open forests** or open landscapes, e.g. intensive management of successional forests on former agricultural land.



Land Use and Biodiversity



Potential for biomass: no competition with food, no displacement, increase organic C in soils, but: risk for biodiversity if not properly mapped

Biomass extraction for energy purposes has the potential to **induce changes in fire regimes** and can be considered a cost-effective landscape-level fuel-reduction treatment.

Figure 2. Typical appearance of an area dominated by *Pinus halepensis* before extracting (**A**) and after extracting (**B**) biomass.

https://link.springer.com/article/10.1007%2Fs10021-016-9968-z

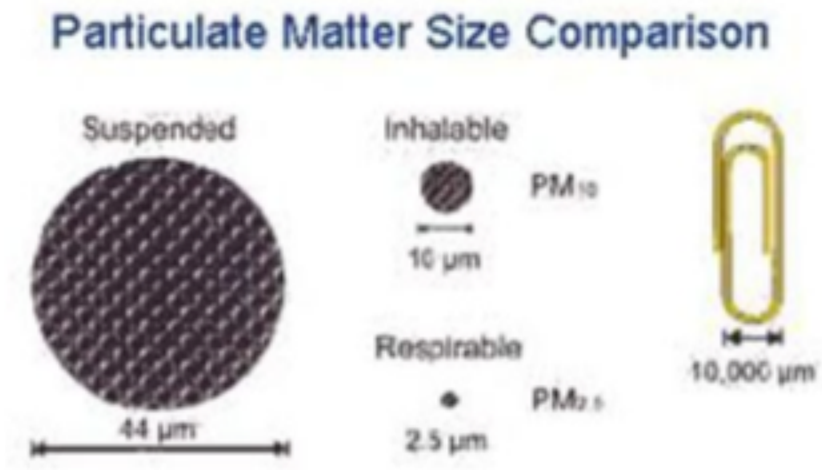
However, the leverage (area suppressed in relation to managed area) was higher when the **treatments were based on the fire-prevention strategy** and focused on high-fire-risk areas (up to 0.45) than with treatment designed for energy reasons (lower than 0.15).

Water and Soil

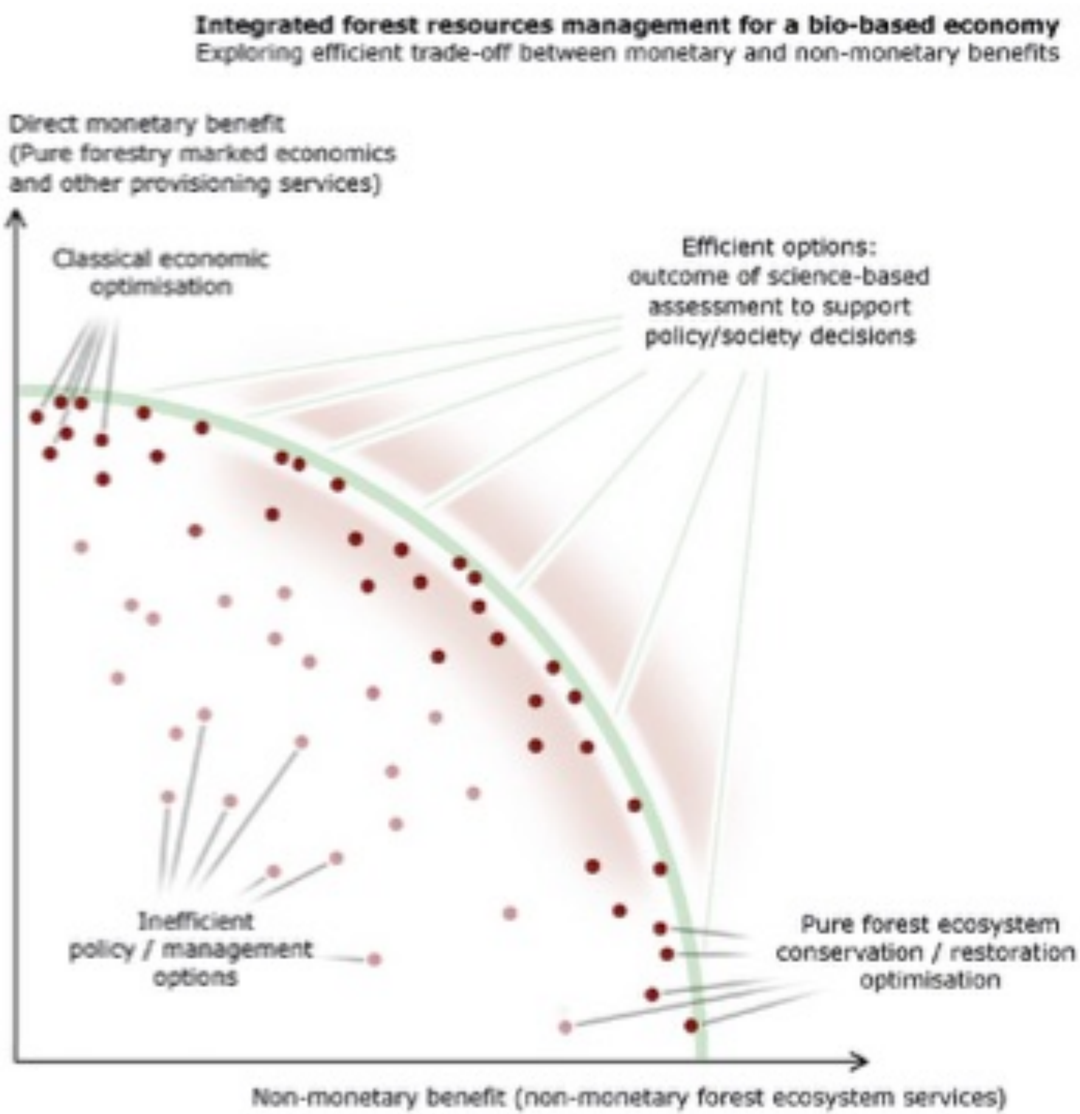
- Water Use of (Bioenergy) Farming Systems
  - Model and data research ongoing
  - Spatial data are key, but (yet) unclear
- Soil Impacts
  - Mapping of biophysical soil properties
  - Qualitative Impact Definition (for farming systems/AEZ)
  - Quantification?

- → More from FAO BIAS Project

Suspended particulate matter (SPM):



- Most harmful forms of SPM
  - fine (PM < 10); written as PM_{10}
  - **Ultrafine (PM 2.5); written as $PM_{2.5}$
- Volcanoes, coal power plants, road dust, vehicle exhaust, wood fires
- 60,000 premature deaths a year in the U.S.
  - increases cardiovascular/respiratory disease
  - decreased lung function


Integrated forest resources management for a bio-based economy
Exploring efficient trade-off between monetary and non-monetary benefits
Direct monetary benefit
(Pure forestry marked economics
and other provisioning services)
Classical economic
optimisation
Efficient options:
outcome of science-based
assessment to support
policy/society decisions
Inefficient
policy / management
options
Pure forest ecosystem
conservation / restoration
optimisation
Non-monetary benefit (non-monetary forest ecosystem services)

Which Standards?

Standard	Scope	Regional Adjustment	Time Horizon
Clarification of land ownership	regional/local	no	short-to-medium term
Avoiding negative impacts from bioenergy-driven changes in land use	global	no	short term
Priority for food supply and food security	regional/local	yes	medium-to-long term
No additional negative biodiversity impacts	regional/local	yes	medium-to-long term
Minimization of greenhouse gas emissions	global	no	short term
Minimization of soil erosion and degradation	regional/local	yes	short-to-medium term
Minimization of water use and avoidance of water contamination	regional/local	yes	short-to-medium term
Improvement of labor conditions and worker rights	regional/local	no	short term
Ensuring a share of proceeds	regional/local	no	short term
Avoiding human health impacts	regional/local	no	medium-to-long term

Standards: EU

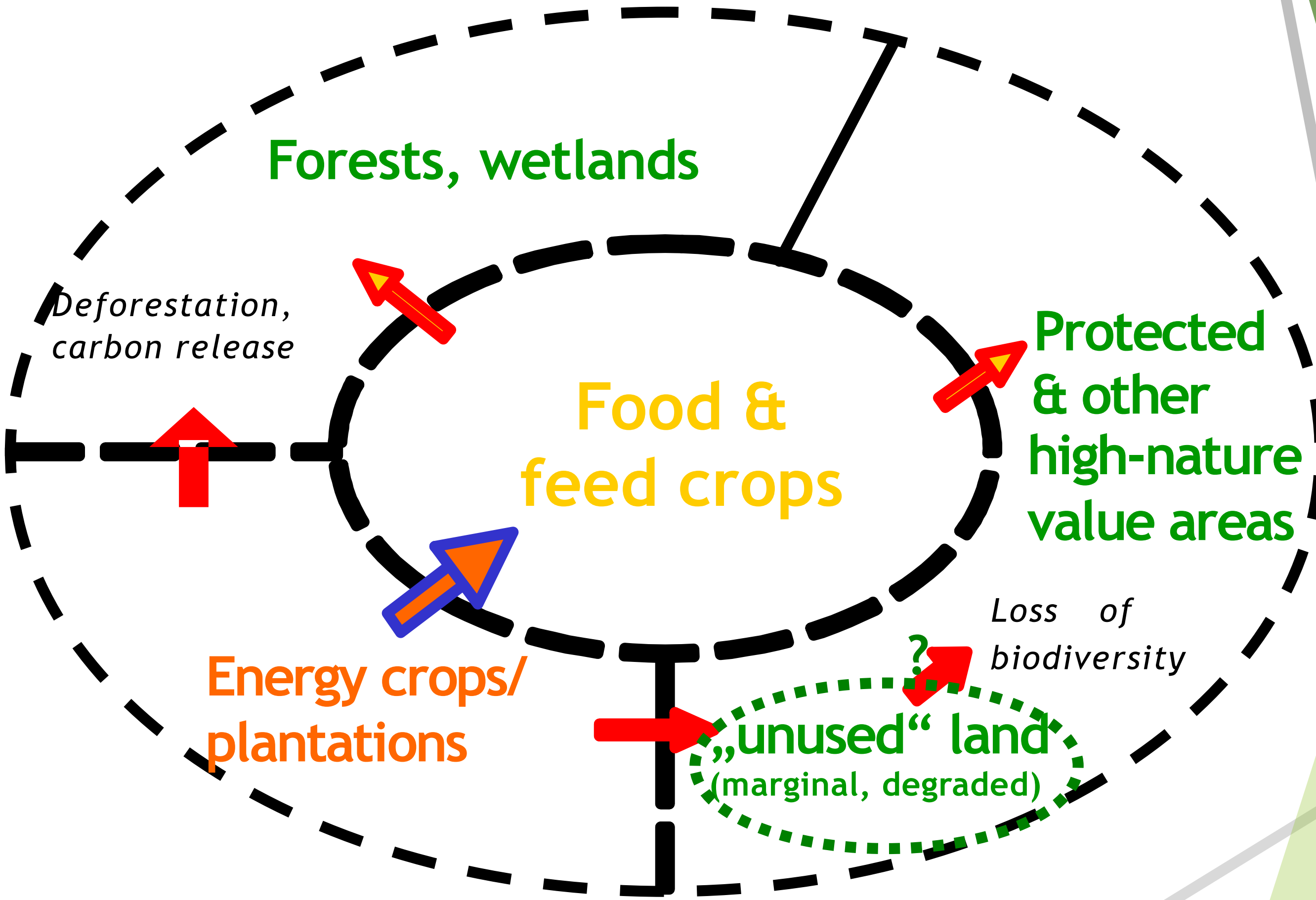
RES Directive establish **mandatory** sustainability requirements for production of biofuels

- Minimum GHG reduction, incl. CO_2 from **direct** land-use change. *Biofuels need to save at least 35% compared to fossil fuels, increasing to 50% in 2017*
- No “relevant” reduction of biological/ecosystem diversity

Biofuels cannot come from land:

With high carbon stock
High biodiversity (primary forest etc.)

Indirect LUC



Source: based on Girard (GEF-STAP Biofuels Workshop, New Delhi 2005)

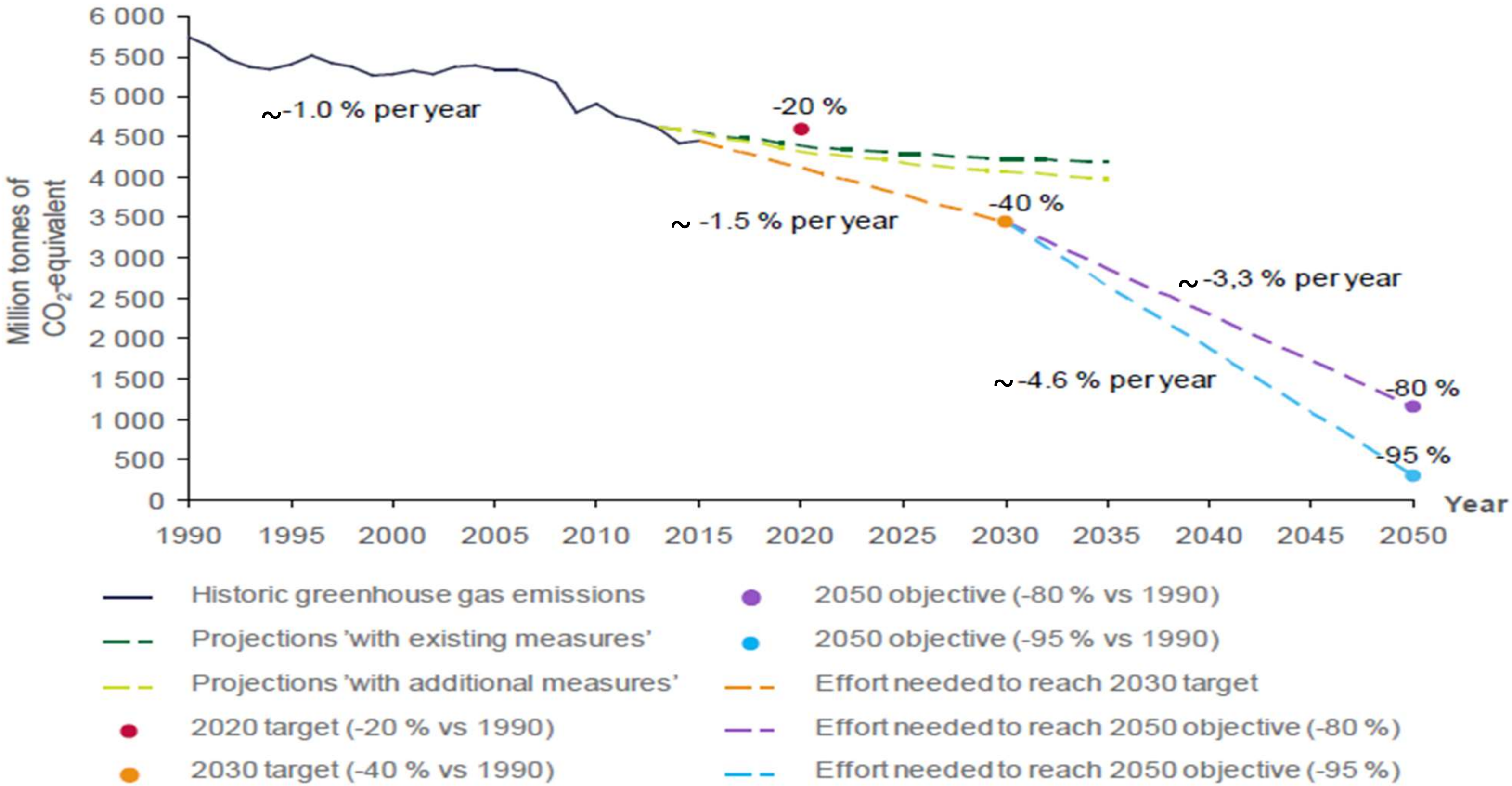
GHG from indirect LUC

- Displacement = generic problem of restricted system boundaries
  - Accounting problem of partial analysis („just“ biofuels, no explicite modelling of agro + forestry sectors)
  - All incremental land-uses imply indirect effects
- Analytical <u>and</u> political implications
  - Analysis: which displacement when & where?
  - Policy: which instruments? Partial certification schemes do not help, but have „spill-over“ effects

Sustainable Biomass

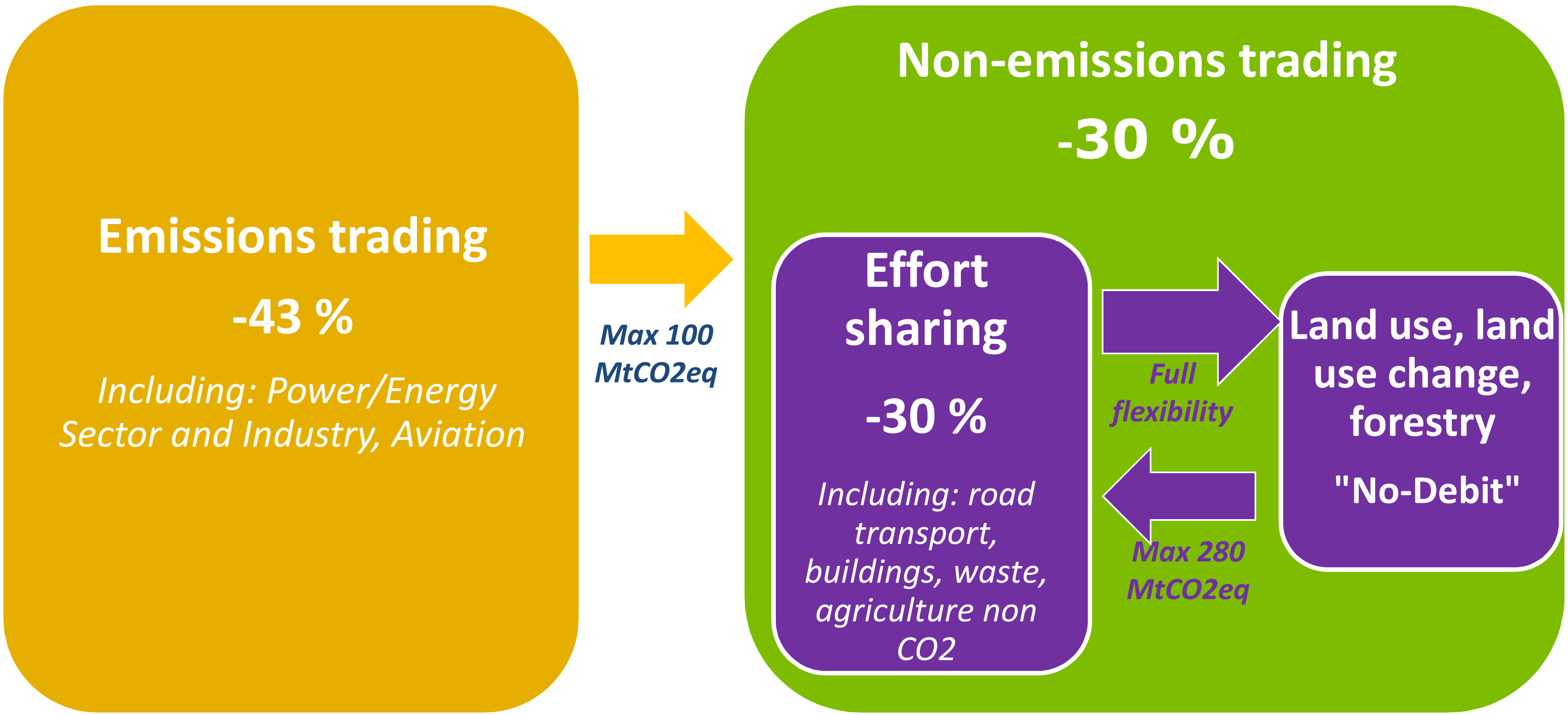
Good practice: Agroforestry in Southern Ruanda – food, fiber and fuel from integrated systems

EU greenhouse gas emissions



Source: EEA – Trends and projections in Europe 2016

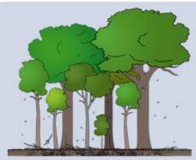
Three pillars of EU 2030 climate policy



Commission proposal (July 2016) brings LULUCF in the climate framework for the **first time**, as *a **stand-alone policy pillar**, with **flexibility** toward ESR*

***No debit rule:** LULUCF accounted emissions to be entirely compensated by removals*

Options for mitigating climate change through forest management

Option		current offset of total EU emissions (%)	Short-term *relative* impact of > harvest	*Reported/accounted in:*
Increase in C stock	**in existing forests (CO_2 sink or "removal")** 	≈ 10% (only 1% "accounted" under KP in 2008-2012)	<<	*LULUCF*
	in wood products 	≈ 1%	>	
Substitution effects by wood (approximate figures)	**Material** 	≈ 1-2%	>	*Other GHG sectors*
	Fossil-fuel energy 	≈ 4-5%	*	

Forest !

