ECOFYS

sustainable energy for everyone

Biofuels for sustainable transport

Carlo Hamelinck

Managing Consultant

2016 10 13

KIVI EnergyNL2050

Main messages

> Biomass is necessary and suitable alternative to fossil resources

> Biofuels are needed for transport, alongside electrification and other solutions

> There is increasing global interest, but role is currently modest

> European policy and market prospects are unclear

> Many types of fuels can be produced from all kinds of feedstock

> The climate performance of biofuels continuously improves – by law

> Indirect Land Use Change: it's complex and relevant, but also manageable

> Impact of biofuels on food prices is very small

> Biofuels' feedstock could be abundant – but this requires broader action

Why biomass?

Why biomass?

> Renewable and sustainable
  - Regrows
  - Reduces greenhouse gas emissions when replacing fossil resources
  - (After initial carbon investment and payback period)

> Versatile
  - Can provide base and peak load electricity
  - Complementary to other renewable energy sources
  - Many different energy products: power, heat, fuels for transport
  - Paves the road to biobased materials & chemicals
  - Only near term option for heavy transport, shipping, aviation

> Cost effective
  - Competitive with other renewable energy sources and with fossil
  - Works with existing infrastructure
  - Connects to existing business

> Secures energy supply
  - Many types of feedstock, including waste streams
  - Locally and globally available, sometimes abundant
  - Saves on oil import costs, diverts sourcing away from oil states

> Rural development
  - Employment opportunities along supply chain
  - Synergy with other agriculture

There's a need for sustainable biomass for "new" applications

> Biopower / heat



> Biofuels


> Biomaterials


Role of bioenergy in WWF Energy Report

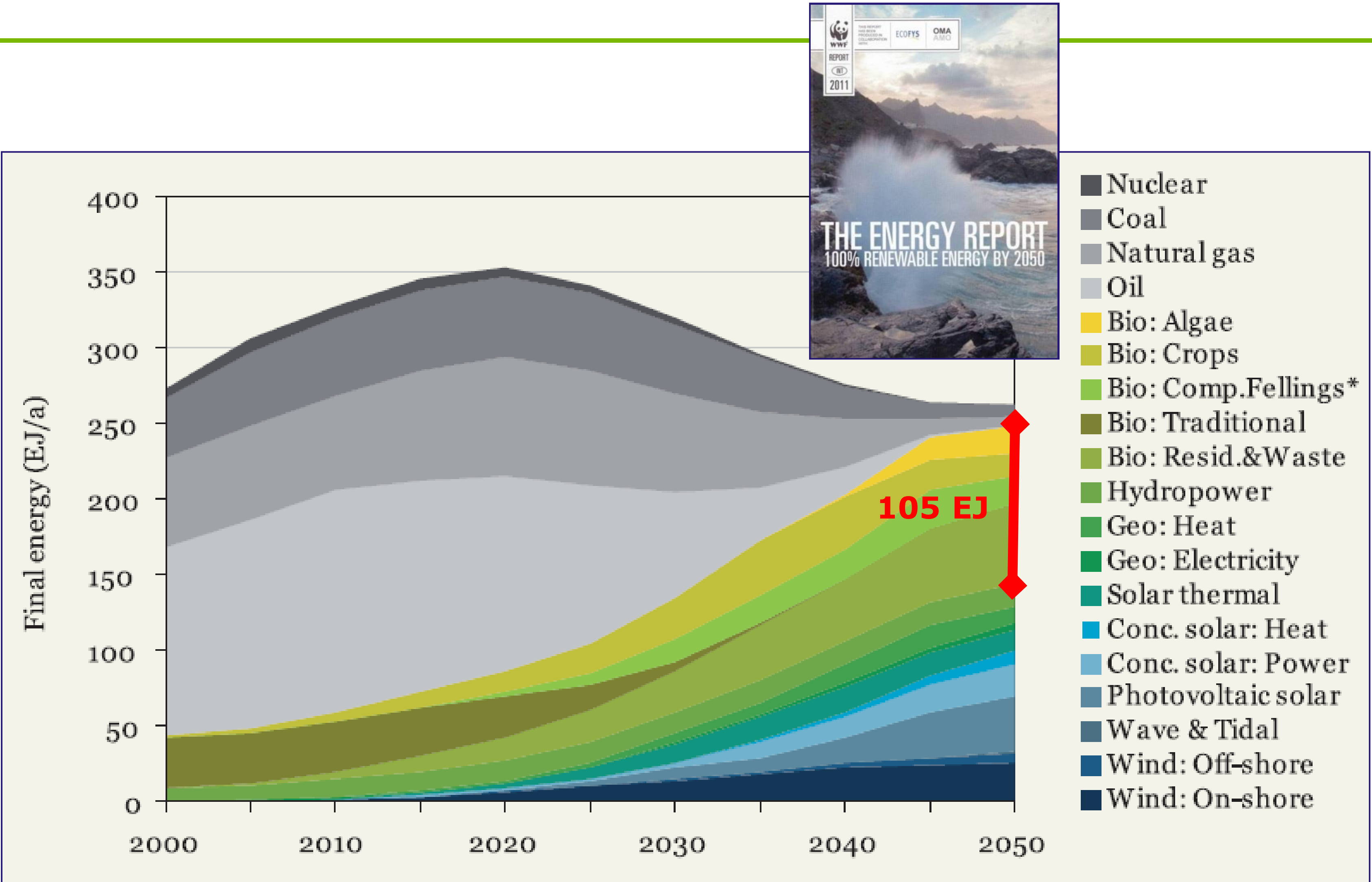


Figure 4: World Energy Supply by Source.
The Ecofys Energy Scenario, December 2010

#1
Biomass is necessary and suitable alternative to fossil resources

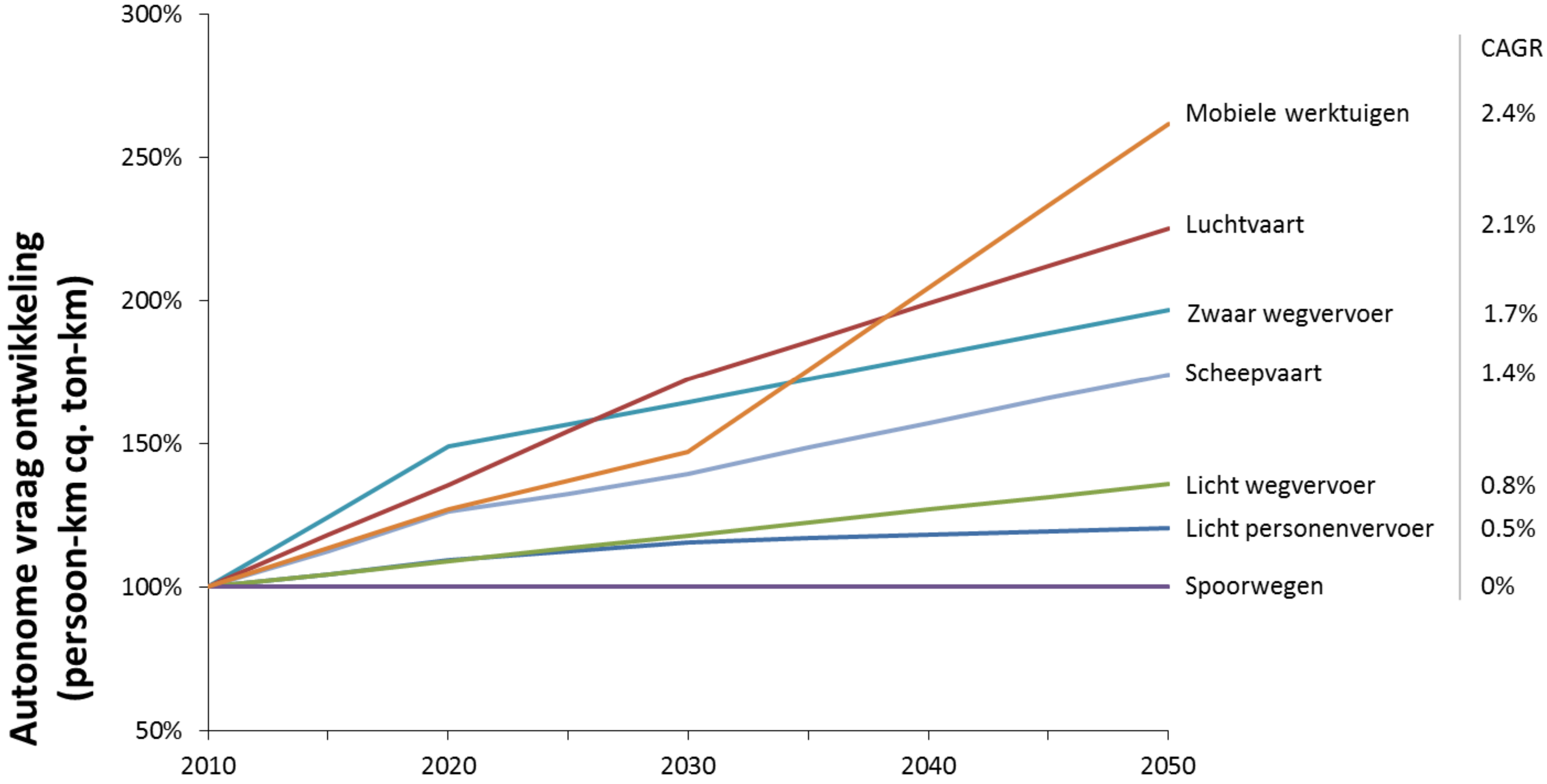
A possible scenario for the Netherlands

Ecofys study for 5 Environmental NGOs:
Een heldergroene visie op duurzame brandstoffen (2014)

(And some new calculations)