* While the emission saving by material substitution are immediate, when wood replaces fossil fuels the emissions saving highly depends on the context, assumptions and time frame.

Trade-offs exist between options, each with its **temporal dynamics** of emissions. E.g. *more harvest may mean less forest sink in the short term but more substitution effects.*

The most effective forest mitigation strategy is the one that optimizes the sum of the above options in a given time frame.

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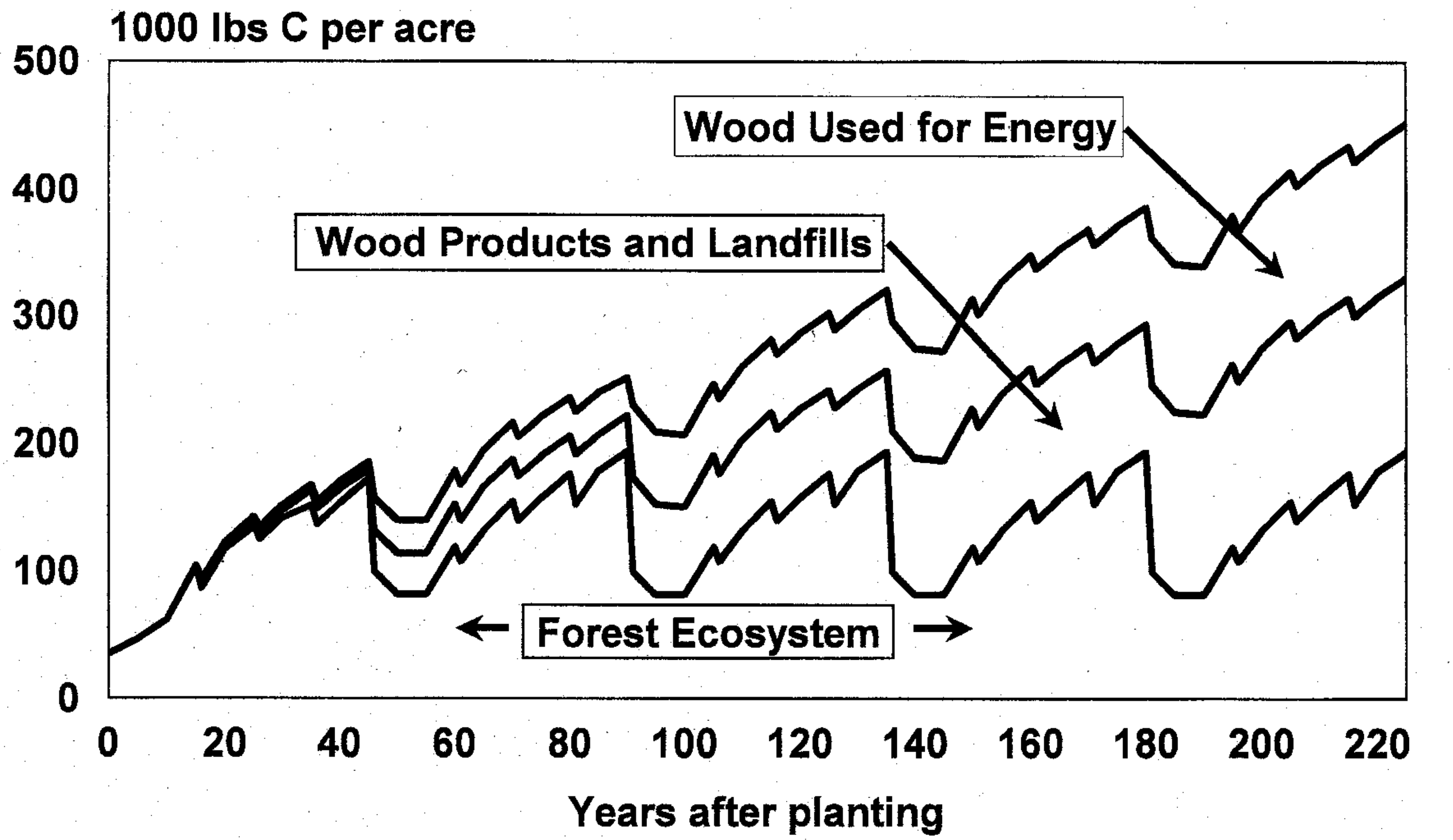
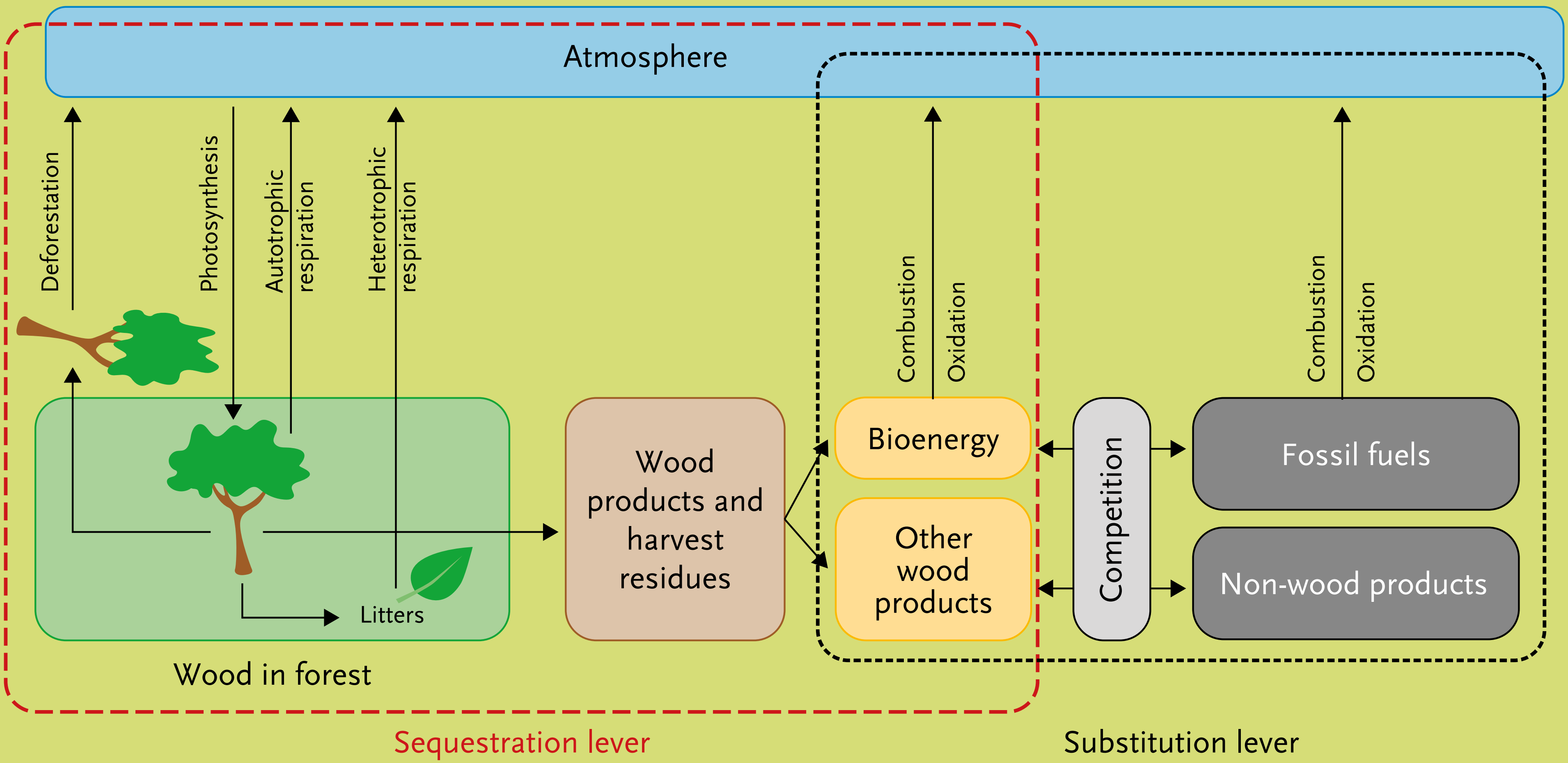


1000 lbs C per acre
500
400
300
200
100
0
Wood Used for Energy
Wood Products and Landfills
Forest Ecosystem
0
20
40
60
80
100
120
140
160
180
200
220
Years after planting


Atmosphere
Deforestation
Photosynthesis
Autotrophic respiration
Heterotrophic respiration
Combustion
Oxidation
Combustion
Oxidation
Litters
Wood in forest
Wood products and harvest residues
Bioenergy
Other wood products
Competition
Fossil fuels
Non-wood products
Sequestration lever
Substitution lever

What science says on the best forest mitigation strategy?

short answer is:

IT DEPENDS

The optimal mix of mitigation options is very much country-specific (e.g. forest and market characteristics, etc.…)

Forest management policies are responsibility of MS

The EU LULUCF legislation does not identify the best mitigation strategy (e.g. harvesting more or less), but **promotes an accounting which is accurate**, including that *bioenergy is properly accounted for,* and comparable to other GHG sectors

Conclusions

- GHG emissions become key issue in biofuels trade
- GHG must include (real) direct land-use changes, and GHG from indirect LUC need „risk hedging“
- Methods for verification of GHG from direct LUC need elaboration and harmonization
- GHG limits for biofuels also reduce (but not avoid) risk of negative biodiversity impacts; mapping of HNV areas (also in degraded lands) needed
- Soil/water restrictions need more attention, but bioenergy also opportunity

- Forest mitigation strategies differ strongly in their temporal effects. **The strategies with largest short-term benefits are often less efficient in the long term**.

- There is a potential **trade-off between forest protection and bioeconomy developments**. Whereas protection contributes to short-term climate change mitigation, it constrains the biomass resource basis for the bioeconomy, reduces the possibility for mitigation in a broader system perspective, taking harvested wood products and substitution into account, and limits mid- to long-term mitigation potentials.

- **Careful spatial planning can minimise conflicts**. Forest carbon sinks could be maximised in habitats of lower value for the bioeconomy and on sites with low disturbance risk and long-term mitigation potential.

- **The mitigation potential of bioenergy is generally less efficient than expanded material use of biomass**, but decision-making needs to consider local circumstances.

Forest biomass is heavily used to achieve renewable energy targets. To fulfil the Paris agreement, bioenergy is needed alongside solar and wind and plays a key role in integrating the latter renewable energy sources in a stable and reliable renewable energy supply

It is recommended that bioenergy is produced as a **side product** in combined material and energy use value chains. Direct use of biomass for energy should not limit material use as this creates longer-term carbon sequestration and larger substitution benefits.

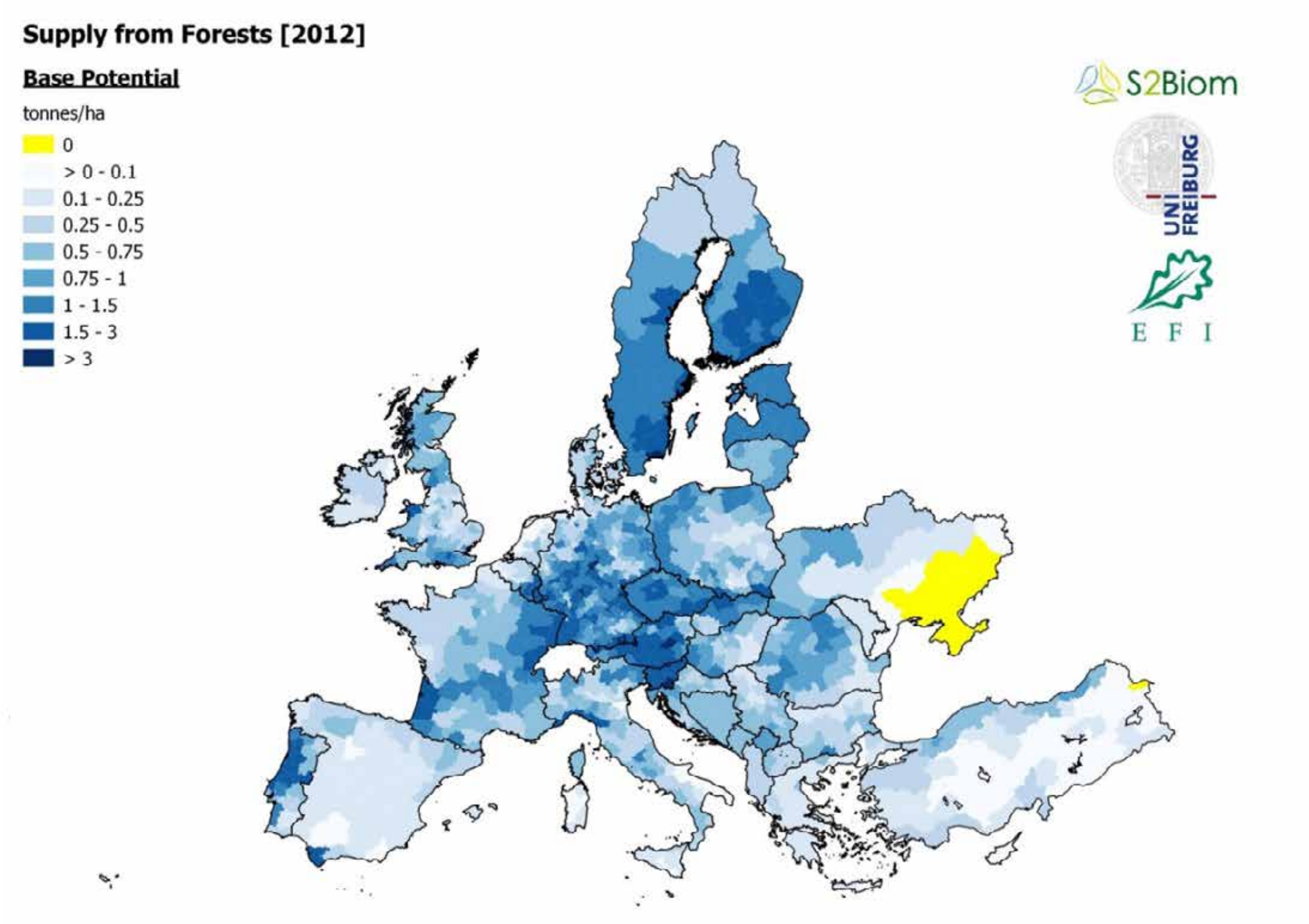
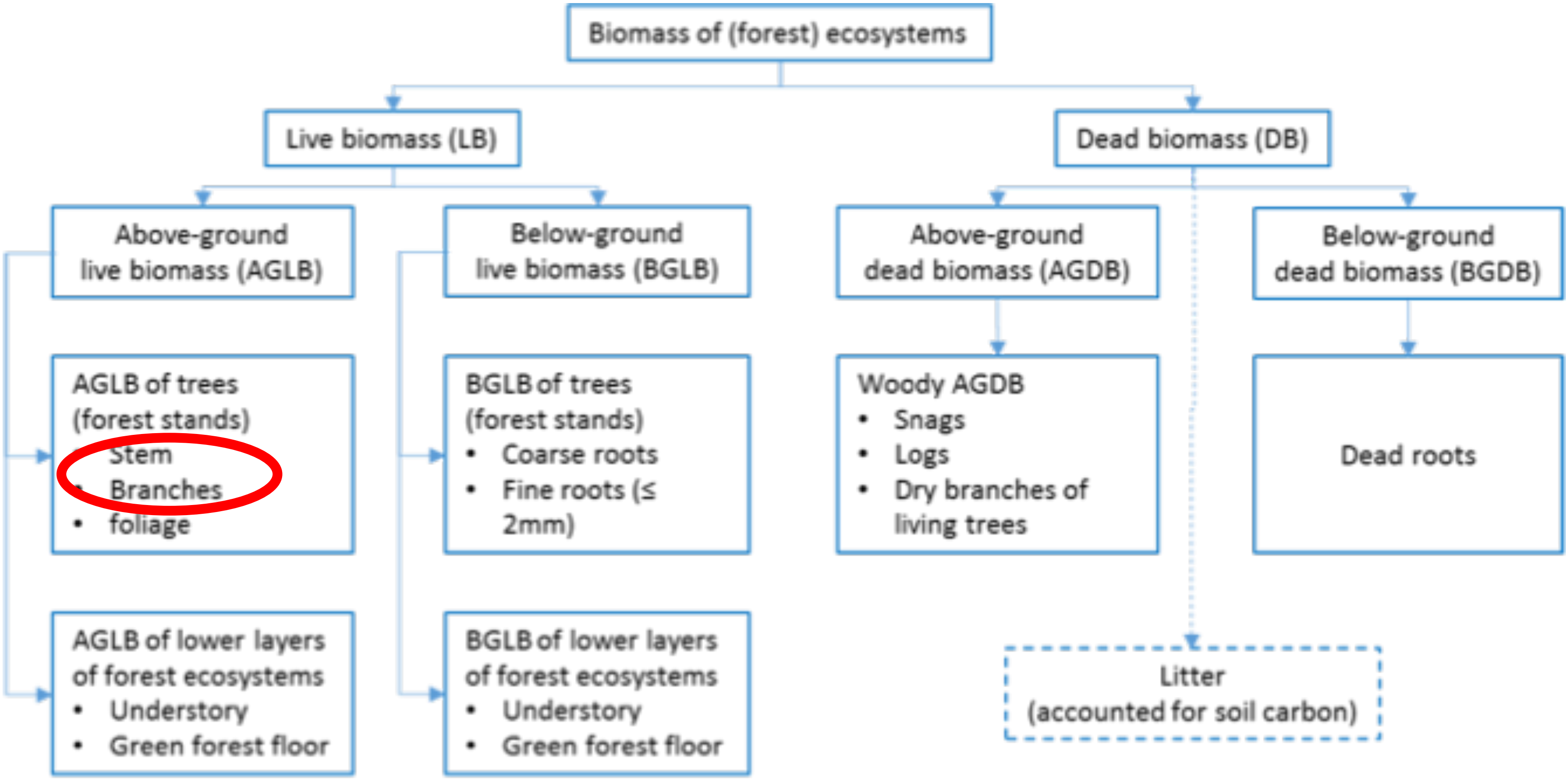


Figure 3. Distribution of potential forest biomass availability (biomass production and primary residues from forests) per ha of land for the base potential in 2012. No data are available for regions marked yellow. Source: Dees et al, 2017 and Panoutsou, 2017.