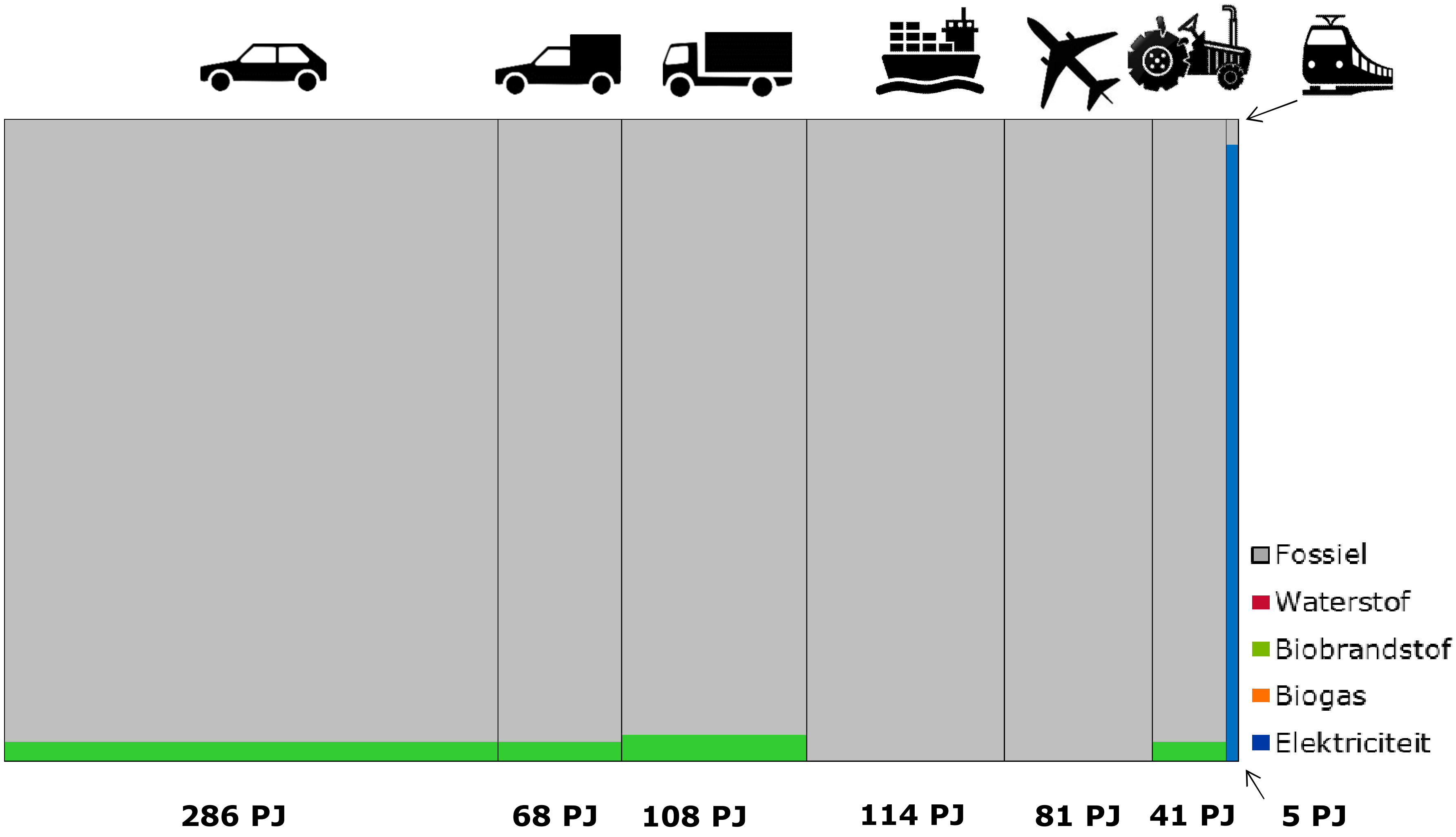
The challenge

Business-as-usual: the demand for transport increases



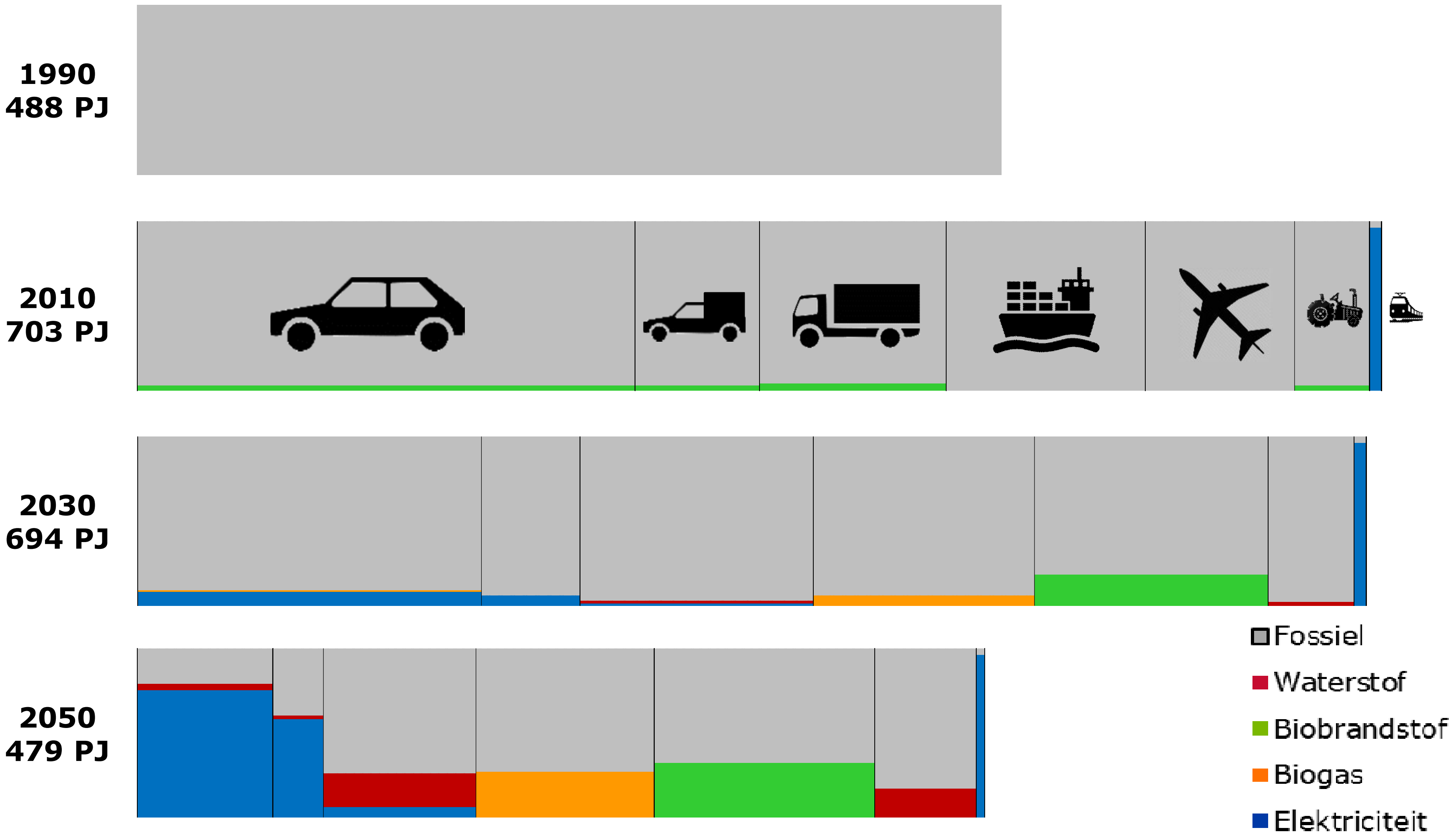
Energy use in transport in 2010

Status in the Netherlands in 2010 (broad scope)



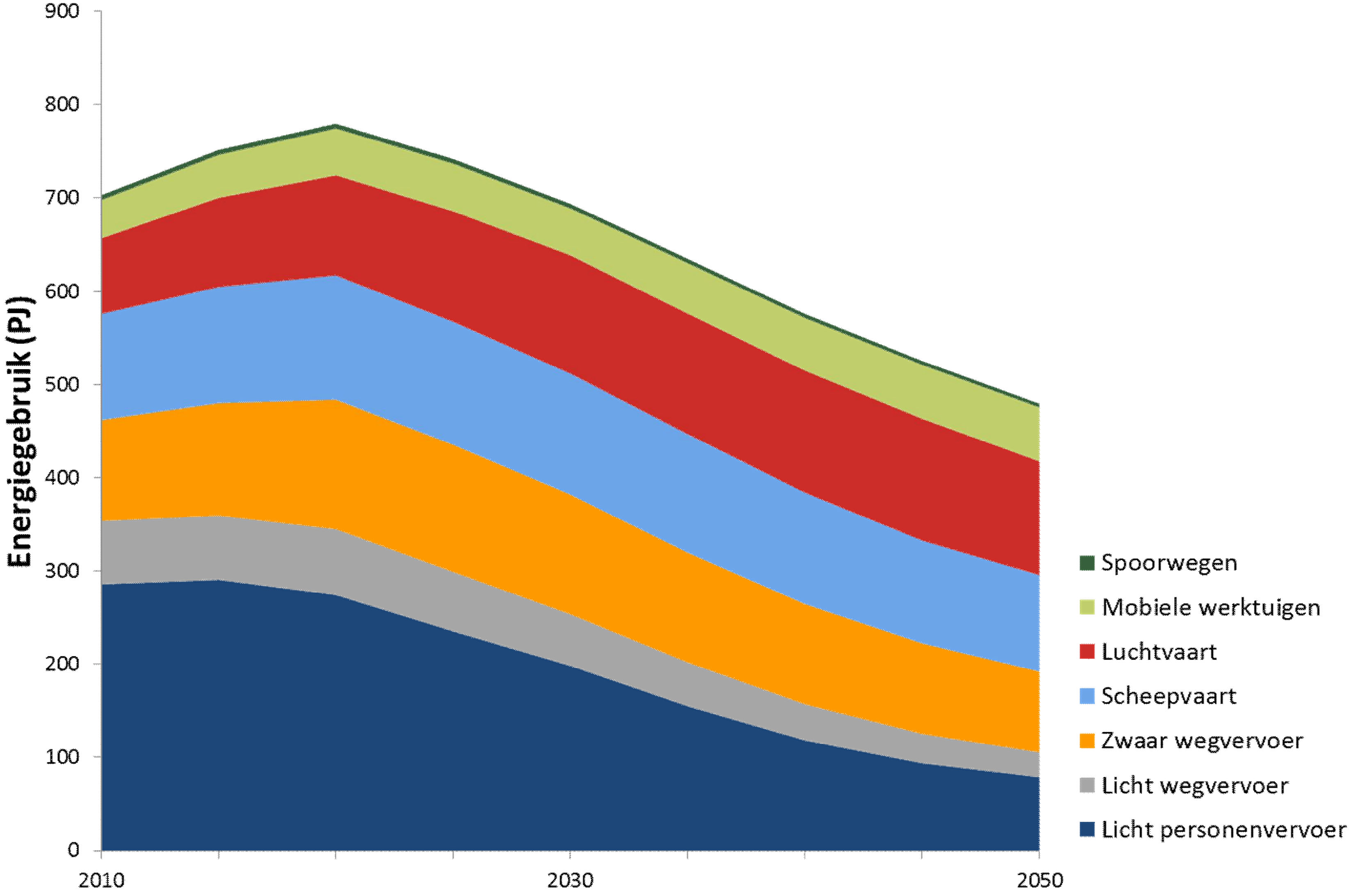
Sustainable transport scenario (NGOs)

Development of final energy use and types (broad scope)



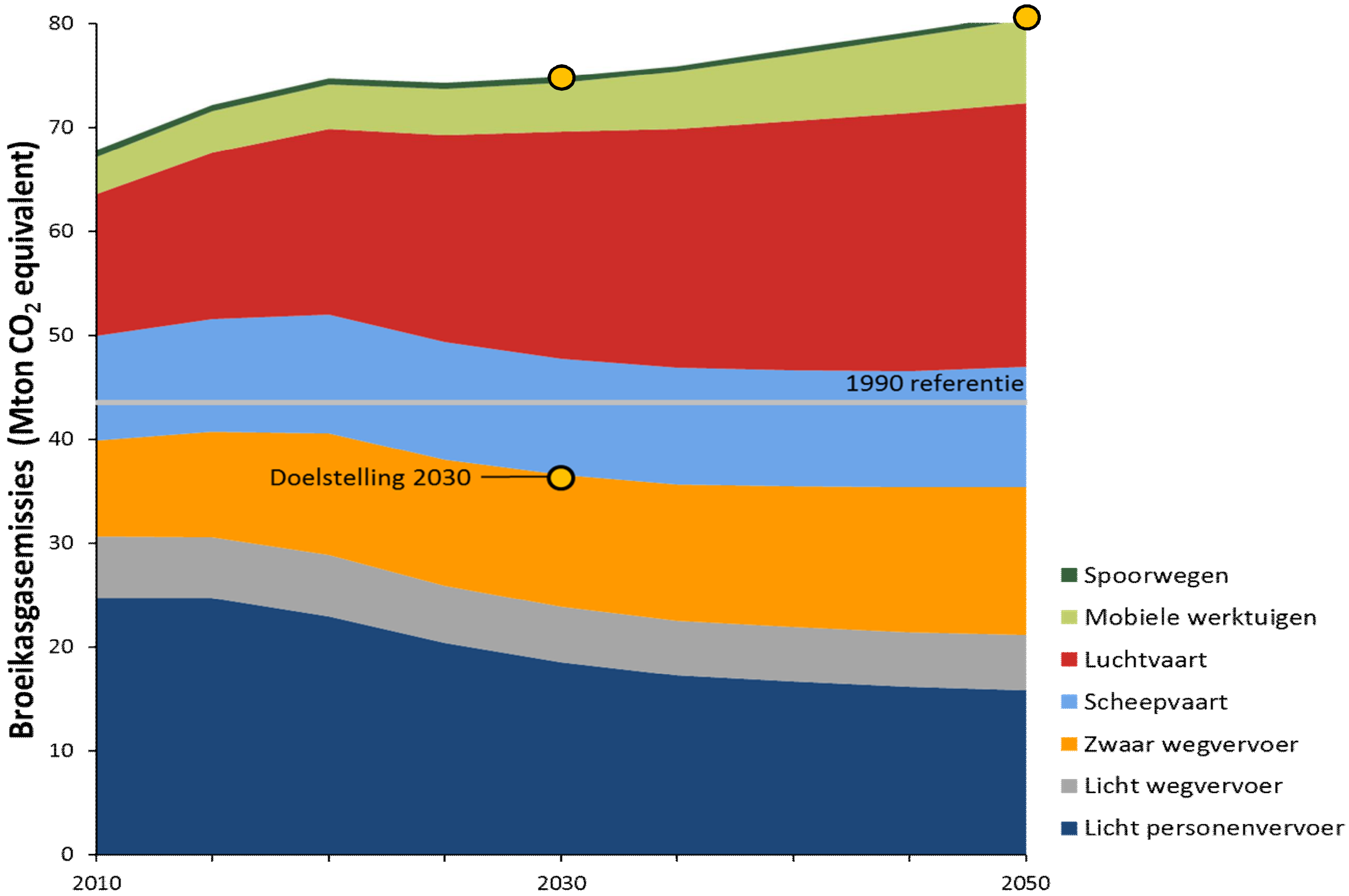
Sustainable transport scenario (NGOs)