Forest biomass

Wait…

What do you mean for 'Biomass'….?



Quantify biomass

1. Destructive measurements

- Cut
- Dry
- Weigh

Quantify biomass

2. In-situ estimation

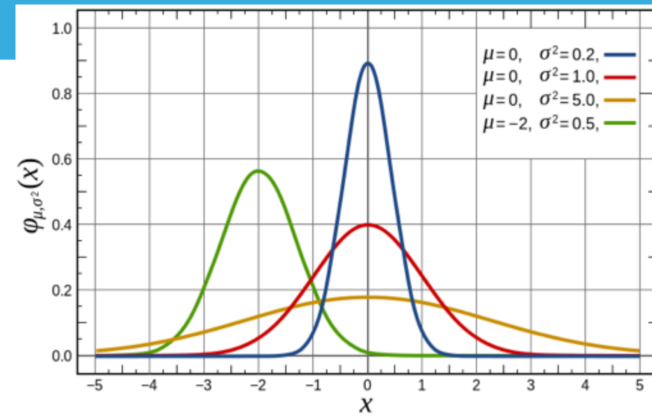
- Allometric equations based on tree parameters
- Biomass = *f (Diameter, wood density, height)*

Quantify biomass

3. Large-area estimation

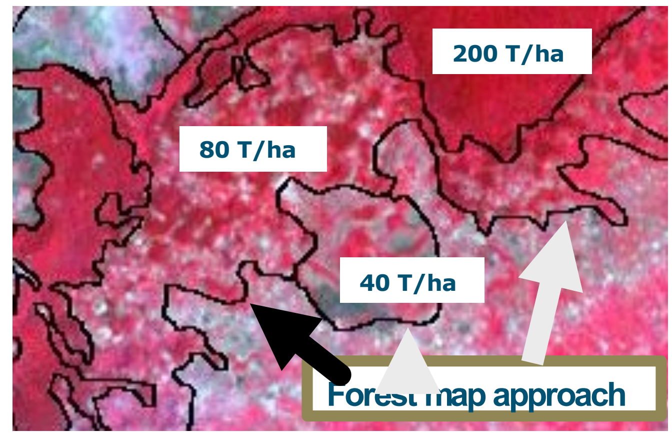
a) Field Plots only

-> Statistics (non-spatial)



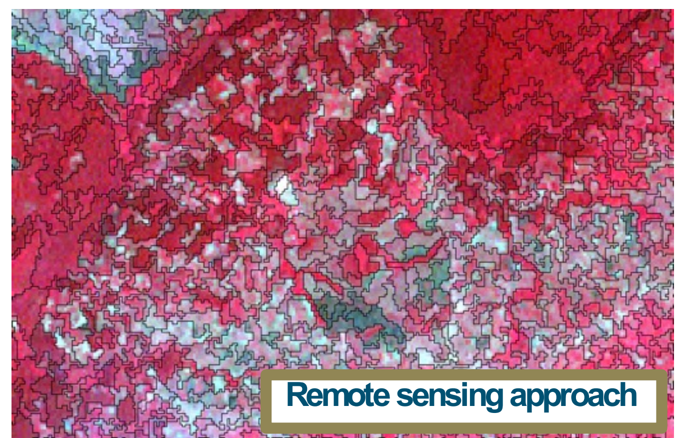
b) Field Plots + Forest map

-> Spatial (Mean values)



c) Field plots + Satellite images

-> Spatial (continuous)

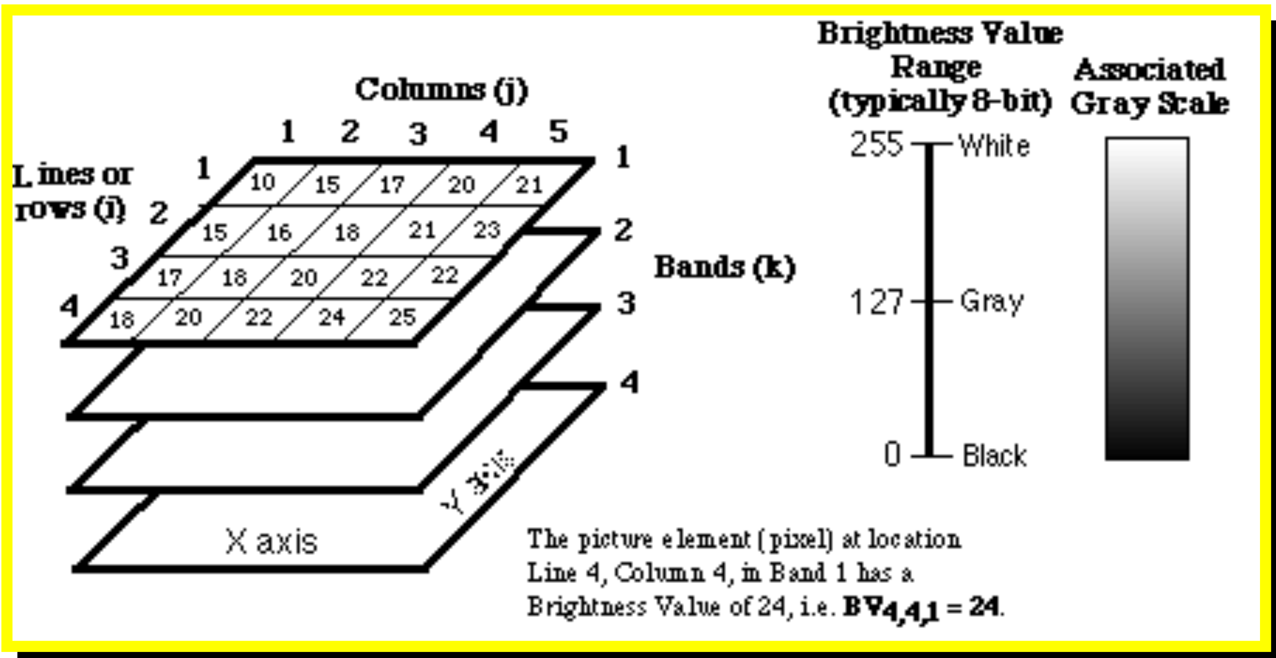


Fully exploit the spectral information

Joint Research Centre

IMAGERY with multiple spectral bands

- A multispectral image is composed of 'n' rows and 'n' columns of pixels in each of two or more spectral bands. There are in reality more than one "data set" which makes up one image.
- These different data sets are referred to as spectral bands, channels, or layers.



Summary Sensor Resolution

Spectral:

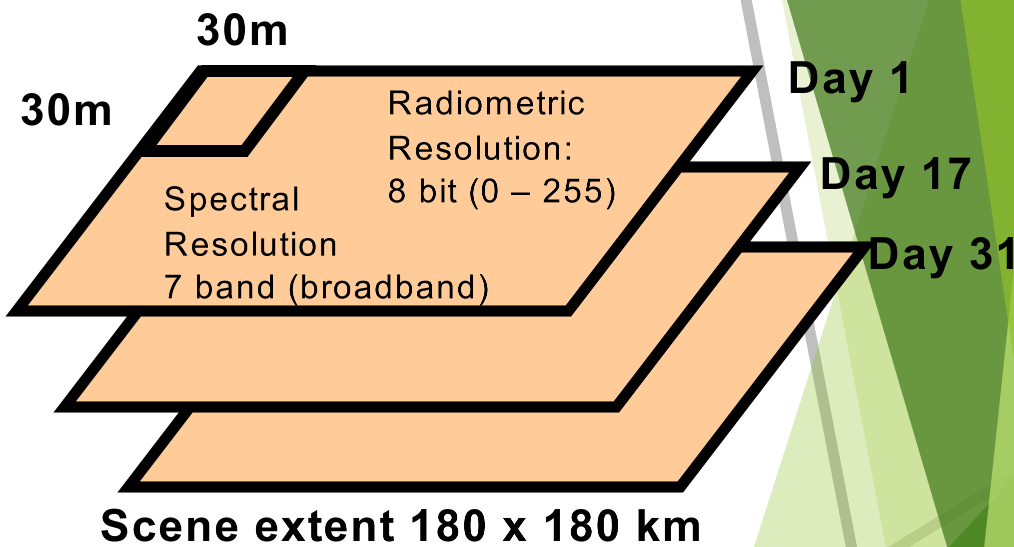
(7 broadband, VIS/NIR/SWIR/TIR)

Spatial (30/120 m, 380x380 km)

Radiometric (8 bit, 256 levels)

Temporal (16 day, if cloud free)

Landsat Thematic Mapper

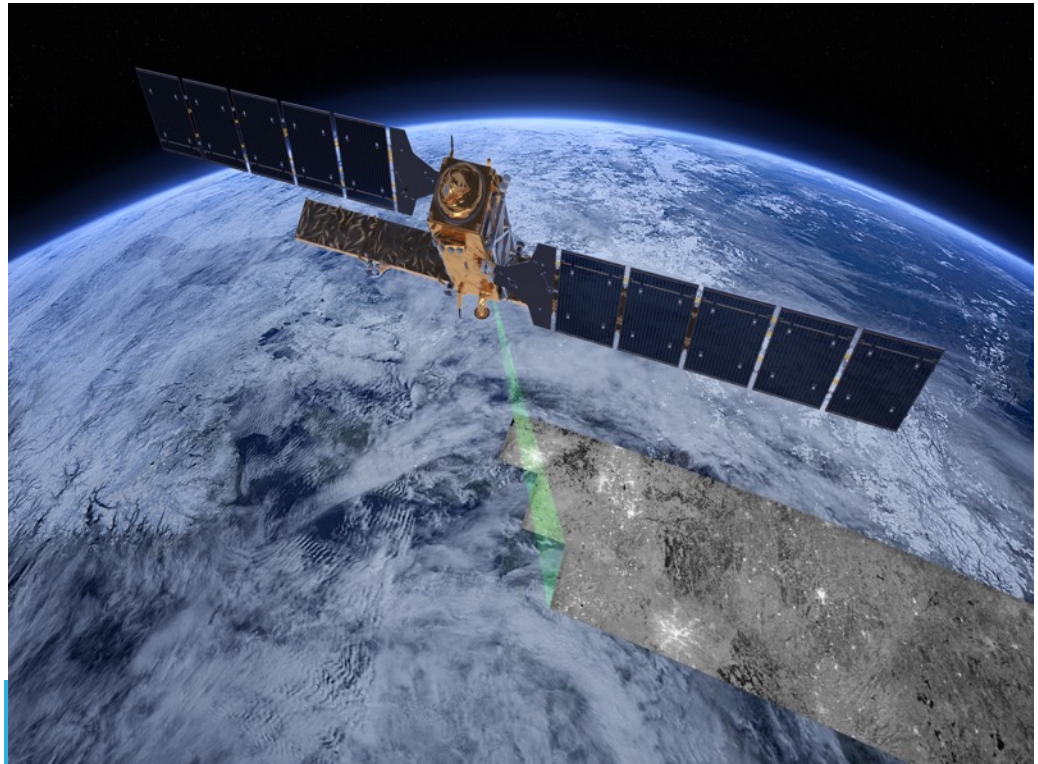


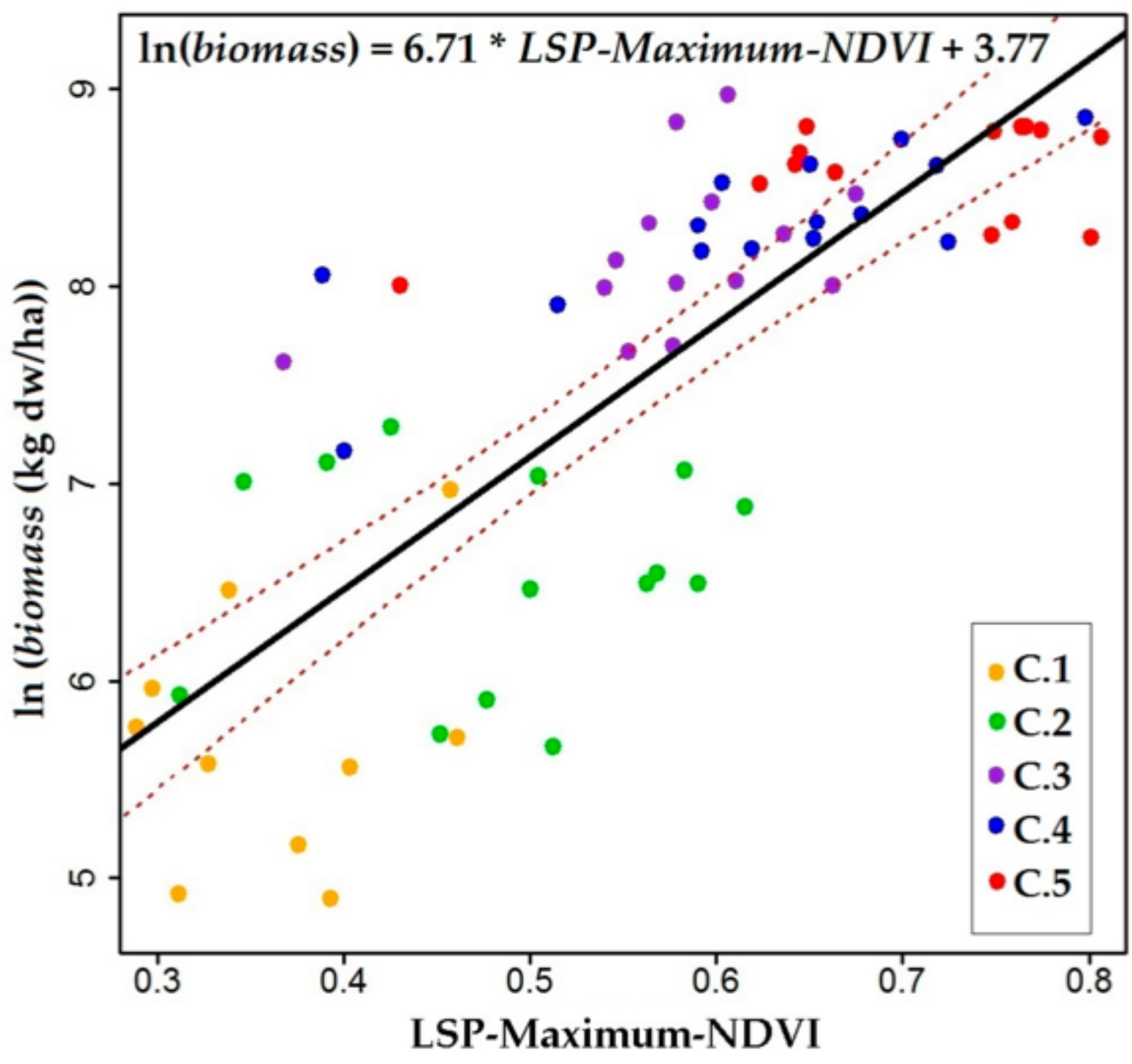
Remote sensing of biomass

- Remote sensing sensors do not measure biomass

- Biomass is estimated from RS signal using **empirical models calibrated with ground data**

- Sensors:
  - Optical (canopy properties)
  - Lidar (vertical structure)
  - Radar (canopy and structure)





ln(biomass) = 6.71 * LSP-Maximum-NDVI + 3.77
ln (biomass (kg dw/ha))
9
8
7
6
5
0.3
0.4
0.5
0.6
0.7
0.8
LSP-Maximum-NDVI
C.1
C.2
C.3
C.4
C.5

Maps vs. Plots

Differences between plots and pixels

Spatial mismatch
- NFI plot area: < 1 ha
- NFI released: 1 Km
- Biomass maps: 1 Km

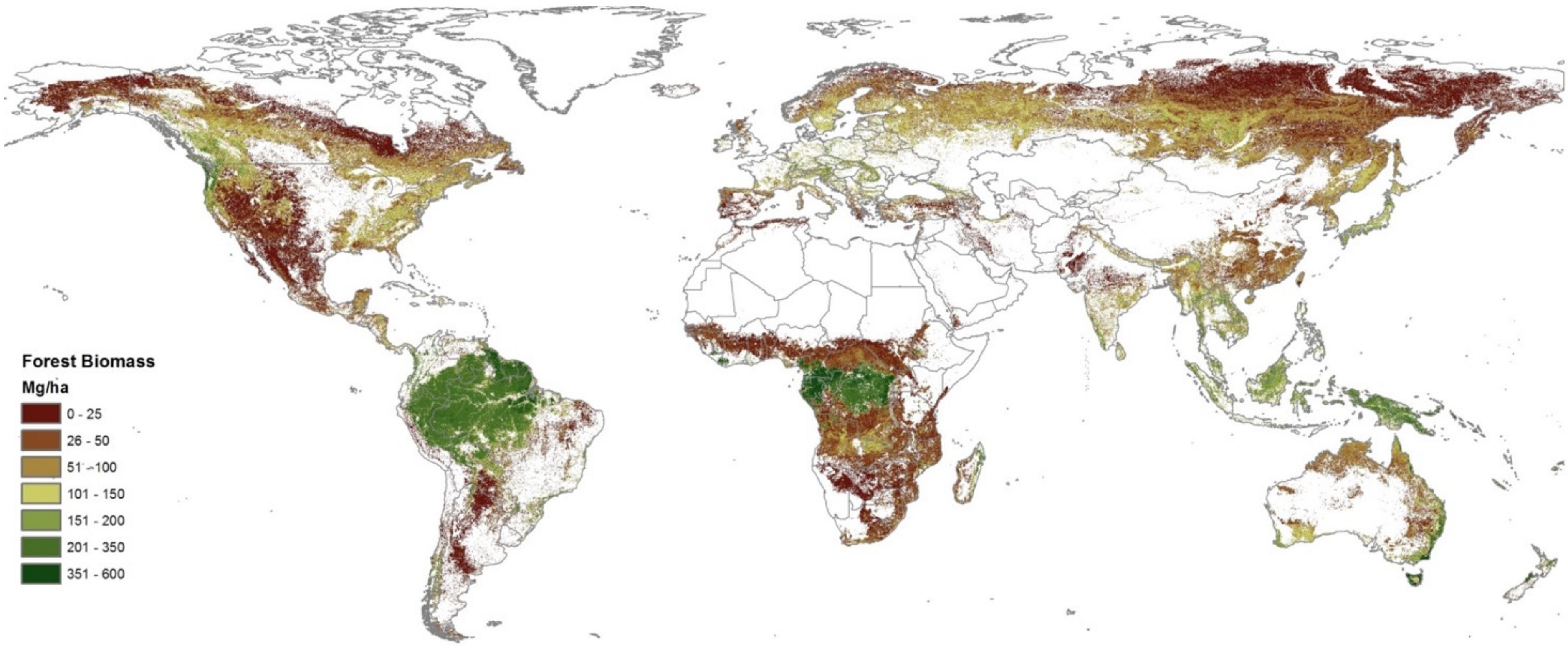
Remove non-representative plots:
- Using tree cover density (%)

Temporal mismatch
- NFI plots cycle: 2001 - 2013
- Biomass maps: 2000 or 2010

Synchronize plots and maps:
- Using growth rates (Mg/ha/yr)

Global map

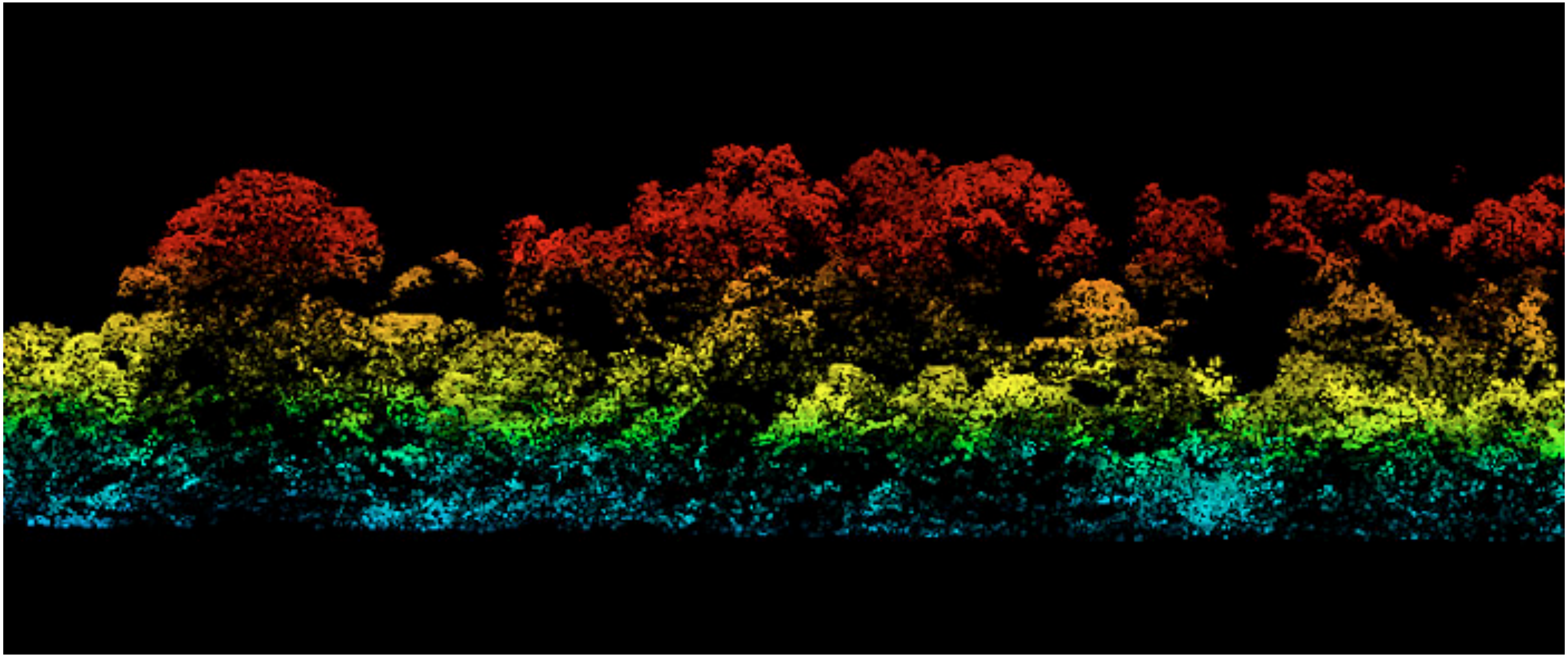
Tropical map + Boreal map (1 Km)



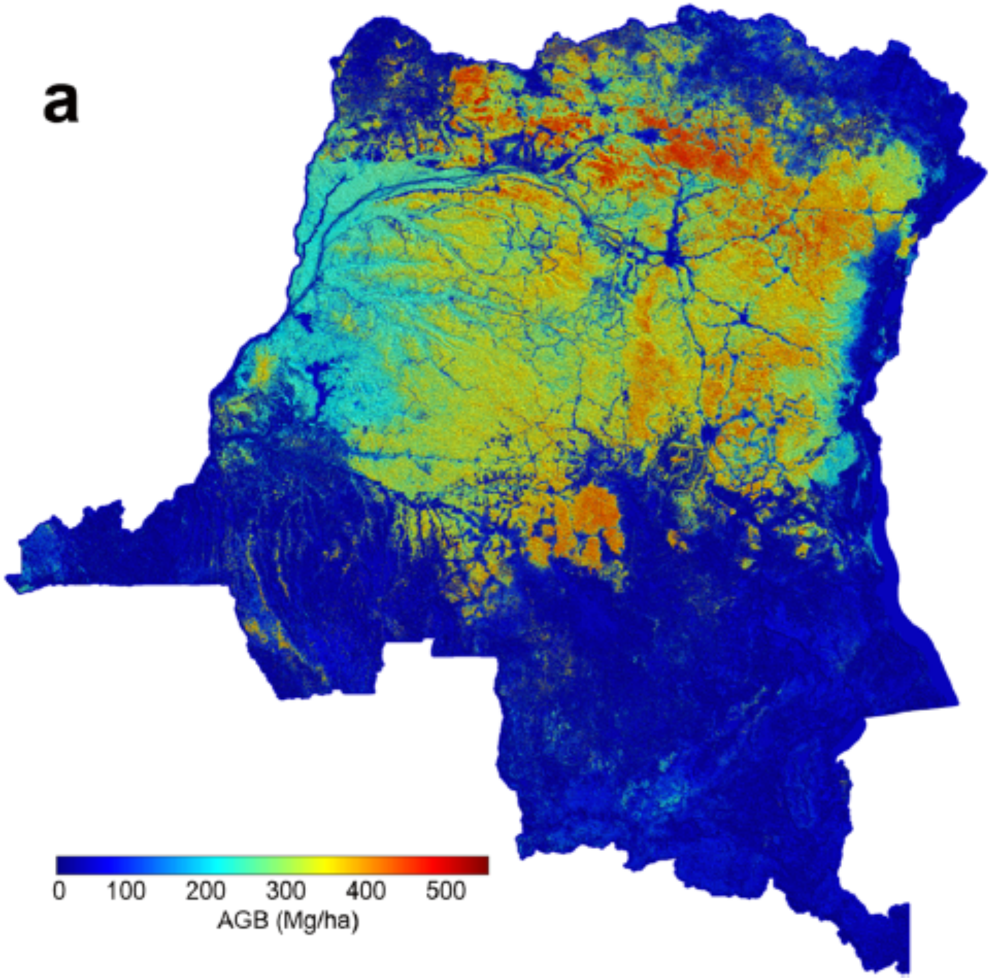
Avitabile et al., 2016

National maps

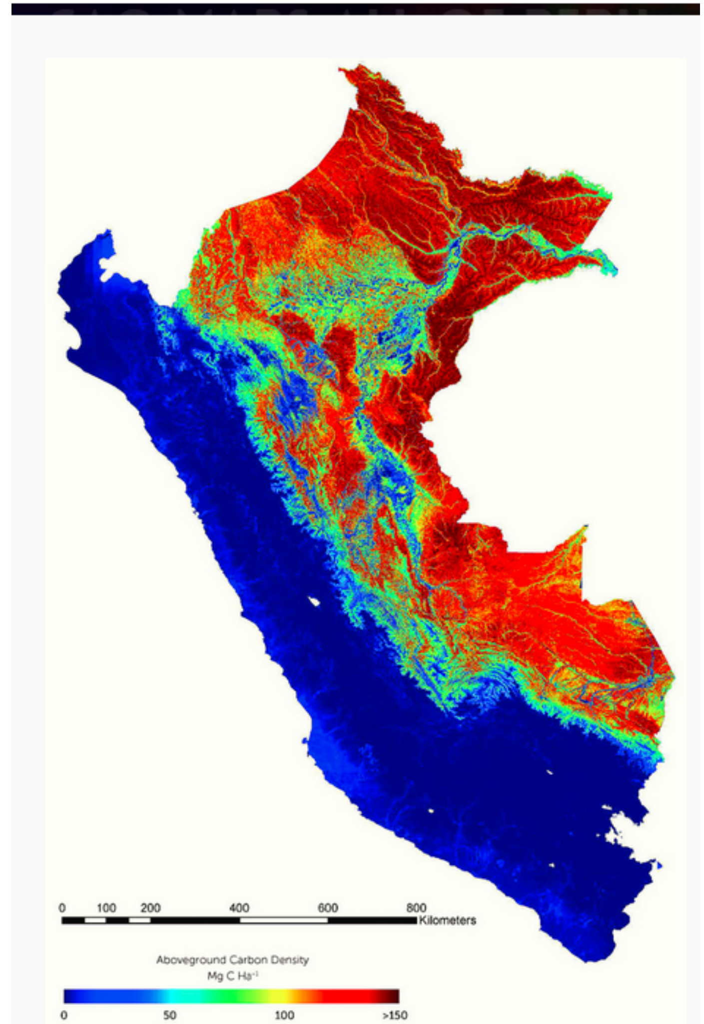
- Nationally-calibrated maps @100m
- Optical/radar + Airborne Lidar + ground data



National maps



Xu et al., 2017 (Nature SR)

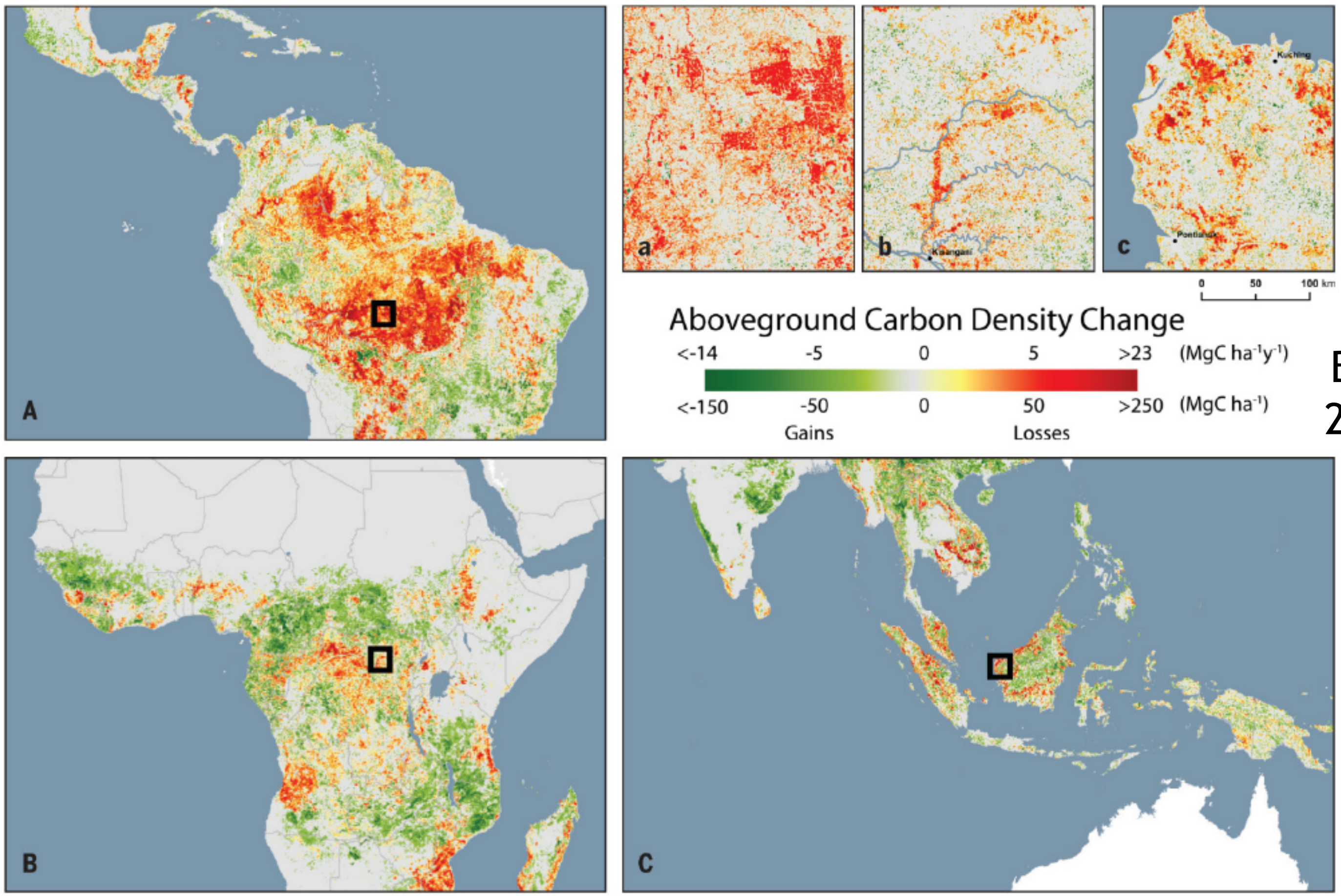


Asner et al., 2013 (PNAS)

Biomass change

Map of Biomass growth and loss (500 m)

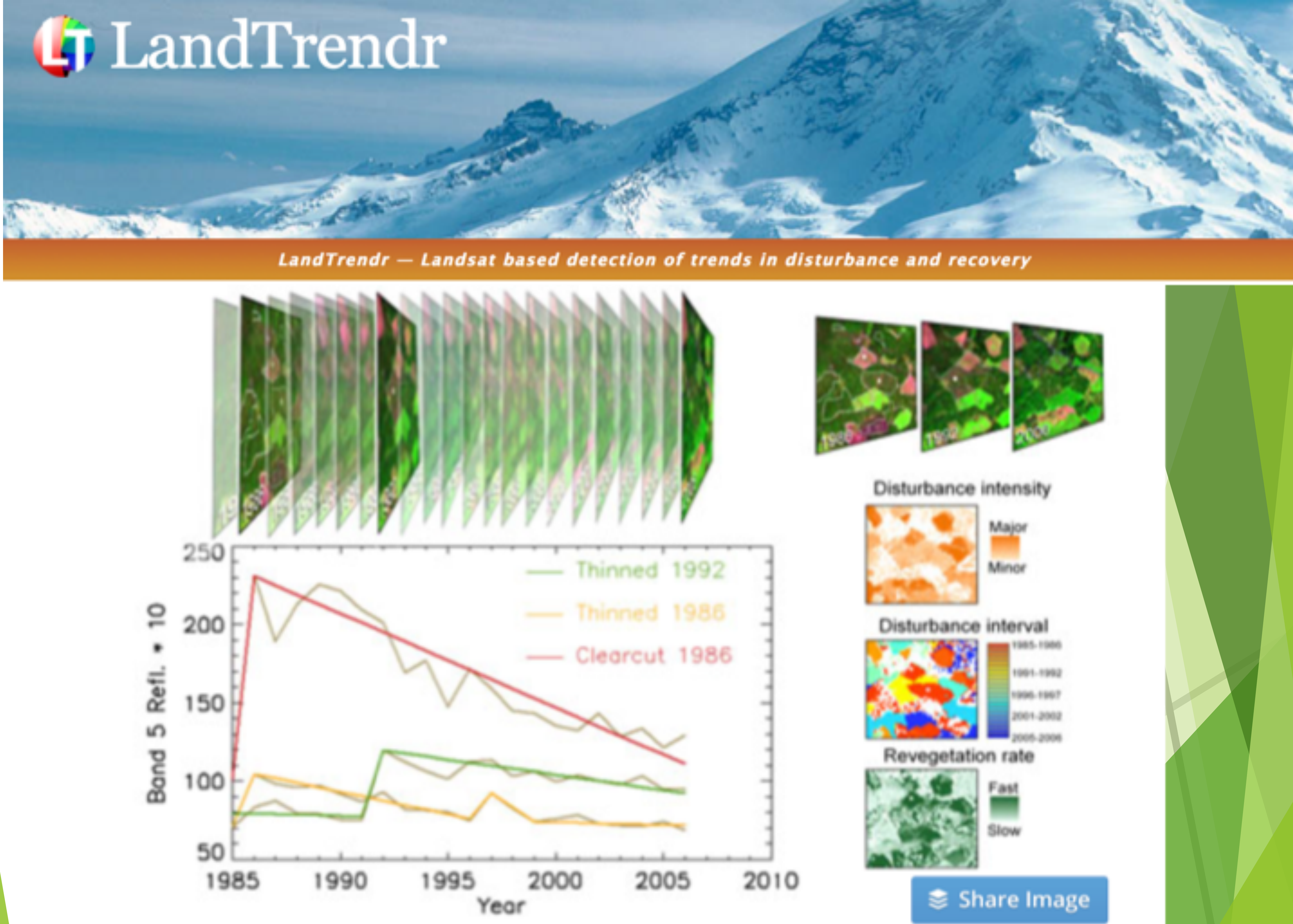
Time-series of Optical data: 2003 - 2014