Final (tank-to-wheel) energy use (broad scope)



Business-as-usual development

Well-to-wheel greenhouse gas emissions (broad scope)



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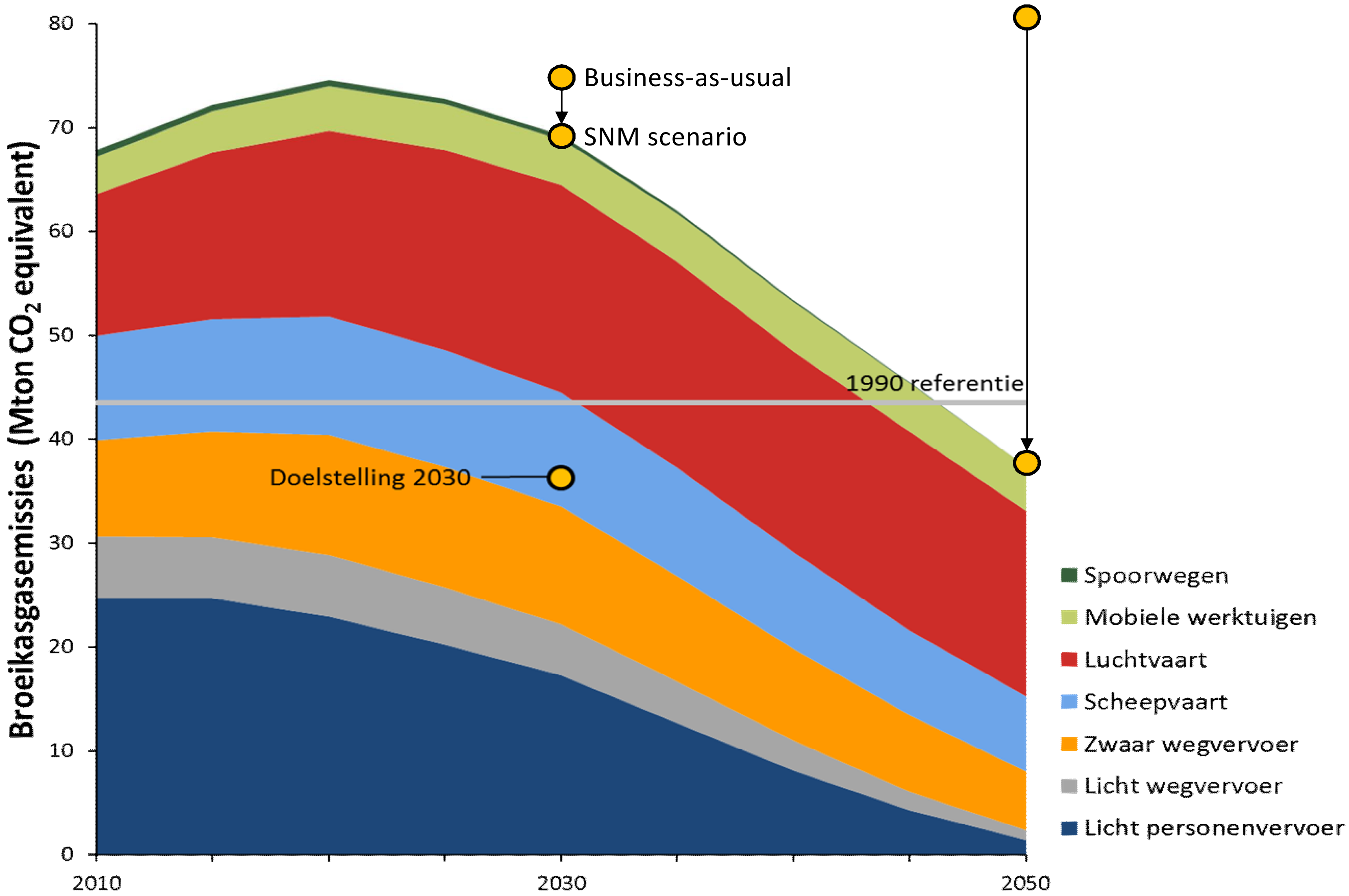
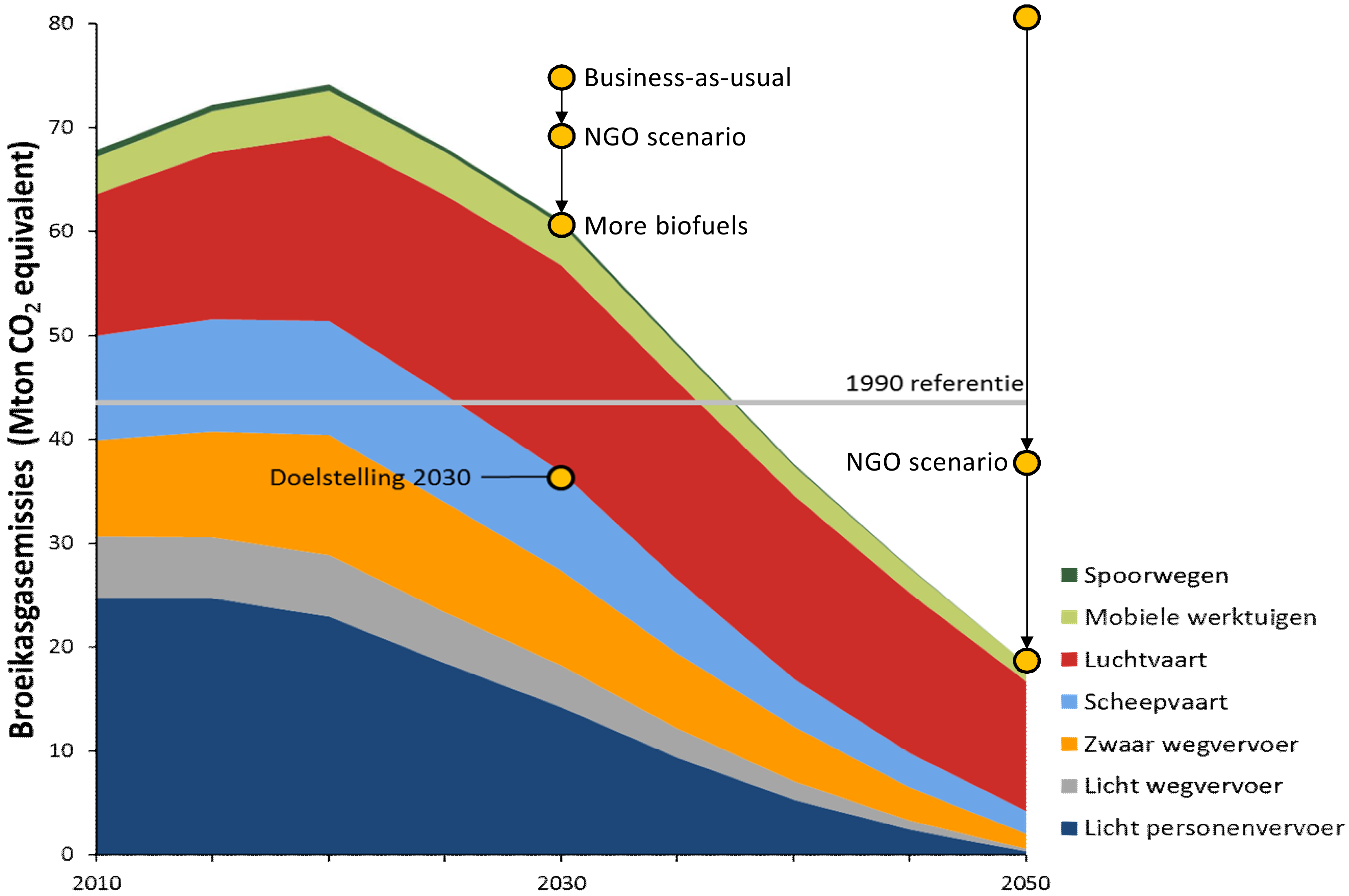
Sustainable transport scenario (NGOs)

Well-to-wheel greenhouse gas emissions (broad scope)



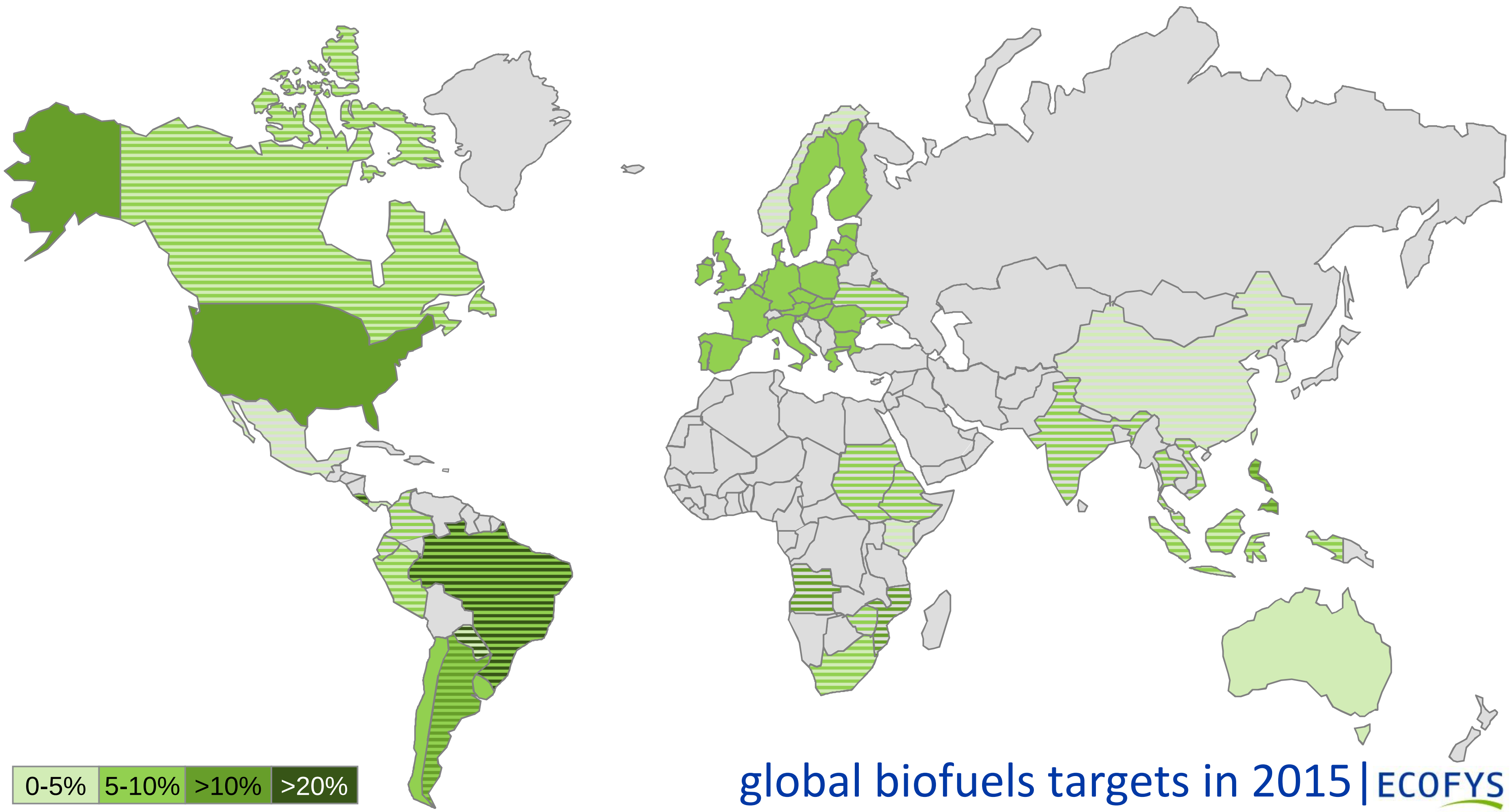
Same scenario – but with more biofuels

Well-to-wheel greenhouse gas emissions (broad scope)