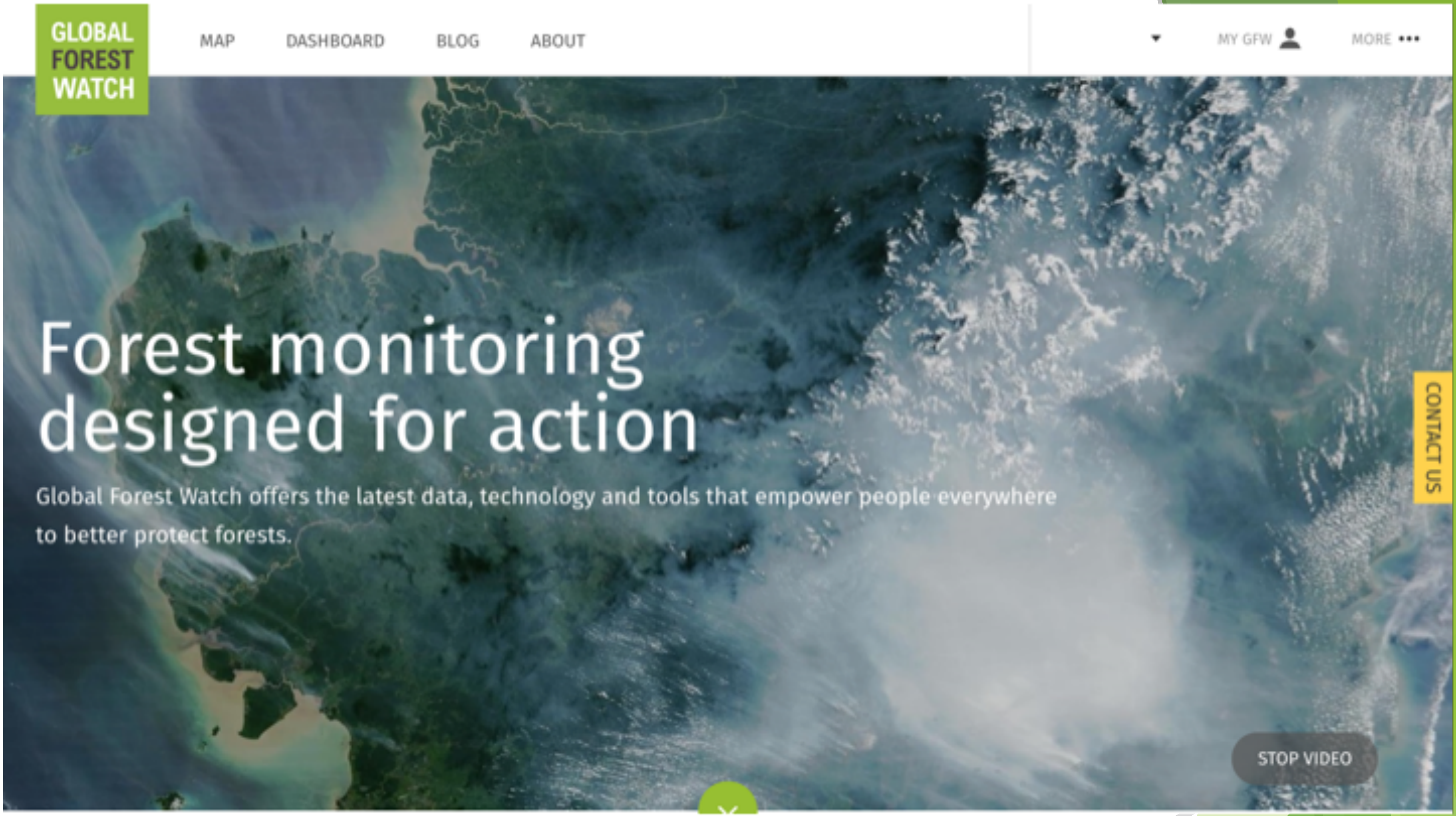


Baccini et al., 2017 (Science)

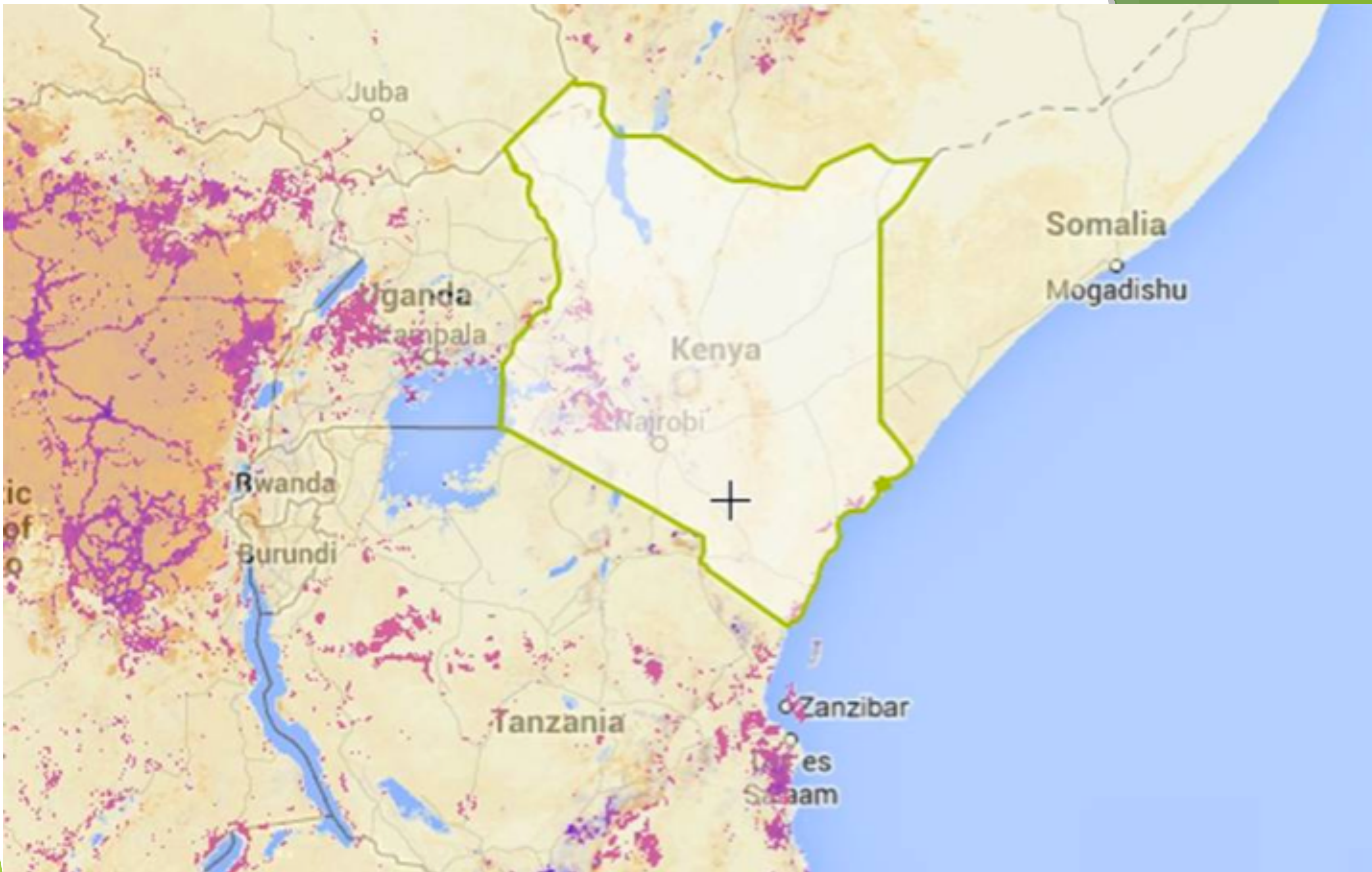
Types of change to observe:

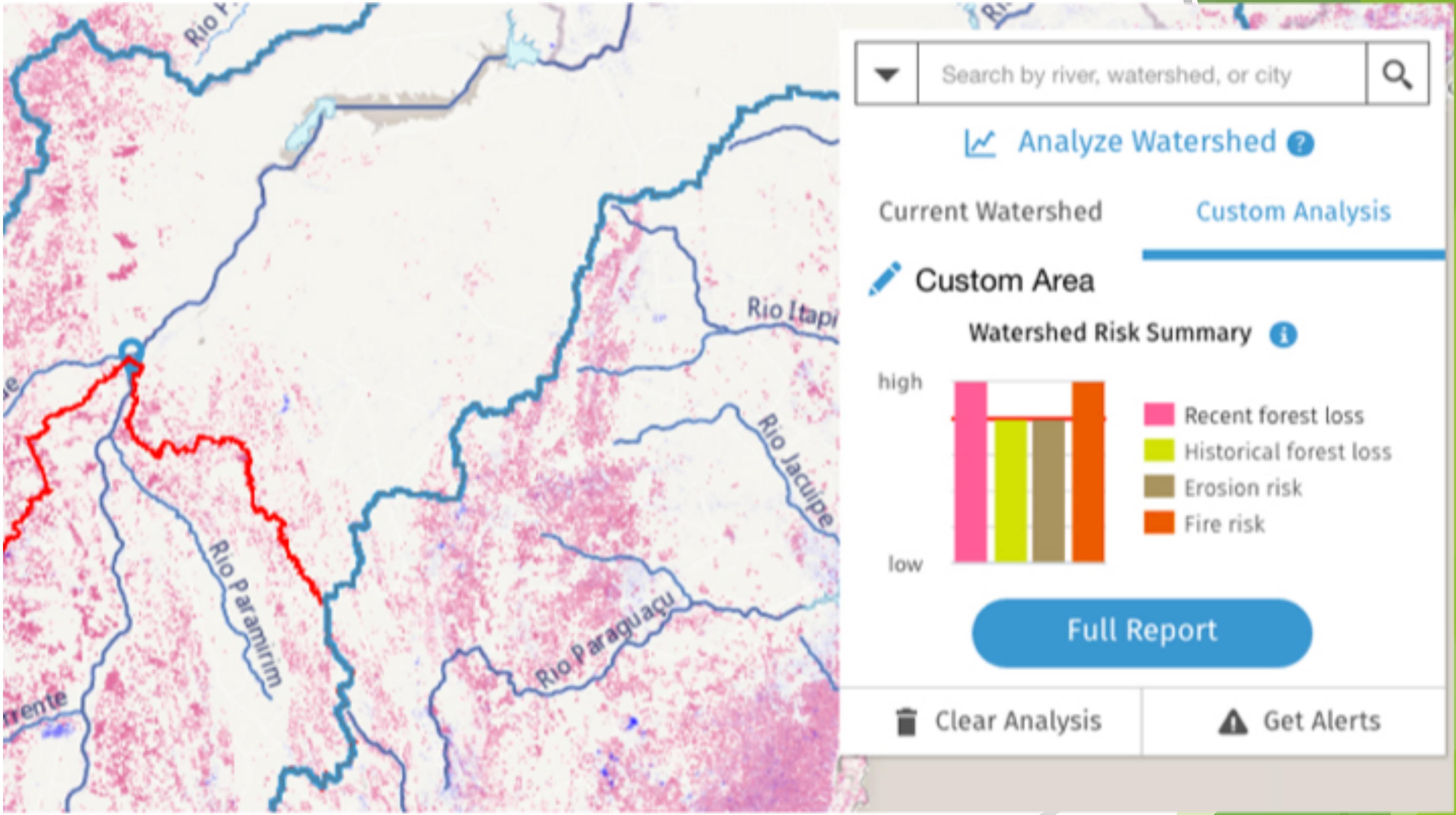
- short term change (synoptic weather events)
- cyclic change (seasonal phenology)
- directional change (urban development)
- multidirectional change (deforestation & regeneration)
- event change (catastrophic fires)


LandTrendr
LandTrendr — Landsat based detection of trends in disturbance and recovery
Disturbance intensity
Major
Minor
Disturbance interval
Revegetation rate
Fast
Slow
Thinned 1992
Thinned 1986
Clearcut 1986
Band 5 Refl. * 10
250
200
150
100
50
1985
1990
1995
2000
2005
2010
Year
Share Image

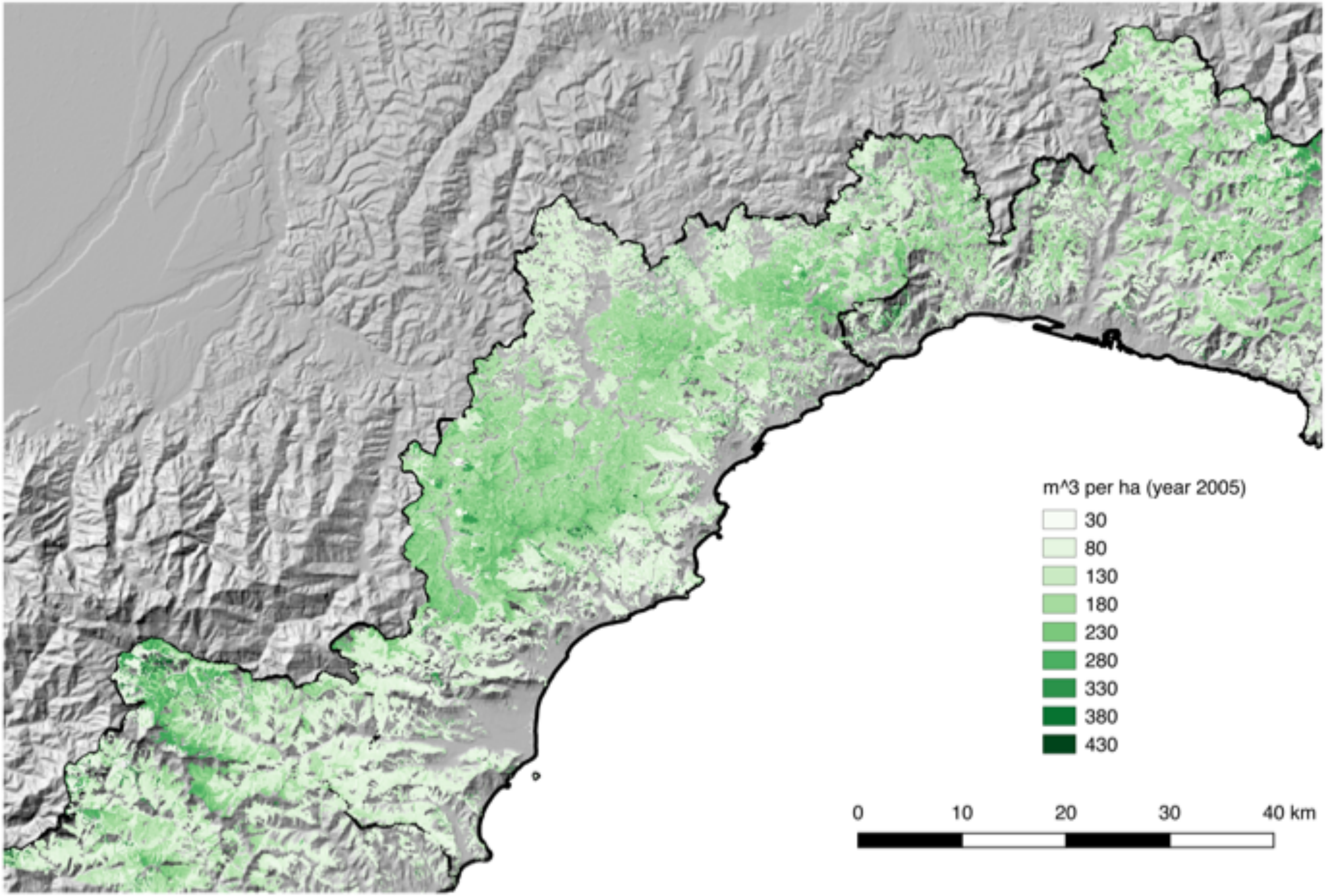


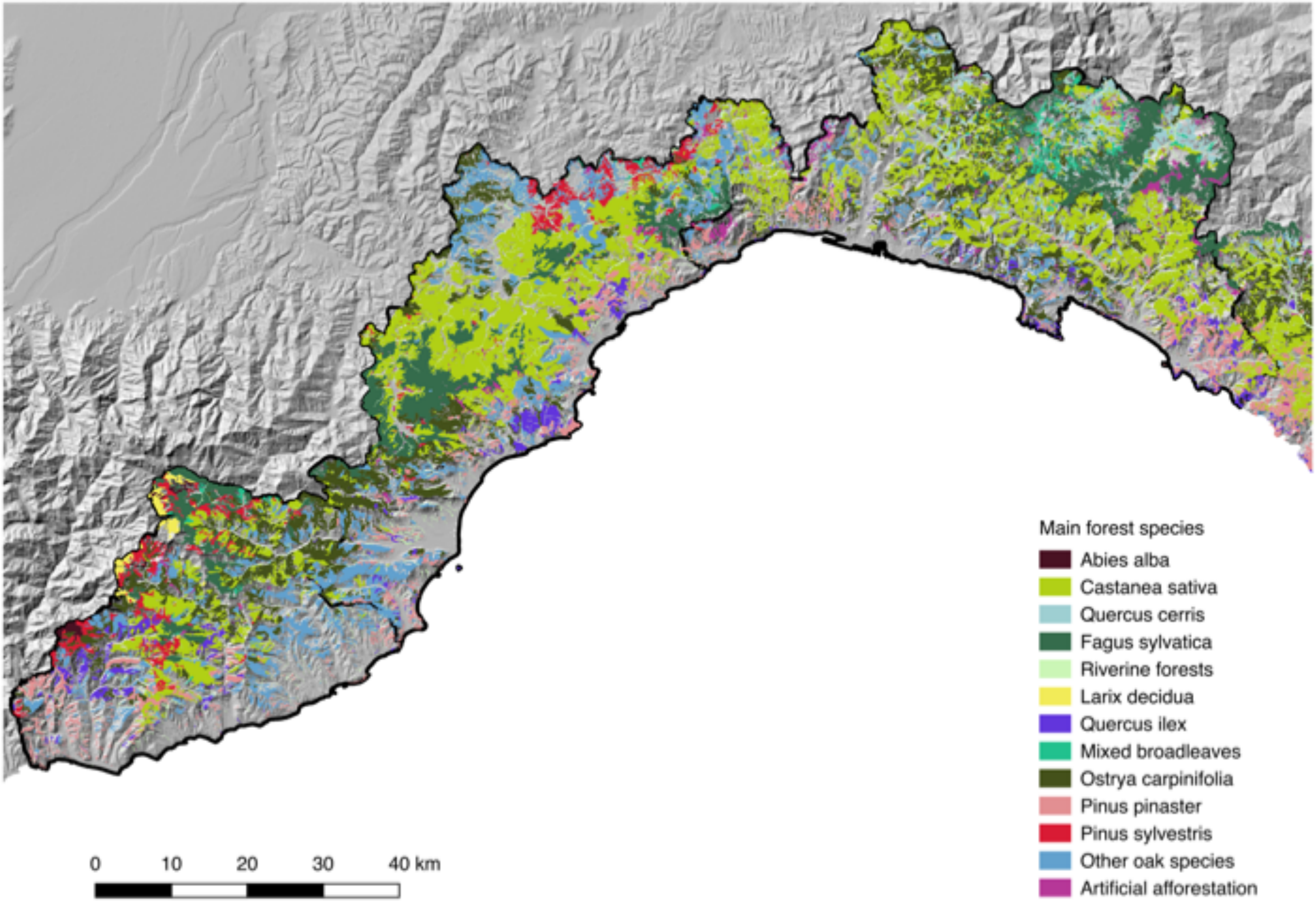
https://www.youtube.com/watch?v=s4HhoSbOgUc