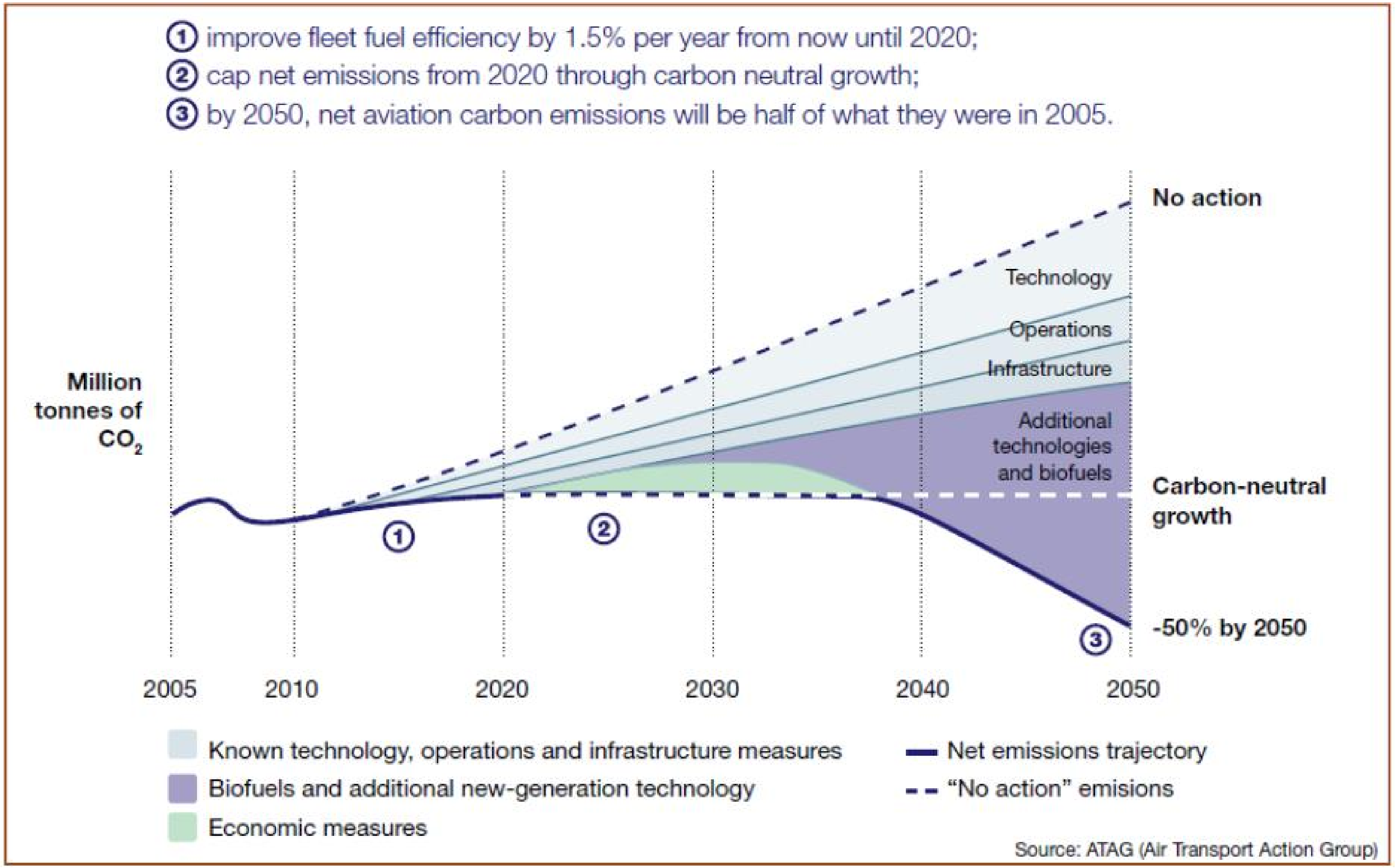


#2
Biofuels are needed for transport, alongside electrification and other solutions

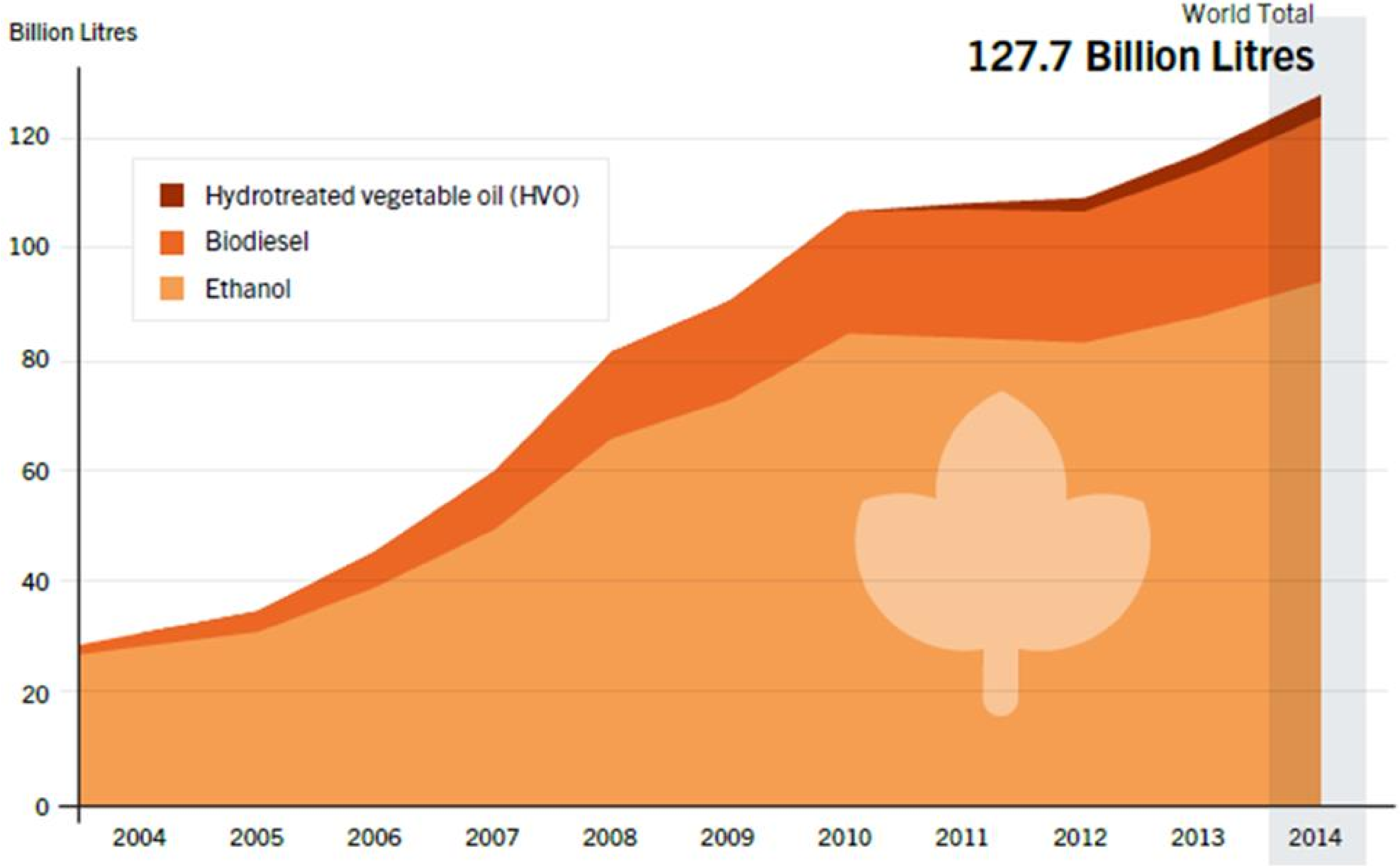
Global biofuel mandates / targets



Aviation sector bets on biofuels, after 2025



World biofuel production fourfolded in last decade

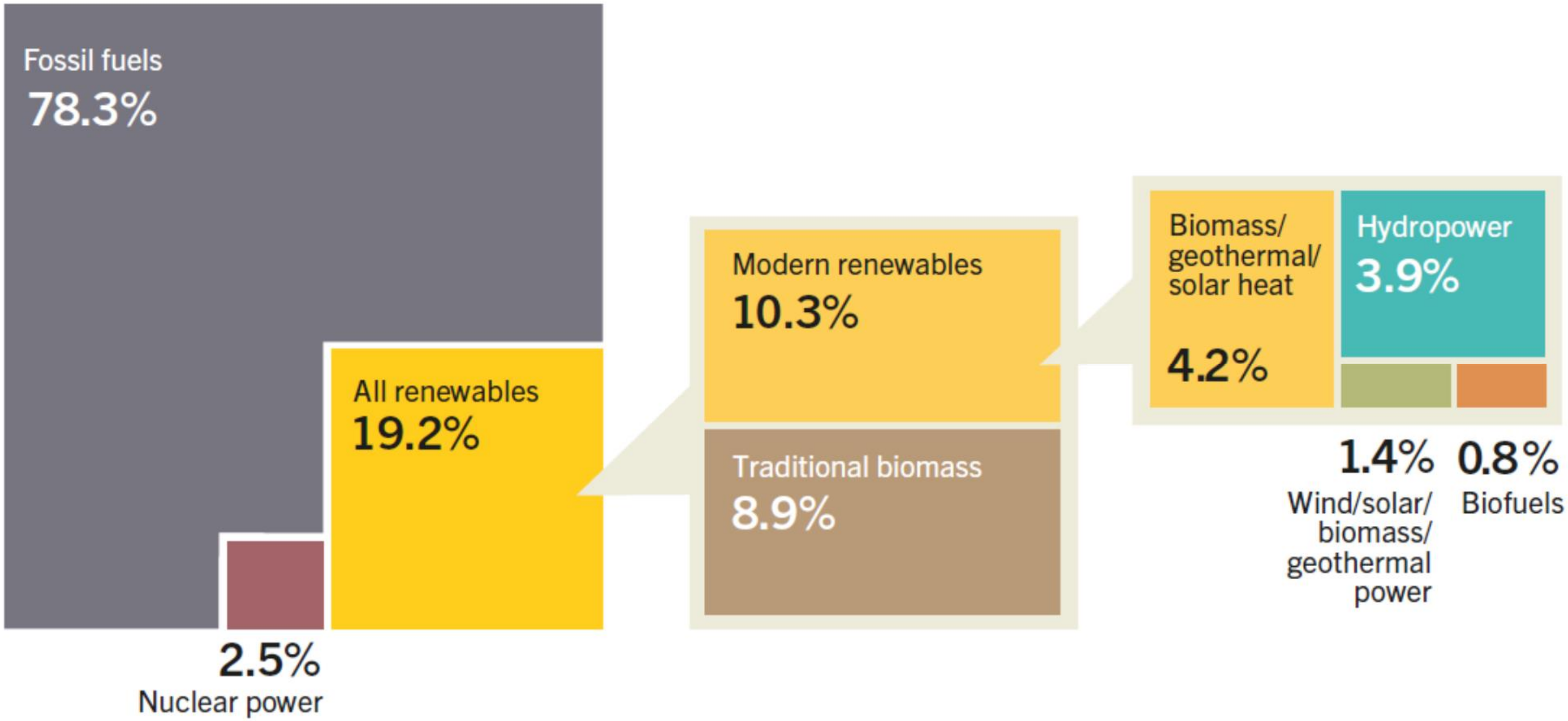


- Ethanol represents 4% of energy in transport
- Biodiesel represents 1% of energy in transport