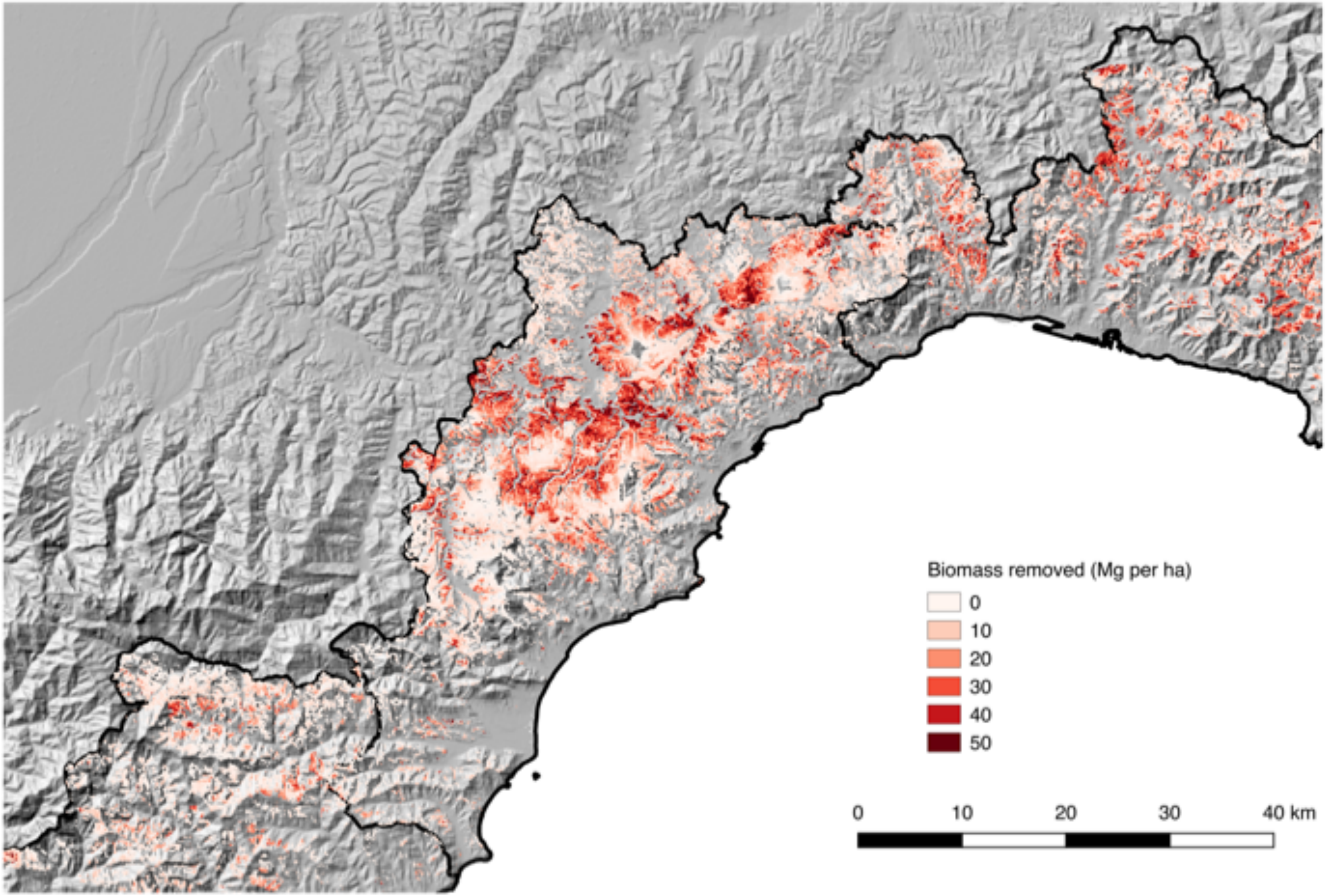

Juba
Uganda
Kenya
Nairobi
Somalia
Mogadishu
Rwanda
Burundi
Tanzania
Zanzibar

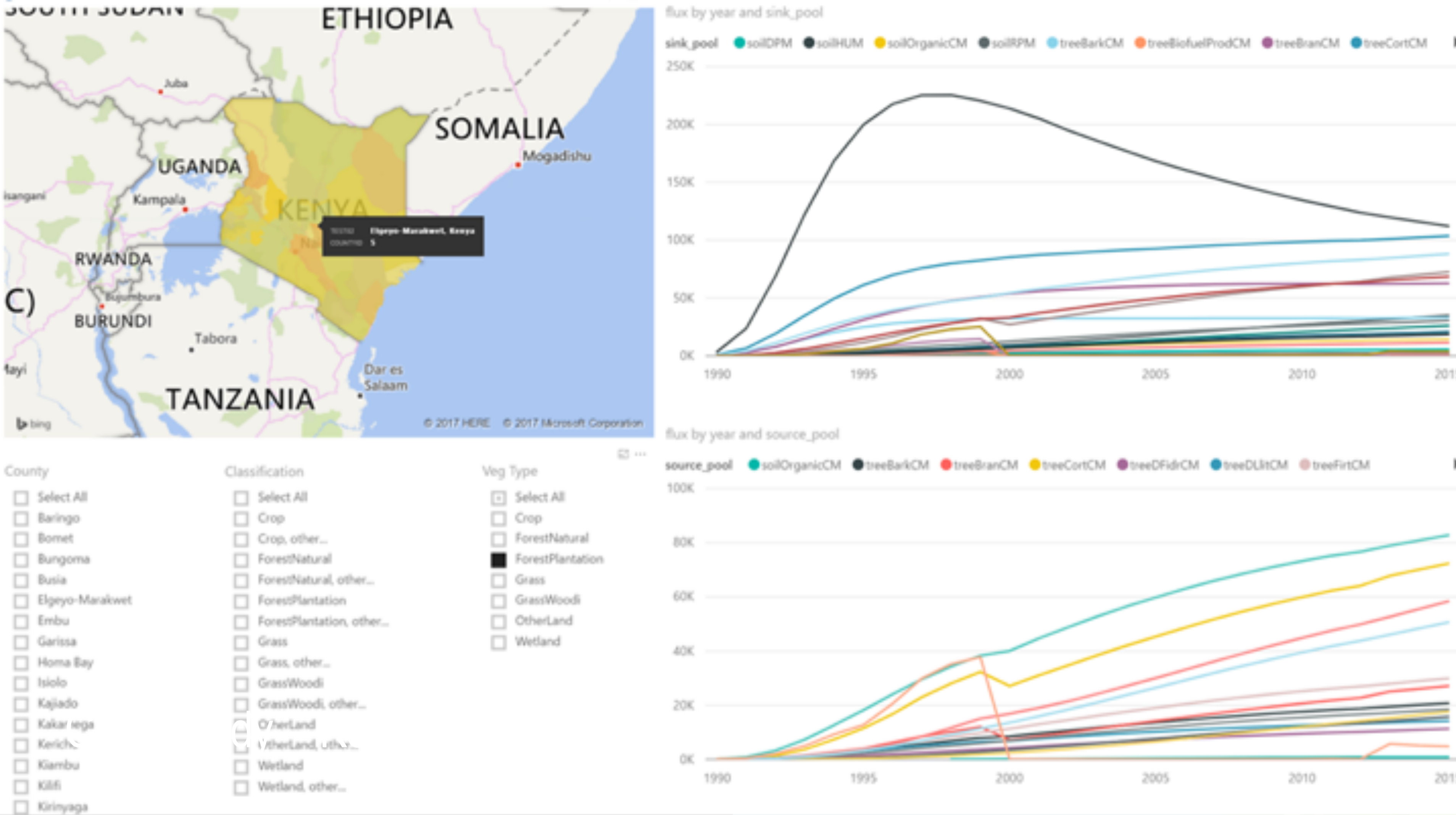


Search by river, watershed, or city
Analyze Watershed
Current Watershed
Custom Analysis
Custom Area
Watershed Risk Summary
high
low
Recent forest loss
Historical forest loss
Erosion risk
Fire risk
Full Report
Clear Analysis
Get Alerts
Rio Itapi
Rio Jacuipe
Rio Paramirim
Rio Paraguacu


m^3 per ha (year 2005)
30
80
130
180
230
280
330
380
430
0
10
20
30
40 km


Main forest species
Abies alba
Castanea sativa
Quercus cerris
Fagus sylvatica
Riverine forests
Larix decidua
Quercus ilex
Mixed broadleaves
Ostrya carpinifolia
Pinus pinaster
Pinus sylvestris
Other oak species
Artificial afforestation
0
10
20
30
40 km


Biomass removed (Mg per ha)
0
10
20
30
40
50
0
10
20
30
40 km



- Government of Kenya - Aim: estimation of GHG emissions from all land uses
- Assessment Area: Entire Country, 582,650 sq km
- 30k+ unique attribute data layers
- ~800 million locations (~25 meter pixels) analyzed
- Daily data sets for prior 24 years
- Delivered temporal trends and spatial patterns of emissions for each pixel and aggregate reporting of national and regional areas

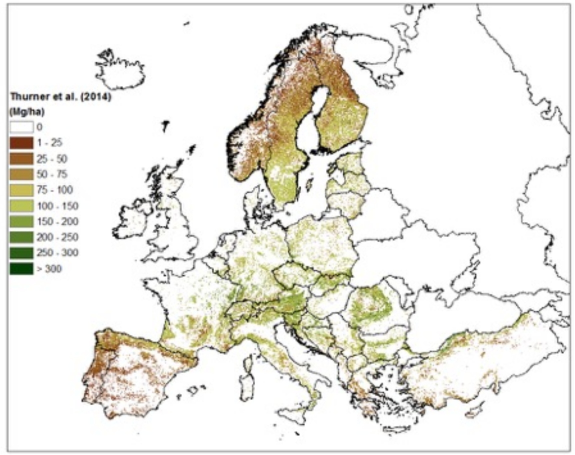
European
Commission

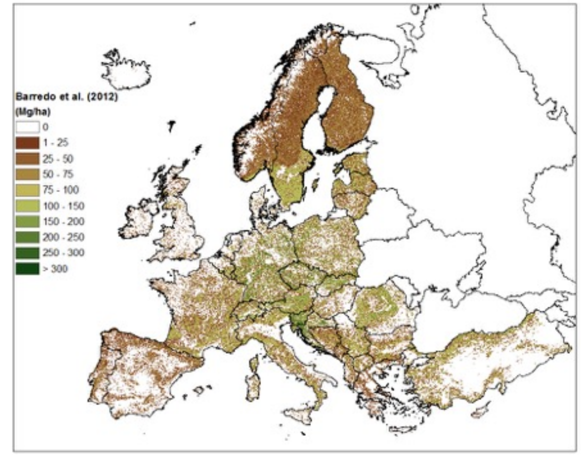
And….
What about Europe?

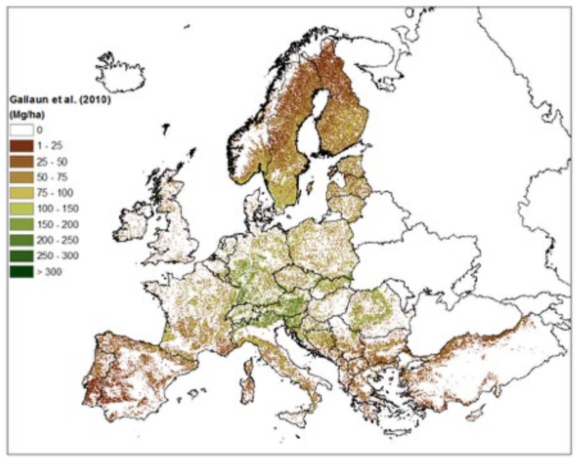
Maps for Europe

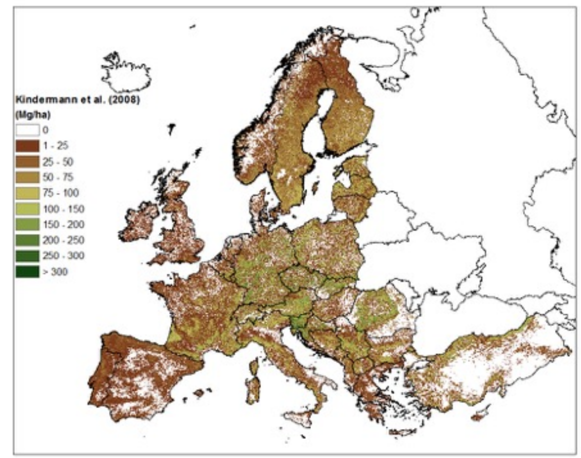
Biomass maps for Europe:

- Thurner et al. 2014
- Barredo et al. 2012
- Gallaun et al. 2010
- Kindermann et al. 2008









Map	Thurner	Barredo	Gallaun	Kindermann
Year	2010	2010	2000	2010
Resolution	0.01°	1 km	500 m	0.083°
Reference data	NFI Stats	IPCC Tier 1	NFI ground data	FRA 2005
Spatial data	Satellite (ASAR)	Land Cover (CORINE)	Satellite (MODIS)	Satellite (MODIS NPP)
Forest mask	GLC2000 (>50%)	CORINE	CORINE, FRA	GLC2000 (>20%)

Biomass in Europe

Reference data:

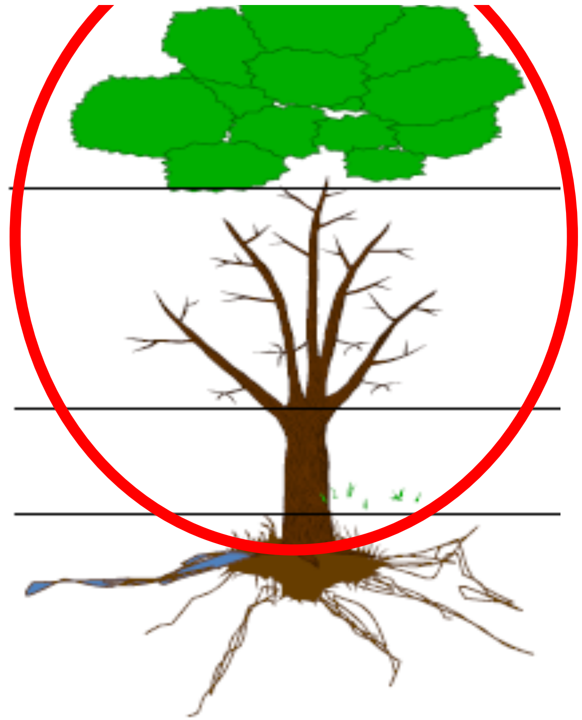
- National Forest Inventory (NFI) -> country-specific!

The harmonized forest biomass dataset:

- JRC: collaboration with 26 European NFIs to harmonize biomass, using:
  - Harmonized definition
  - Common estimator

26 countries with harmonized data

Harmonized Biomass definition



Biomass in Europe

Harmonized Statistics:

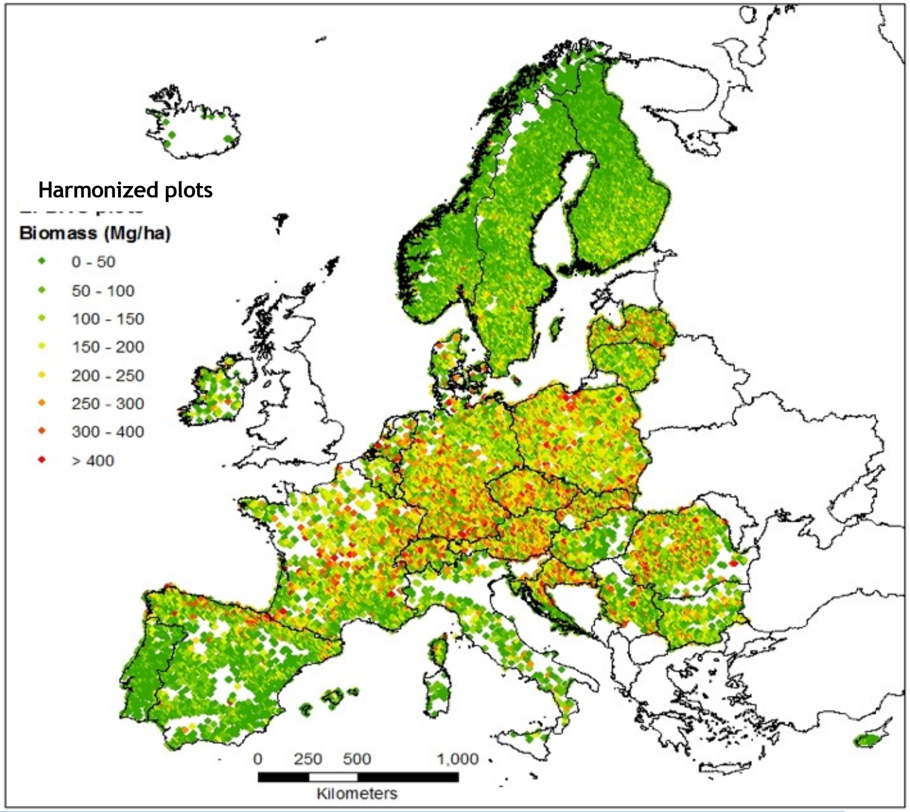
- Based on ~500,000 plots
- Biomass (±SE) at sub-national level

National vs. Harmonized stats:

- Significant differences for 14 countries

Plots:

- Subset of 22,166 plots
- Geolocation @ 1km



Total biomass stock (Tg)			
	National definition	**Harmonized definition**	**Difference definition (%)**
National estimator	16,234	16,907	4.1%
Common estimator	16,213	16,846	3.9%
Difference estimator (%)	-0.13%	-0.36%	3.8%

ESA GlobBiomass

European
Commission

GlobBiomass Project (2015 - 2017)

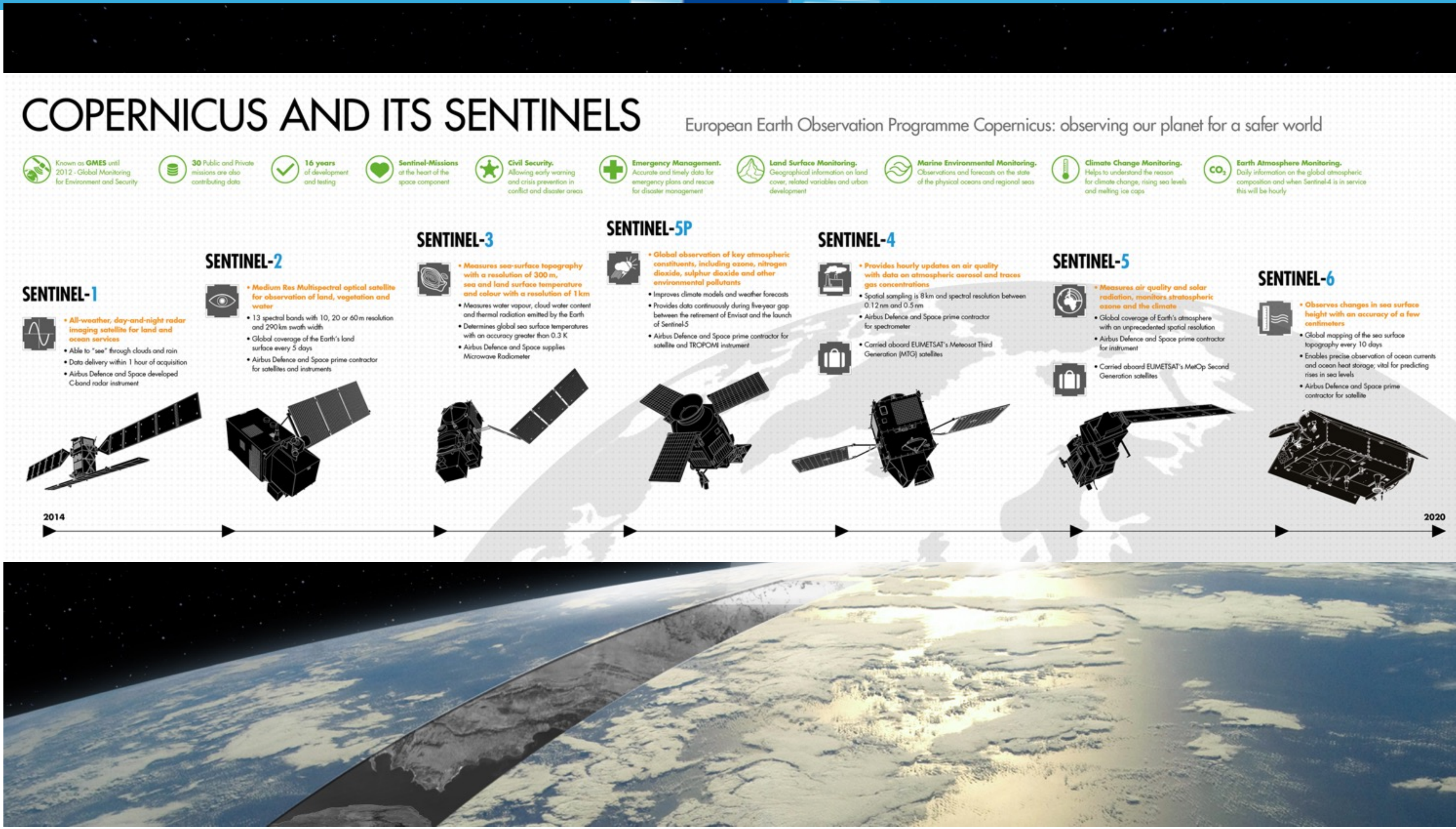
- Global map for 2010 (100 m)
  - Combination of Radar, LiDAR and Optical data
  - DUE: Data User Element
- JRC: User
  - Assessment of Volume and Biomass map for Europe