[REN21, 2015, Global Status Report]

But remains still small compared to all energy

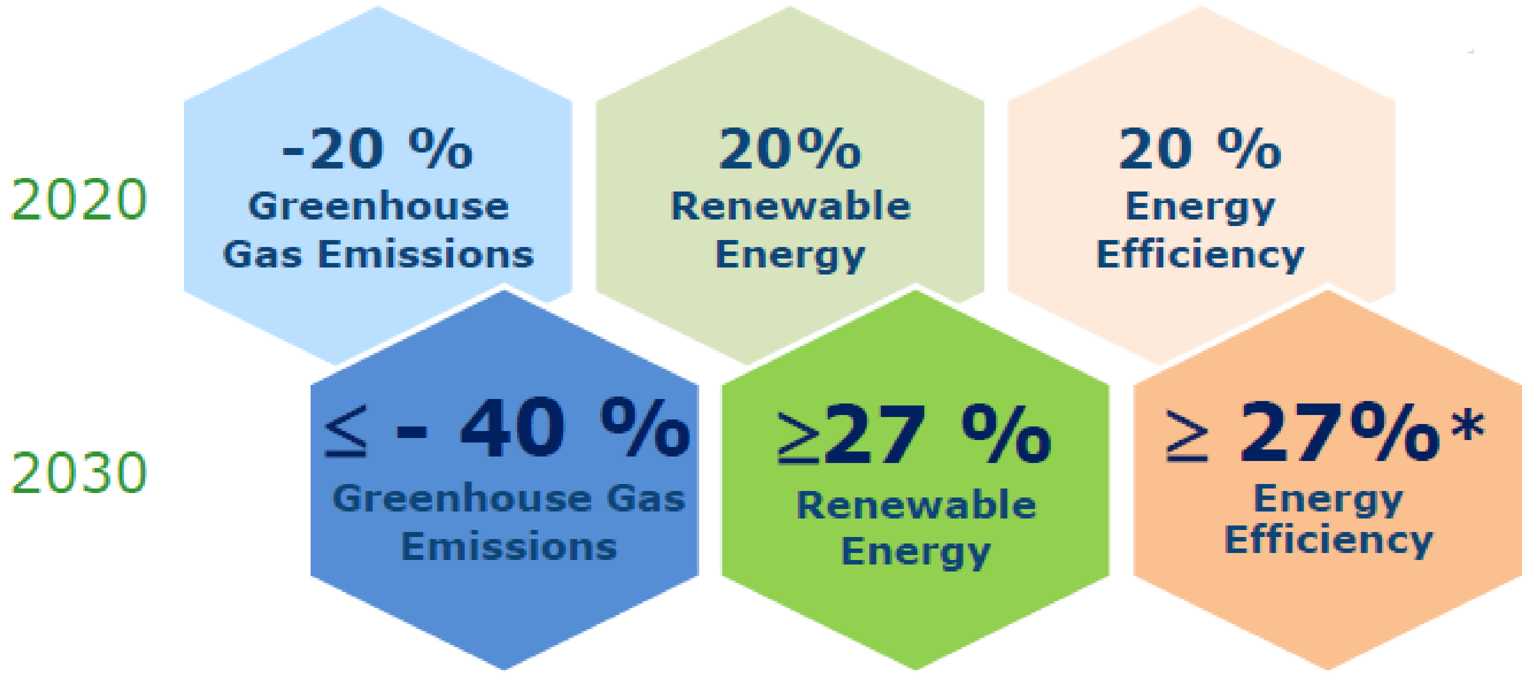
> *Renewable Energy Share of Global Final Energy Consumption, 2014*



[REN21, 2016, Global Status Report]

#3
There is increasing global interest, but role is currently modest

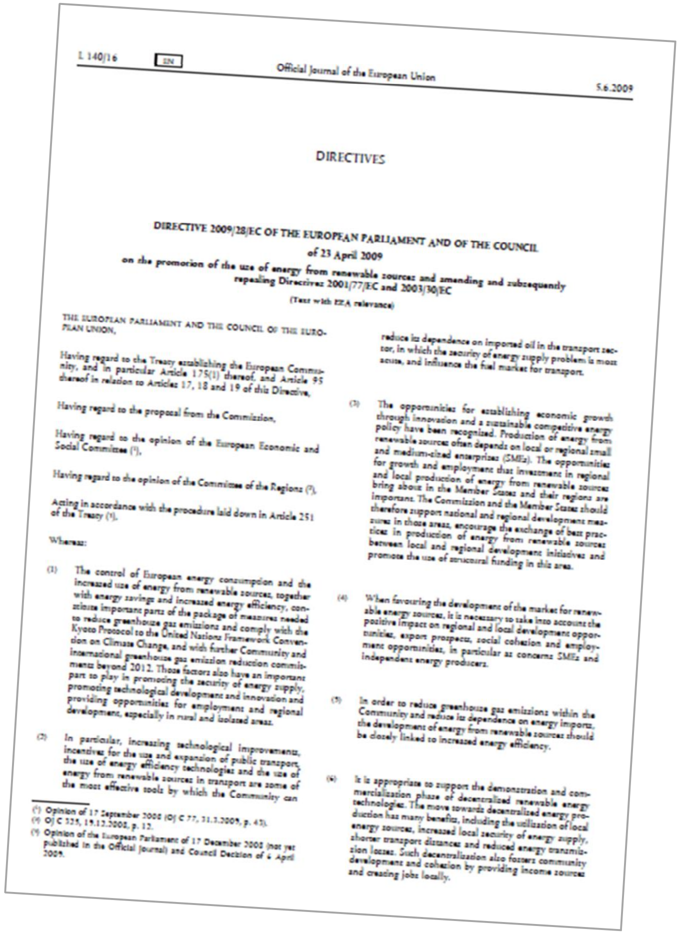
Biofuels in the EU – policy



[EC 2016, EU ETS Reform and Renewable Energy]

Biofuels in the EU – policy

> Renewable Energy Directive (2009/28/EC)



L 140/16 EN Official Journal of the European Union 5.6.2009

DIRECTIVES

DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 23 April 2009

on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

(Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1) thereof, and Article 95 thereof in relation to Articles 17, 18 and 19 of this Directive,

Having regard to the proposal from the Commission,

Having regard to the opinion of the European Economic and Social Committee (1),

Having regard to the opinion of the Committee of the Regions (2),

Acting in accordance with the procedure laid down in Article 251 of the Treaty (3),

Whereas:

(1) The control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased energy efficiency, constitute important parts of the package of measures needed to reduce greenhouse gas emissions and comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change, and with further Community and international greenhouse gas emission reduction commitments beyond 2012. Those factors also have an important part to play in promoting the security of energy supply, promoting technological development and innovation and providing opportunities for employment and regional development, especially in rural and isolated areas.

(2) In particular, increasing technological improvements, incentives for the use and expansion of public transport, the use of energy efficiency technologies and the use of energy from renewable sources in transport are some of the most effective tools by which the Community can reduce its dependence on imported oil in the transport sector, in which the security of energy supply problem is most acute, and influence the fuel market for transport.

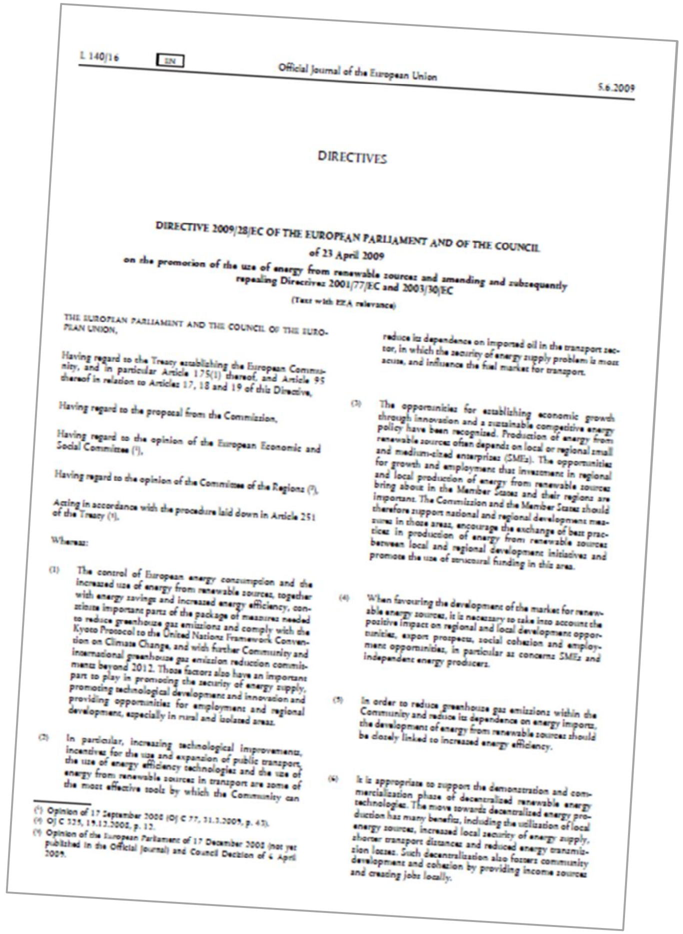
(3) The opportunities for establishing economic growth through innovation and a sustainable competitive energy policy have been recognised. Production of energy from renewable sources often depends on local or regional small and medium-sized enterprises (SMEs). The opportunities for growth and employment that investment in regional and local production of energy from renewable sources bring about in the Member States and their regions are important. The Commission and the Member States should therefore support national and regional development measures in those areas, encourage the exchange of best practices in production of energy from renewable sources between local and regional development initiatives and promote the use of structural funding in this area.

(4) When favouring the development of the market for renewable energy sources, it is necessary to take into account the positive impact on regional and local development opportunities, export prospects, social cohesion and employment opportunities, in particular as concerns SMEs and independent energy producers.

(5) In order to reduce greenhouse gas emissions within the Community and reduce its dependence on energy imports, the development of energy from renewable sources should be closely linked to increased energy efficiency.

(6) It is appropriate to support the demonstration and commercialisation phase of decentralised renewable energy technologies. The move towards decentralised energy production has many benefits, including the utilisation of local energy sources, increased local security of energy supply, shorter transport distances and reduced energy transmission losses. Such decentralisation also fosters community development and cohesion by providing income sources and creating jobs locally.

(1) Opinion of 17 September 2008 (OJ C 77, 31.3.2009, p. 43).
(2) OJ C 325, 19.12.2008, p. 12.
(3) Opinion of the European Parliament of 17 December 2008 (not yet published in the Official Journal) and Council Decision of 6 April 2009.