GlobBiomass 2: in preparation

European Space Agency

Joint
Research
Centre

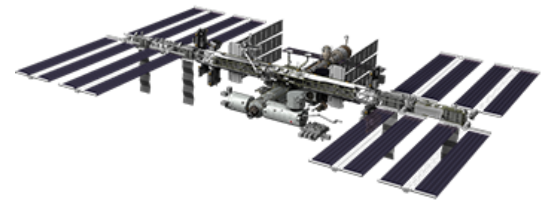
Copernicus Programme

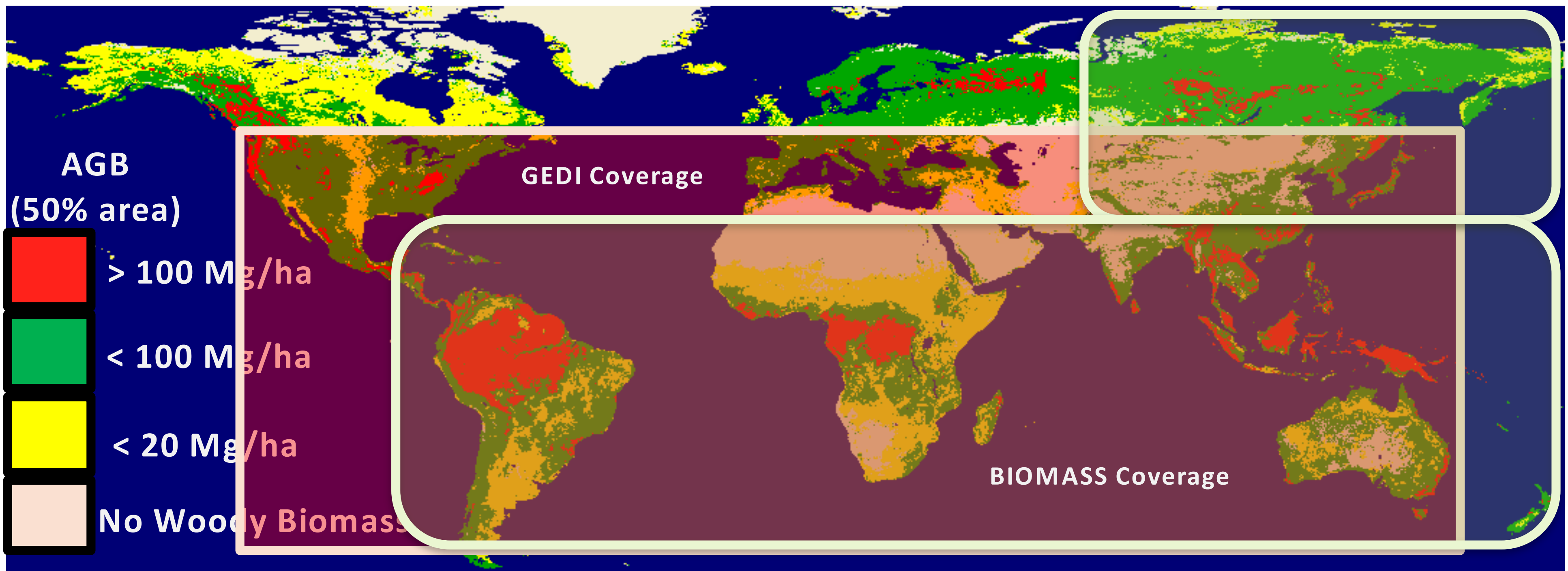


Joint Research Centre

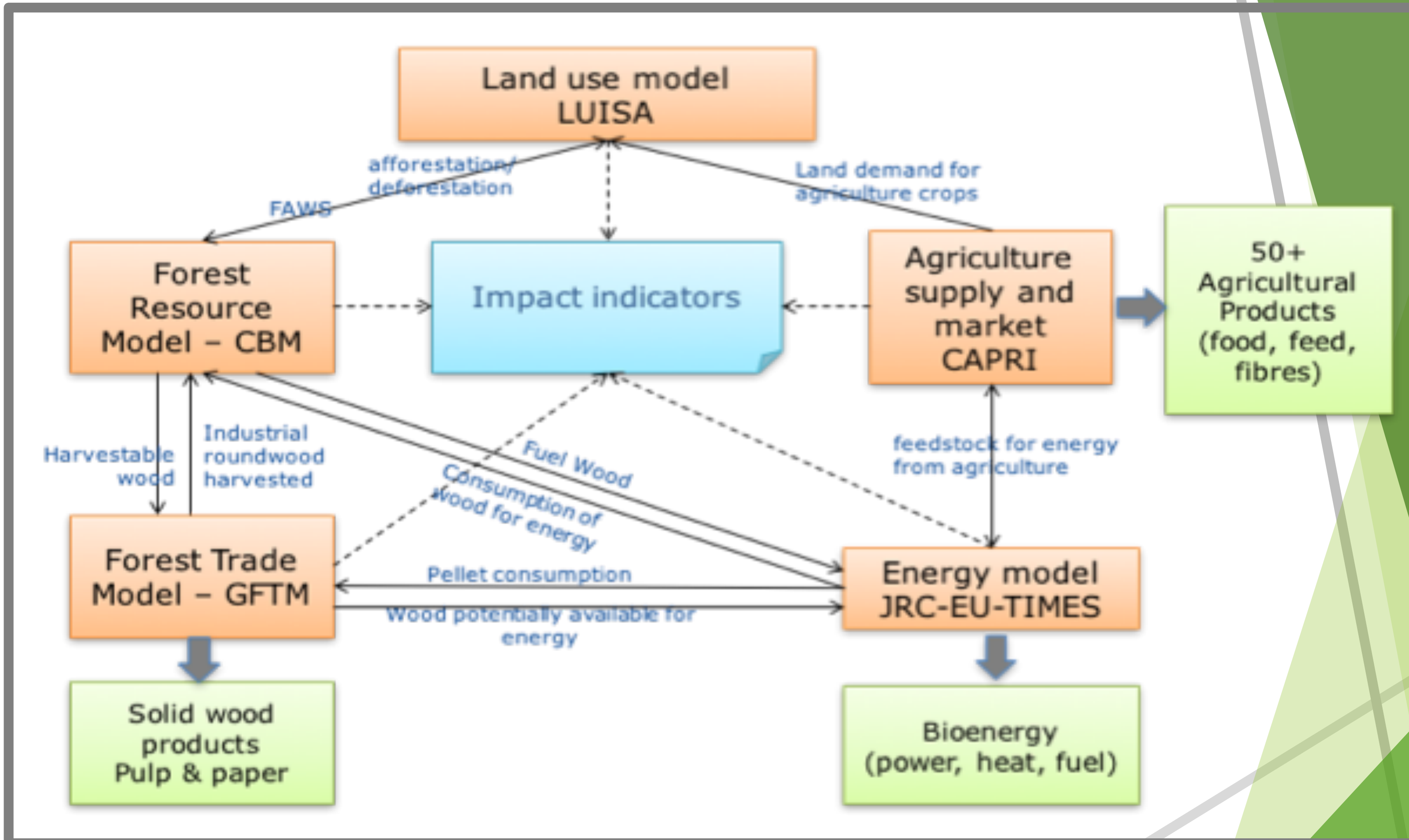
Upcoming satellites

- **GEDI (NASA) - 2019**
  - Lidar, 25m - Biomass (>20 t/ha) - Below 50° N
- **NISAR (NASA) - 2020**
  - Radar (L), 25m - Biomass (<100 t/ha) & changes - Global
- **BIOMASS (ESA) - 2021**
  - Radar (P), 200m - Biomass (>50 t/ha) - Tropics





Integrated Modelling Framework EU



DISAFA Dipartimento di Scienze Agrarie, Forestali e Alimentari

NatRisk

UNIVERSITÀ DEGLI STUDI DI TORINO

Voluntary carbon credits by forest management in the Italian Alps

Giorgio Vacchiano, R Berretti, F Piccobotta,

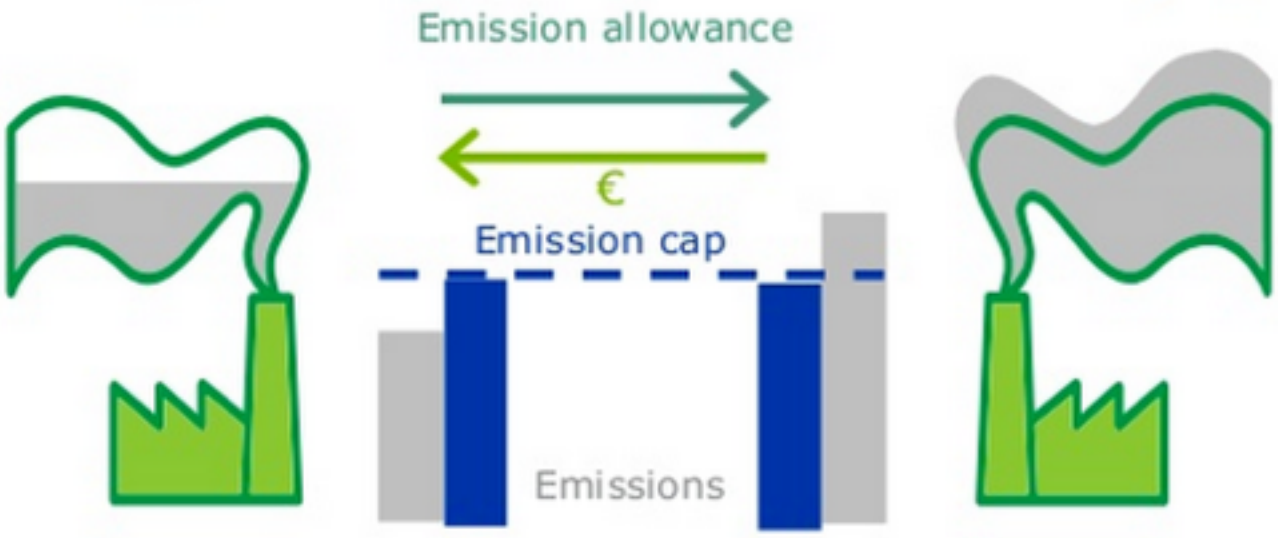
M Allocco, A Dotta, F Petrella, PG Terzuolo, R Motta

SEAcoop

Consorzio Forestale Alta Valle Susa
comunitá montana alta valle

ipla istituto per le piante da legno e l'ambiente ipla spa
società controllata dalla Regione Piemonte

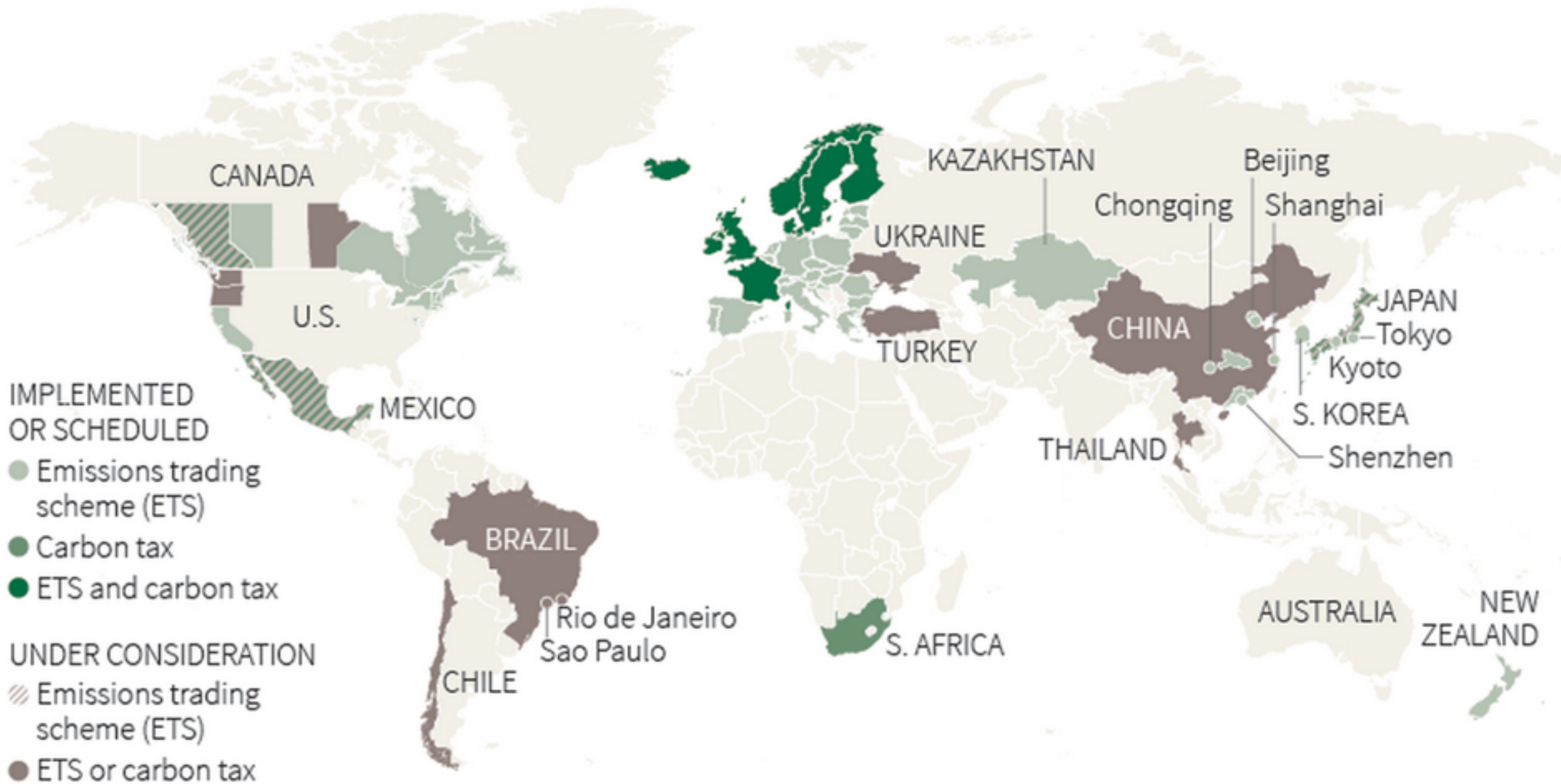
1. Cap-and-Trade / Emissions Trading System



Cap on emissions: entities can trade (EU ETS, California)

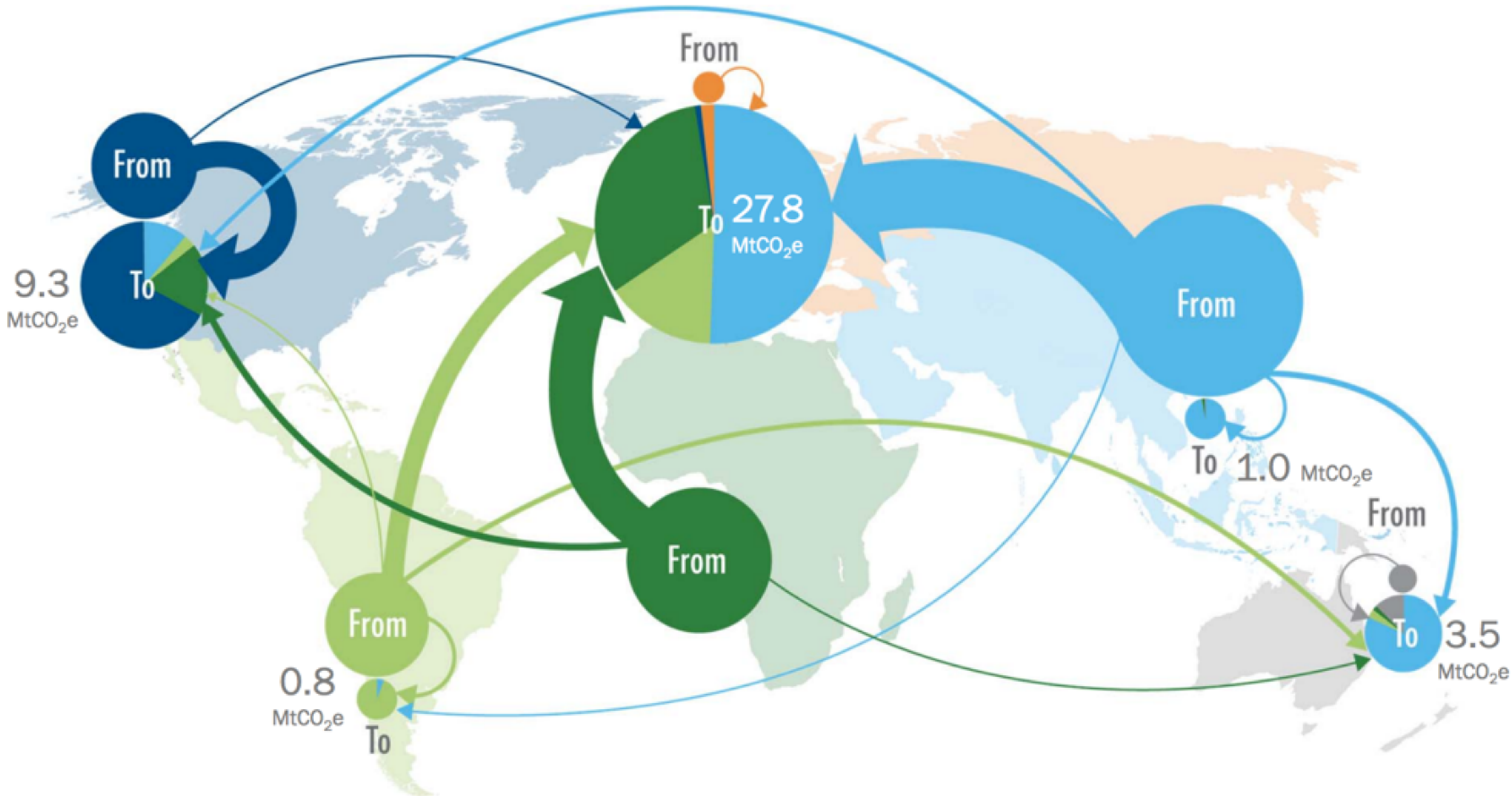
2. Baseline-and-crediting System

No cap on emissions: but credits can be traded to those under a mandatory or voluntary cap