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> Fuel Quality Directive (2009/30/EC)

EU Renewable Energy Directive

> 10% target in 2020 “renewable energy in transport”

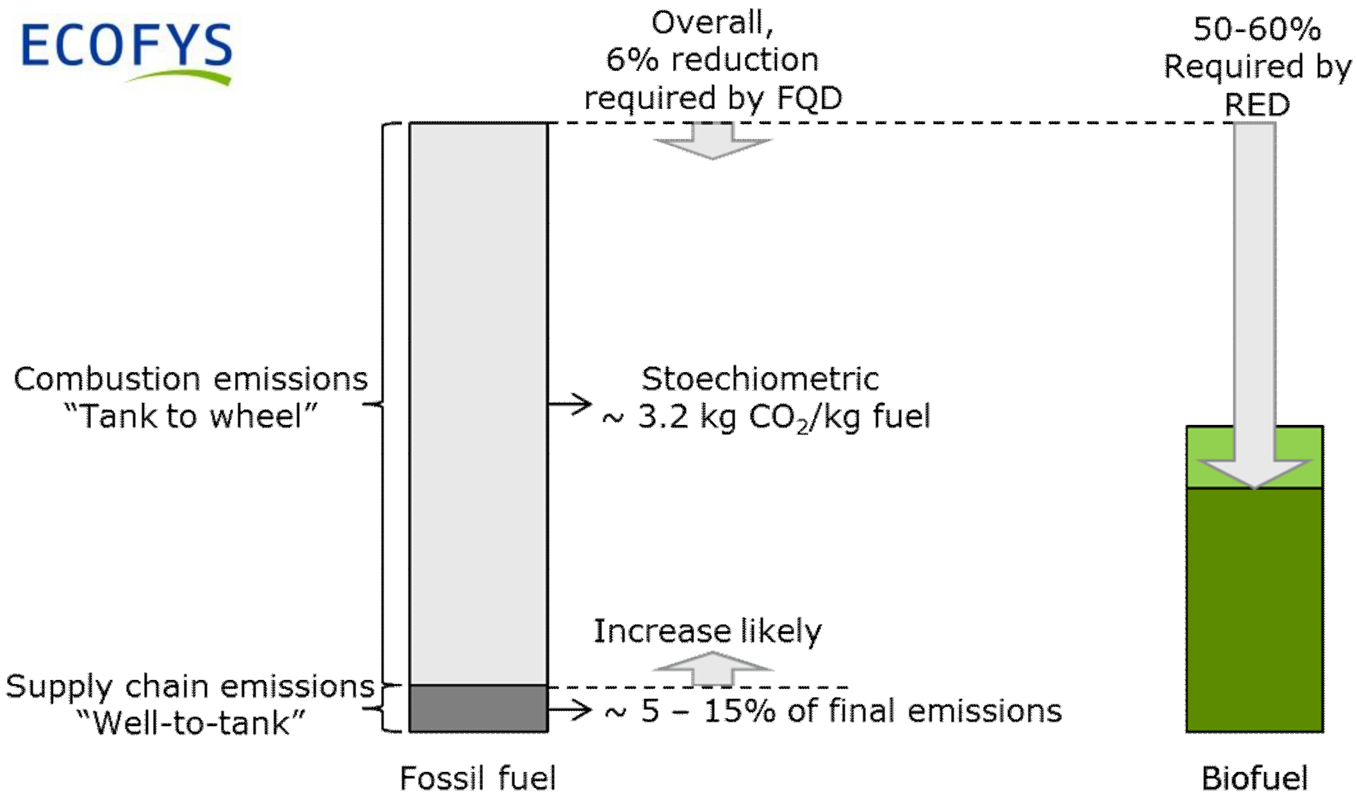
$$10\% = \frac{\textbf{\textit{All}}\ \textbf{Renewable Energy in}\ \textbf{\textit{all}}\ \textbf{forms of transport}}{\textbf{Petrol, diesel, }\underbrace{\textbf{biofuels,}}_{\textbf{In road and rail transport}}\ \underbrace{\textbf{electricity}}_{\textbf{In all transport}}}$$

- Electricity in road vehicles counts 2.5 times
- Biofuels have to comply with sustainability criteria
  - 35% emission reduction, 50% from 2018 onwards
  - Not produced from land that was formerly high in carbon or biodiversity
- Biofuels from waste, residues, …, counts twice

EU Fuel Quality Directive

- Mandatory 6% reduction of greenhouse gas emissions from all energy used in transport for 2020 compared with 2010
  - First 2% by December 2015
  - Another 2% by December 2017
  - Last 2% by 2020
- By far most emissions result from final combustion
  - Final emissions from fossil fuels are stoichiometric
  - Difficult to improve exploration, transport and refining
- Emissions *could* be reduced by using biofuels
  - 6% reduction for the total pool, using fuels that perform 60% better then average, requires 10% of those fuels
  - FQD and RED harmonised sustainability requirements
- This part of FQD is not yet implemented by MS
  - Lack of instructions from EC

EU Fuel Quality Directive



[Ecofys 2014]

EU ILUC Directive

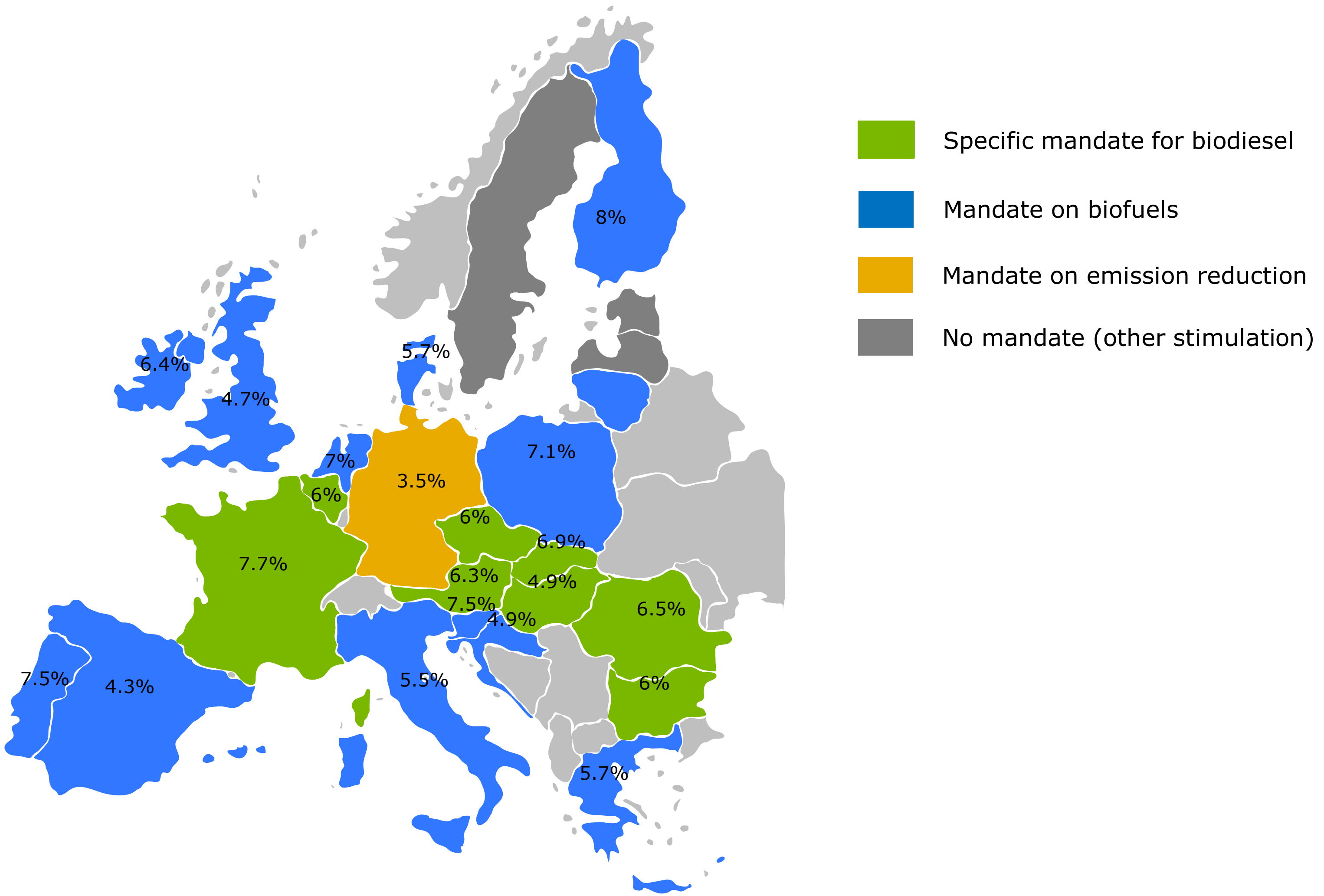
> Addresses concerns related to Indirect Land Use Change (discussed later) and amends the Renewable Energy and Fuel Quality Directives

> Key changes:

RED & FQD	Biofuels produced from food crops and energy crops limited to 7%
RED & FQD	Remainder of 10% / 6% should come from advanced biofuels, electricity in transport, renewable fuels from non-biological origin or other savings in the case of the FQD
RED	0.5% non-binding subtarget for advanced biofuels in RED
RED & FQD	RED & FQD minimum required GHG saving threshold for biofuels is increased to 60%
RED	RED: Contribution of electricity in rail transport is counted 2.5 times (was once) the energy content of the input and electricity in road transport 5 times (was 2.5 times);
RED & FQD	introduction of a definition for 'low ILUC risk biofuels'
RED & FQD	Increasing transparency of certification
RED & FQD	Review of default emission values

> (Furthermore, many detailed amendments)