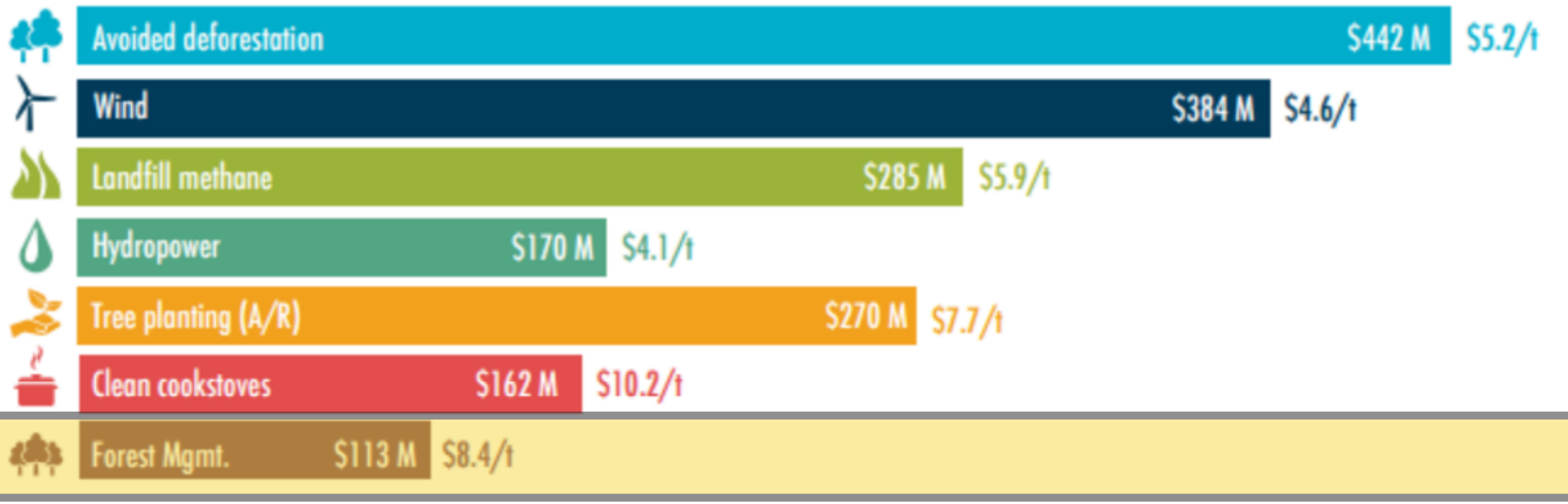

CANADA
U.S.
MEXICO
BRAZIL
Rio de Janeiro
Sao Paulo
CHILE
KAZAKHSTAN
UKRAINE
TURKEY
S. AFRICA
CHINA
Beijing
Chongqing
Shanghai
Shenzhen
THAILAND
JAPAN
Tokyo
Kyoto
S. KOREA
AUSTRALIA
NEW ZEALAND
IMPLEMENTED OR SCHEDULED
Emissions trading scheme (ETS)
Carbon tax
ETS and carbon tax
UNDER CONSIDERATION
Emissions trading scheme (ETS)
ETS or carbon tax

Flow of Transacted Offset Volumes from Supplier to Buyer Region, 2013

% share and Sized by Volume



SOURCE: Forest Trends' Ecosystem Marketplace. State of the Voluntary Carbon Markets 2014.



Notes: Based on 412 MtCO2e in transacted offsets associated with a project type, 2007-2014.
Source: Forest Trends' Ecosystem Marketplace. *State of the Voluntary Carbon Markets 2015*.

REGIONE PIEMONTE
Direzione OO.PP., Montagna, Foreste
Settore Foreste

Crediti di carbonio volontari da gestione forestale

Proposta di approccio per la Regione Piemonte

A cura IPLA S.p.A.

con la collaborazione di
Università di Torino - DISAFA
Fondazione per l'Ambiente Teobaldo Fenoglio
Consorzio Forestale Alta Valle di Susa
SEACoop

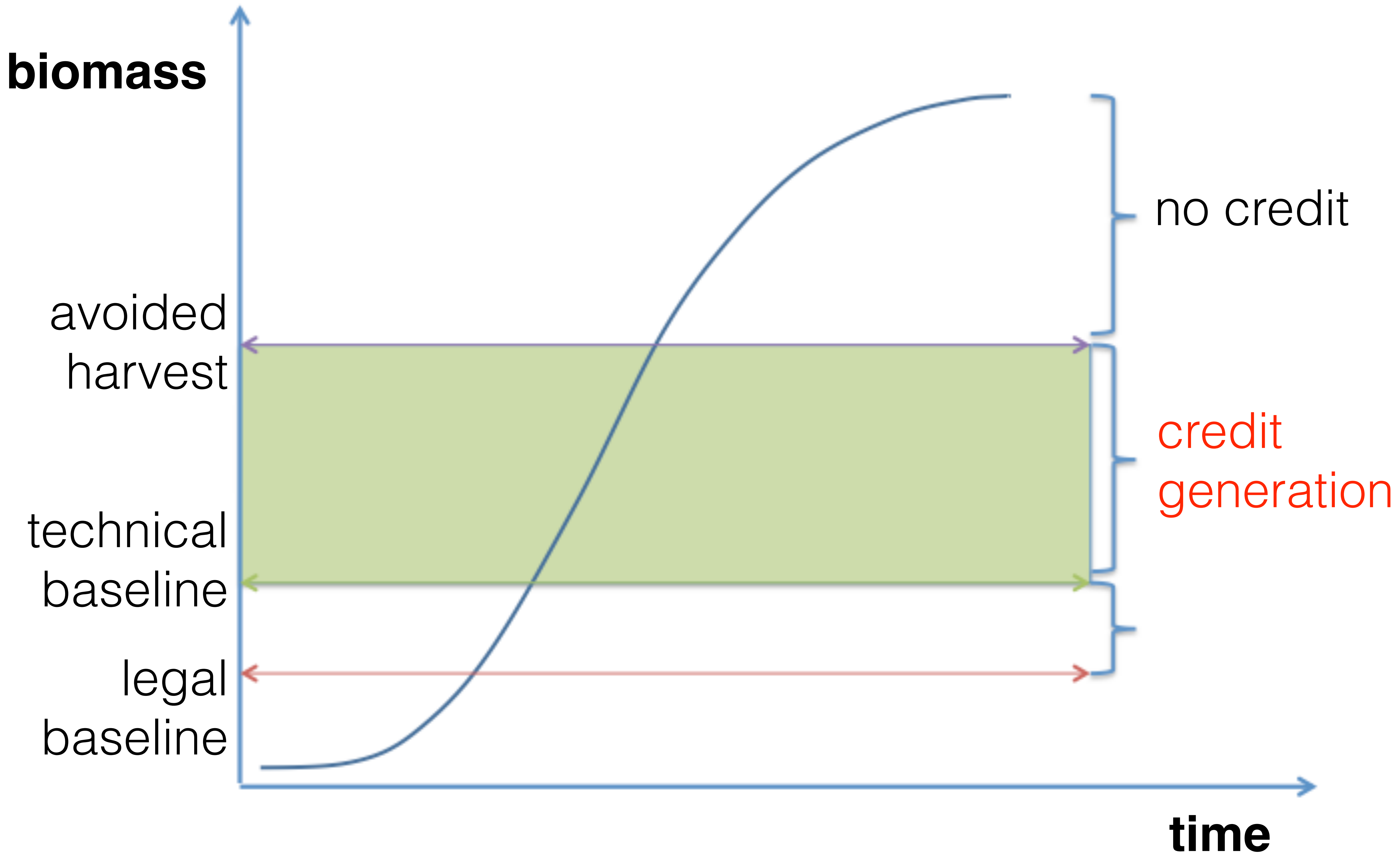
Secondo rapporto intermedio

Consorzio Forestale Alta Valle Susa
comunitá montana

istituto per le piante da legno e l' ambiente ipla spa
società controllata dalla Regione Piemonte

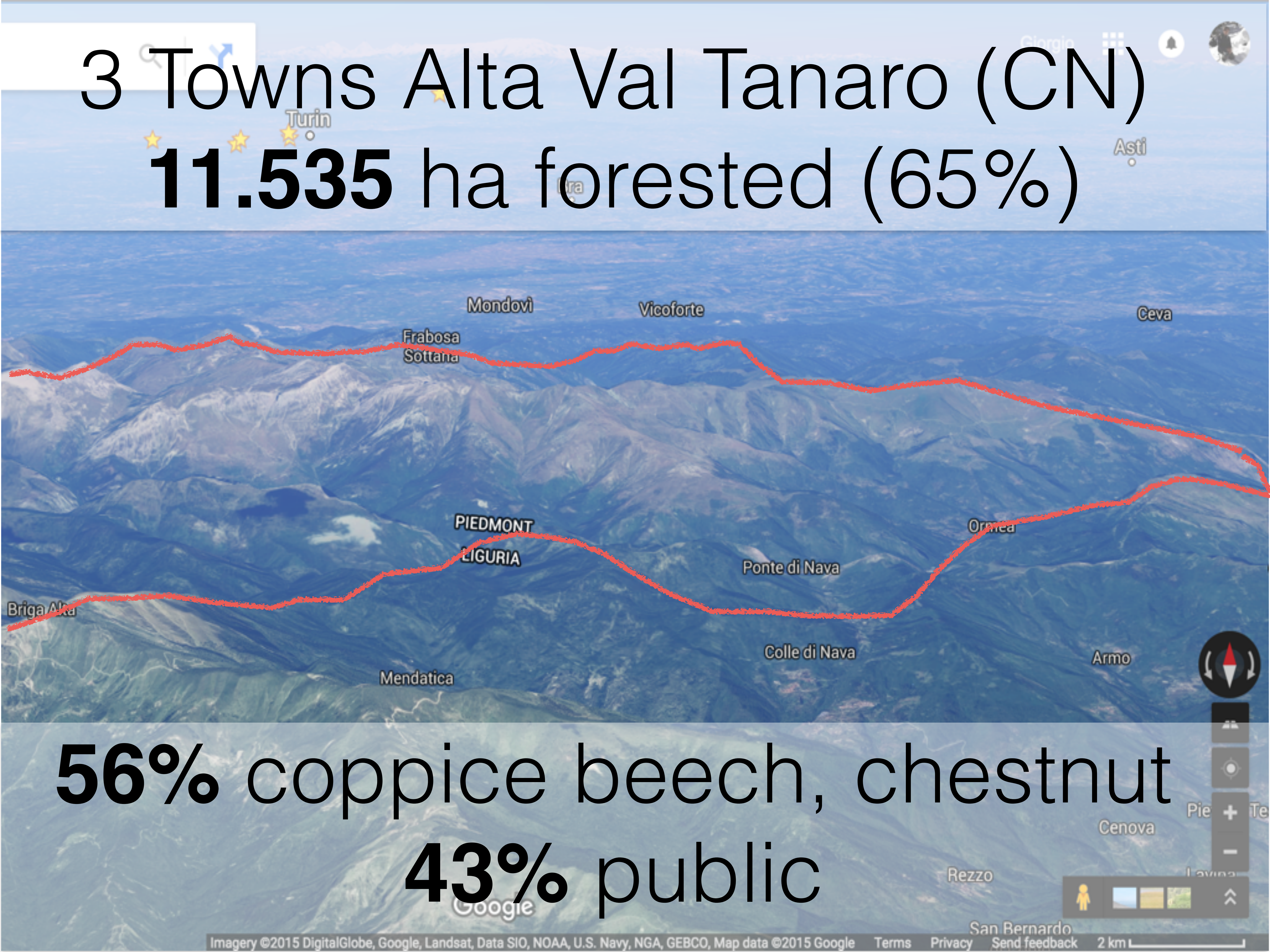
SEAcoop

UNIVERSITÀ DEGLI STUDI DI TORINO


biomass
avoided
harvest
technical
baseline
legal
baseline
no credit
credit
generation
time

3 Towns Alta Val Tanaro (CN)

11.535 ha forested (65%)



56% coppice beech, chestnut

43% public

Standing volume

inventory 2000 + increment INFC

(163 plots)

		fustaia	ceduo
AB	abetine di abete bianco	5,4	
AF	acero-tiglio-frassineti	4,5	5,1
AN	ontaneti		
AS			
BS	boscaglie pioniere d'invasione	4,5	5,1
CA	castagneti	5,4	6,1
CE	cerrete	4,5	1
FA	faggete	4,4	5,3
LC	lariceti	3,2	
OS	orno-strieti	1,8	3,6
OV	alneto ontano verde	4,5	5,1
PN	pinete di pino montano	3,1	
PS	pinete pino silvestre	3,1	
QC	querco-carpineti	1,8	3,6
QR	orno-querceto	1,8	3,6
QV	querceti di rovere	3,9	2
RB	robinieti	4,5	5,1
RI	rimboschimenti	5,8	
SP	saliceti arbustivi - pioppeti		

240 m^3 ha^{-1}

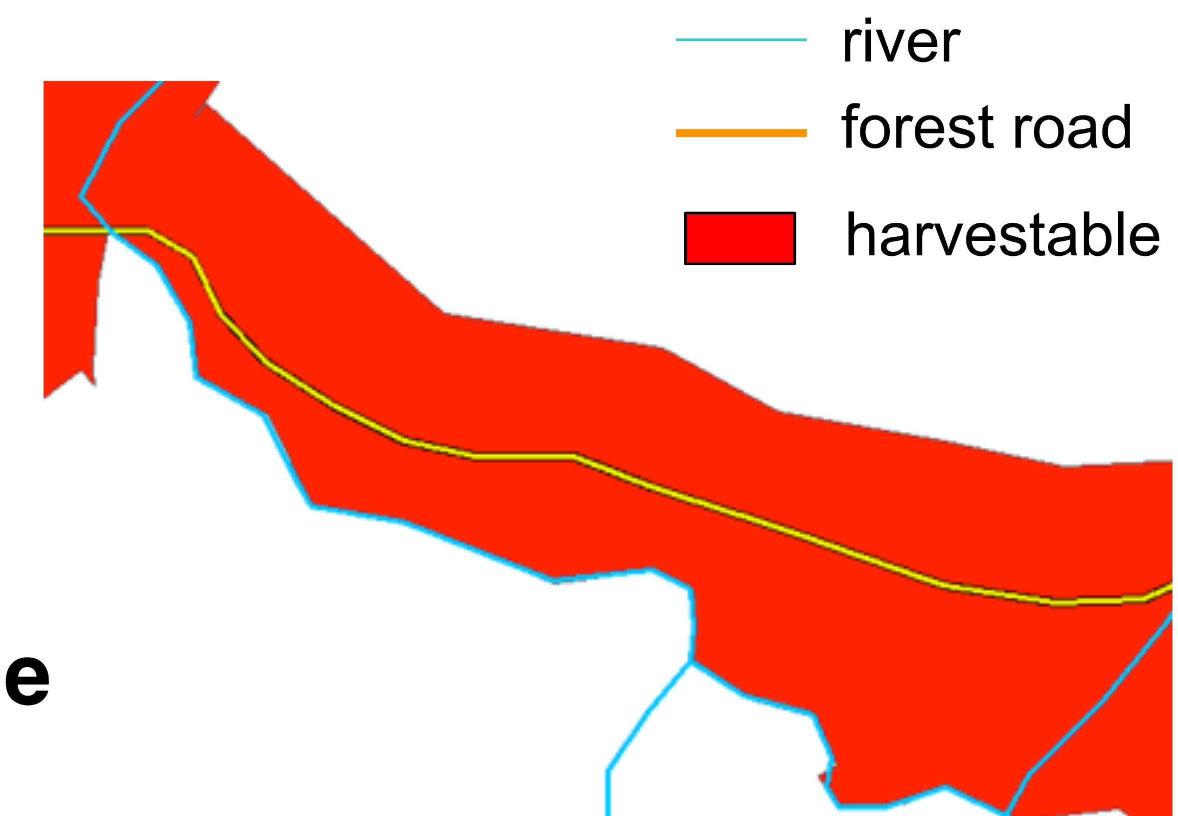
Exclusions

- wildfires 2000-2015
- harvest 2000-2015
- private land
- unmanaged forests
- low fertility sites
- protected areas

Harvestable area
winch / cable

Technical baseline
Harvest rates
180 authorizations

Legal baseline
Forest
Management Act



1550 ha

Management class	Legal baseline	Technical baseline
Coppice, age < 40 years	84% in beech	83% in beech
Coppice, age < 40 years,	84% in beech	80% in beech
Coppice, age < 40 years,	55%	50%
Coppice, age > 40 years,	60%	50%
Mixed coppice and high forest	60%	50%
Mixed coppice and high forest, conversion to high forest	55%	50%
High forest, even-aged, shelterwood	a	a
High forest, gap cut	40%	40%
Hig	66%	35% from above
Hig	70%	35% in conifers
Bla … nversion of coppice to high forest)	90%	87% if monospecific
Chestnut, regeneration cut (except conversion of coppice to high forest)	90%	90% if monospecific

115 m^3 ha^{-1}

Assortments

118 plots

forest type	% timber	% chips	% other
Silver fir	16	84	0
Larch	16	84	0
Scots pine	30	70	0
Afforestation	11	89	0
Chestnut	15	85	0
Hornbeam	0	25	75
Oaks	10	25	65
Beech	13	25	62

Managing for carbon

Silver fir **Scots pine** **Larch**	high forest	gaps (30% volume)	→	cable
Chestnut **Oaks** **Hornbeam**	coppice	coppicing (70% volume)	→	cable
Beech	coppice	conversion (40% volume)	→ $>100\ m^3\ ha^{-1}$ →	cable
			→ $<100\ m^3\ ha^{-1}$ →	winch
Beech	high forest	thinning (30% volume)	→	winch

o

$89\ m^3\ ha^{-1}$

$$Ct_{co2e} = [(1-d_i) \times (Rp_i - Rr_i) \times BCEF_i] \times Sb \times 0.5 \times 44/12$$

disturbances (12%)

avoided harvest

biomass expansion factors

area

Emission Ratio Quality ($kgCO_2\ m^{-3}$)

10 experimental harvest areas

Coppice: 21 $kgCO_2\ m^{-3}$

Conversion: 16 $kgCO_2\ m^{-3}$

Forest type	Area	Avoided harvest	CO2	€	€ per ha
Silver fir	39	1080	1145	11449	291
Larch	313	887	0	0	0
Scots pine	27	737	959	9591	358
Afforestation	206	5641	5755	57550	279
Chestnut	95	2269	2958	29575	310
Hornbeam	105	2499	4054	40535	388
Oaks	3	68	123	1229	432
Beech	765	28680	47599	475990	622
total	**1 552 ha**	**41 861 m^3**	**62 592 t**	**625 919 €**	**403 € ha^{-1}**

Permanence: 20 years

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