Biofuel mandates in the EU-28

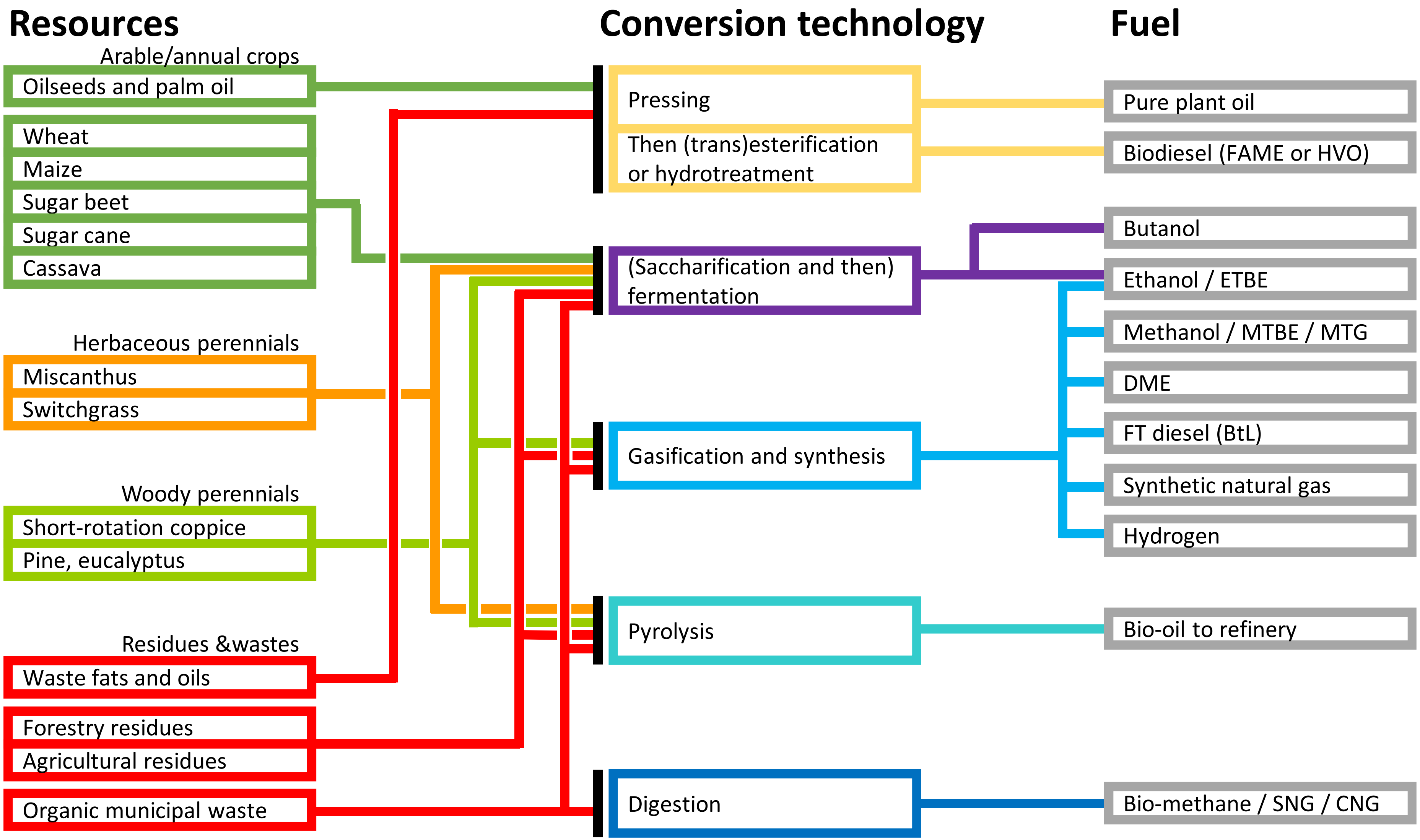


Fuentes: RES Legal.eu; GAIN, 2016 Biofuel mandates in the EU by Member State

#4

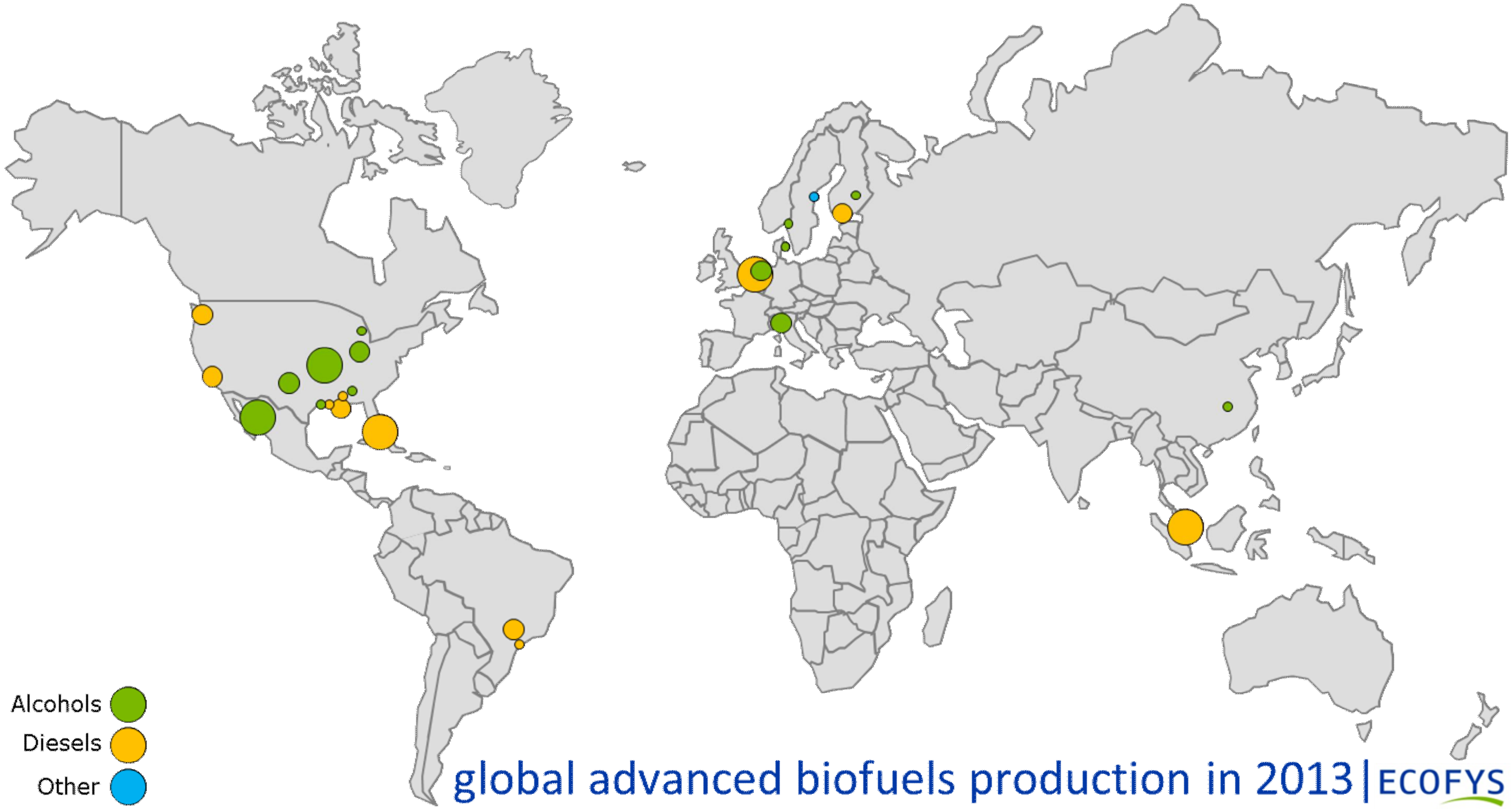
European policy and market prospects are unclear

Many possible production pathways

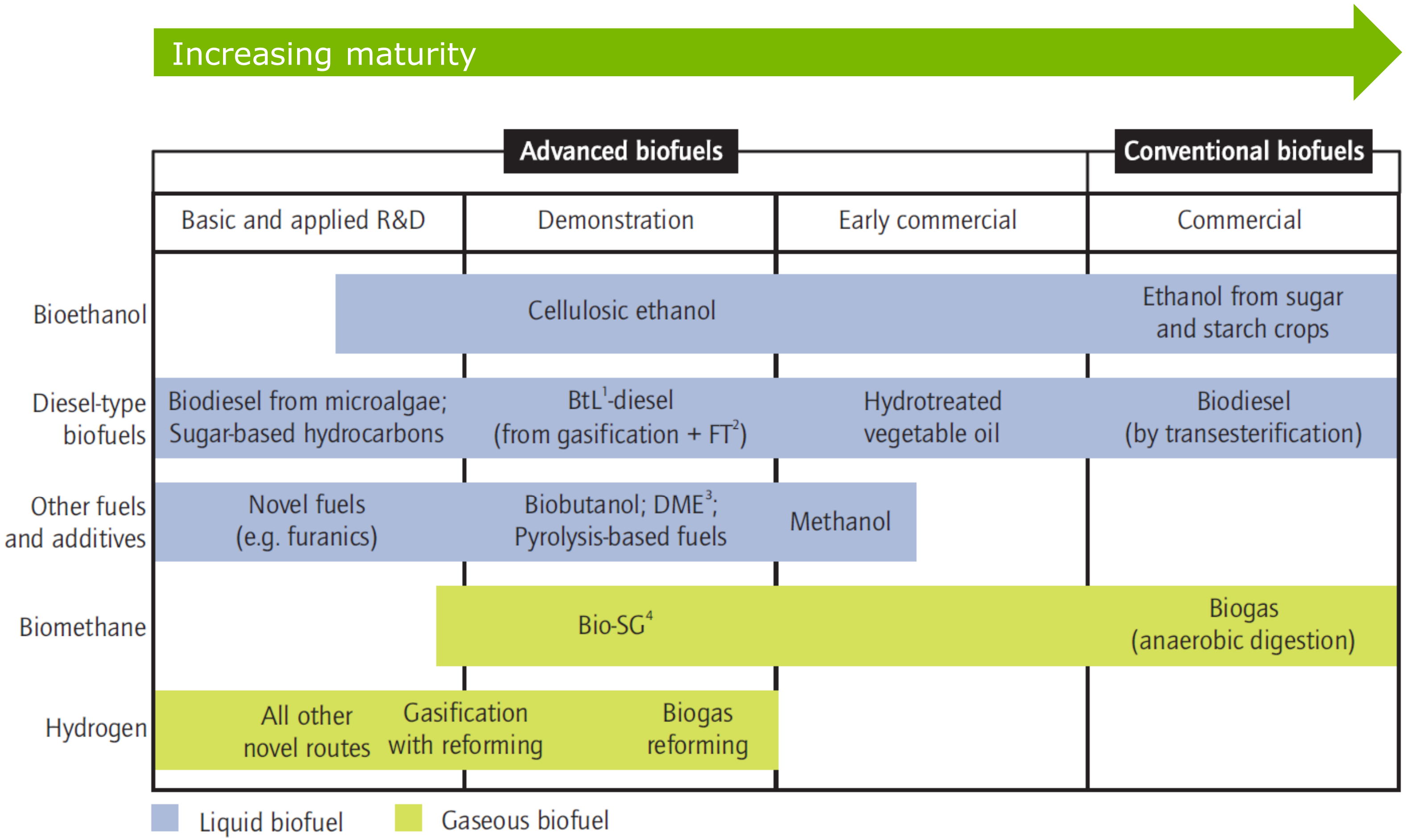


biofuel conversion pathways | ECOFYS

Production of advanced biofuels



Maturity of conversion technologies



1. Biomass-to-liquids; 2. Fischer-Tropsch; 3. Dimethylether; 4. Bio-synthetic gas.

[International Energy Agency 2011. Biofuels for Transport. Technology Roadmap]

Feedstocks for biofuels

Sources of biomass (1) purpose grown

> “traditional” crops

> Energy crops

> Aquatic biomass

Sources of biomass (2) wood residues

Primary (e.g. agricultural and forestry residues)

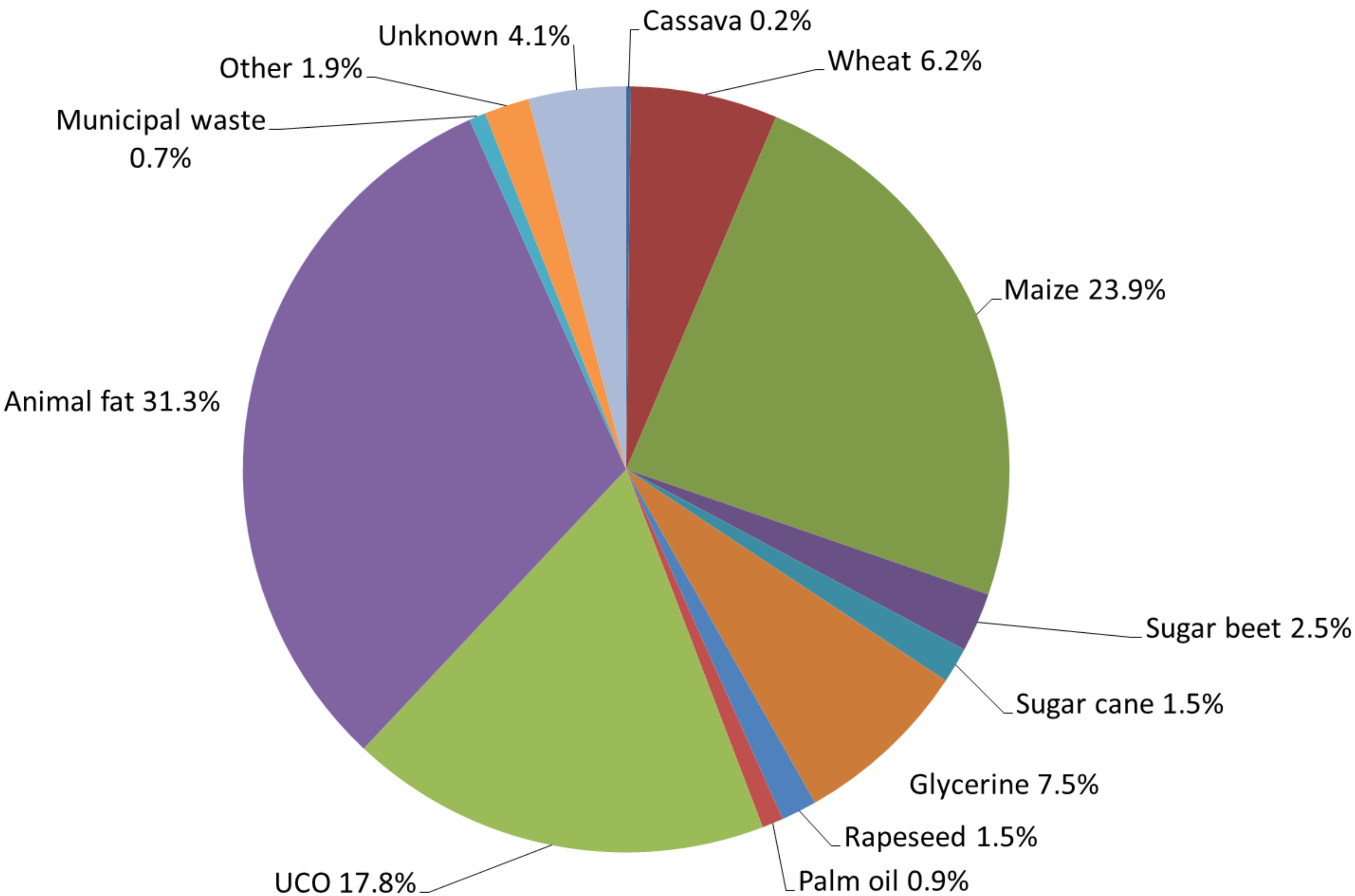
Secondary (e.g. sawmill waste)

Tertiary (e.g. waste wood)

Harvesting residues → **Processing** → **End-of life**

Sources of biomass (3) other residues

Feedstock for biofuels sold in the Dutch market



[NEA 2013]

Renewable fuels
from non-biological origin

Other novel fuels

> Hydrogen
  – Electrolyse water to H_2, then use

> Power to liquids
  – Electrolyse water to H_2, then react with CO_2 to methanol

CARBON RECYCLING INTERNATIONAL

> Power to gas
  – Electrolyse water to H_2, then react with CO_2 to methane

> Industrial waste gases to fuels
  – Fermenting CO, CO_2 and H_2

LanzaTech

> Municipal Solid Waste to fuels
  – Gasification, followed by Fischer-Tropsch synthesis

Fulcrum BIOENERGY

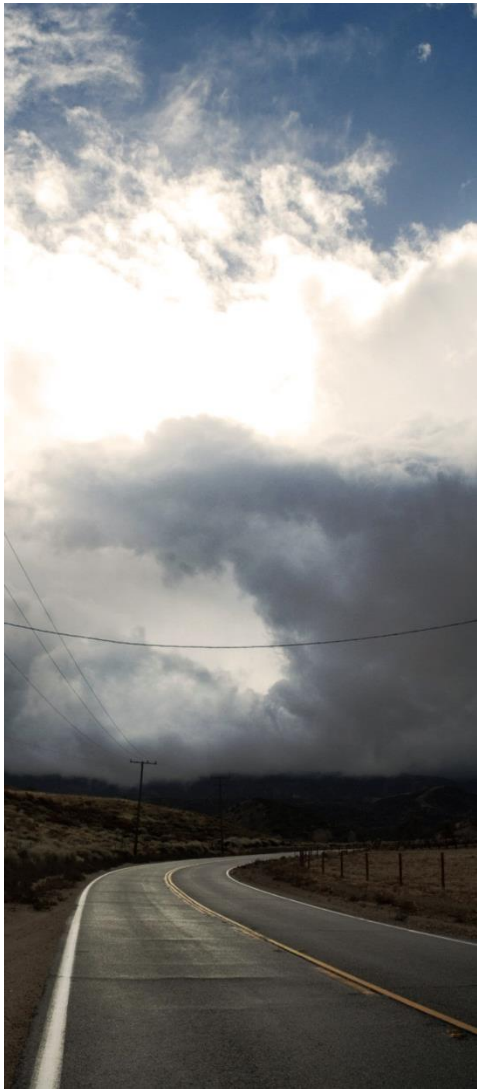
SOLENA FUELS

Enerkem

#5
Many types of fuels can be produced from all kinds of feedstock

How sustainable are biofuels?

Biofuels have received much criticism

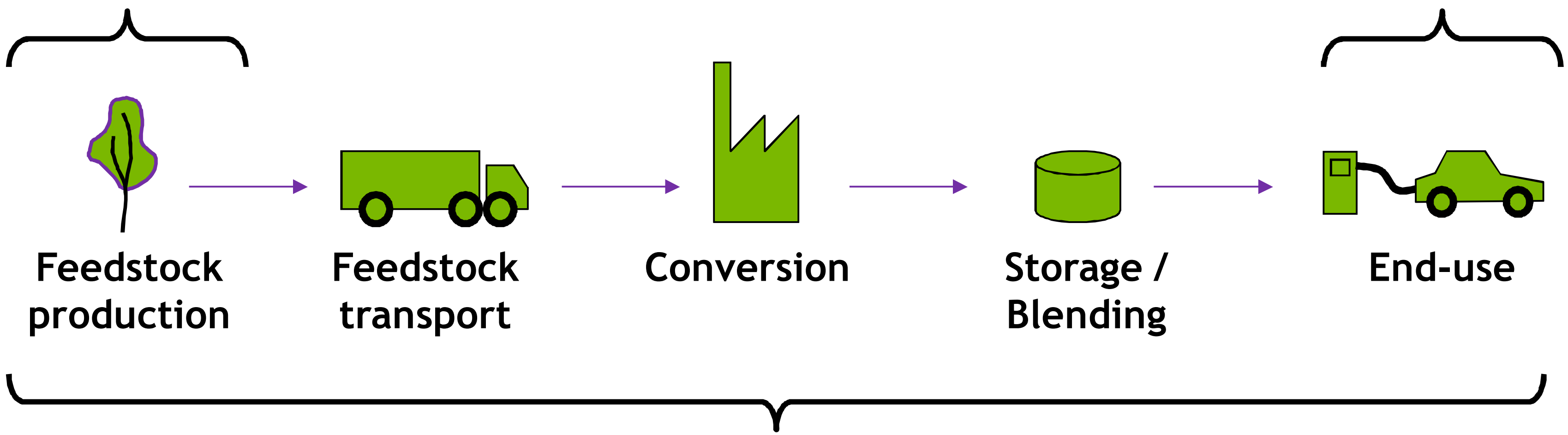


[© misterhuyun/freeimages.com]

- July 2006 Shell: *"biofuels from food crops are morally inappropriate"*
- April 2008 UN Special Rapporteur on the Right to Food: *"Biofuels are a crime against humanity"*
- April 2008 World Bank President: *"While many worry about filling their gas tanks, many others around the world are struggling to fill their stomachs. And it's getting more and more difficult every day."*
- April 2008 UN Secretary General Ban Ki-moon: *"We need to be concerned about the possibility of taking land or replacing arable land because of these biofuels […] While I am very much conscious and aware of these problems, at the same time you need to constantly look at having creative sources of energy, including biofuels. Therefore, at this time, just criticising biofuel may not be a good solution. I would urge we need to address these issues in a comprehensive manner."*
- *April 2014 IPCC: increased cultivation of biofuel crops may "exacerbate the already serious water scarcity" and may have "negative impacts on the lives of poor people"*

Feedstock sustainability
e.g. avoid biodiversity loss

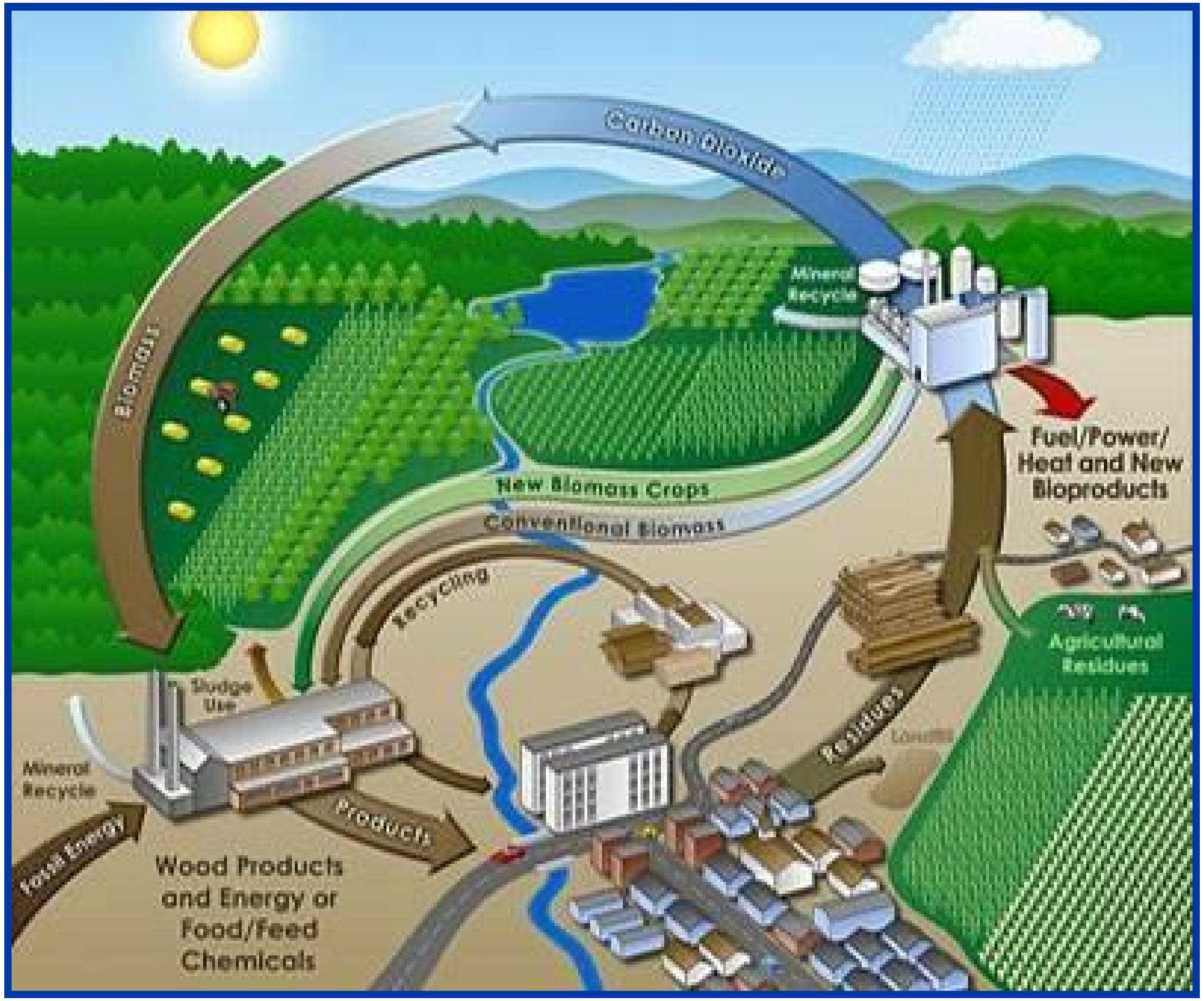
End-use sustainability
e.g. decrease local air pollution



Chain sustainability
e.g. realise greenhouse gas savings

Climate change &
Greenhouse gas emissions

Bioenergy is carbon neutral...



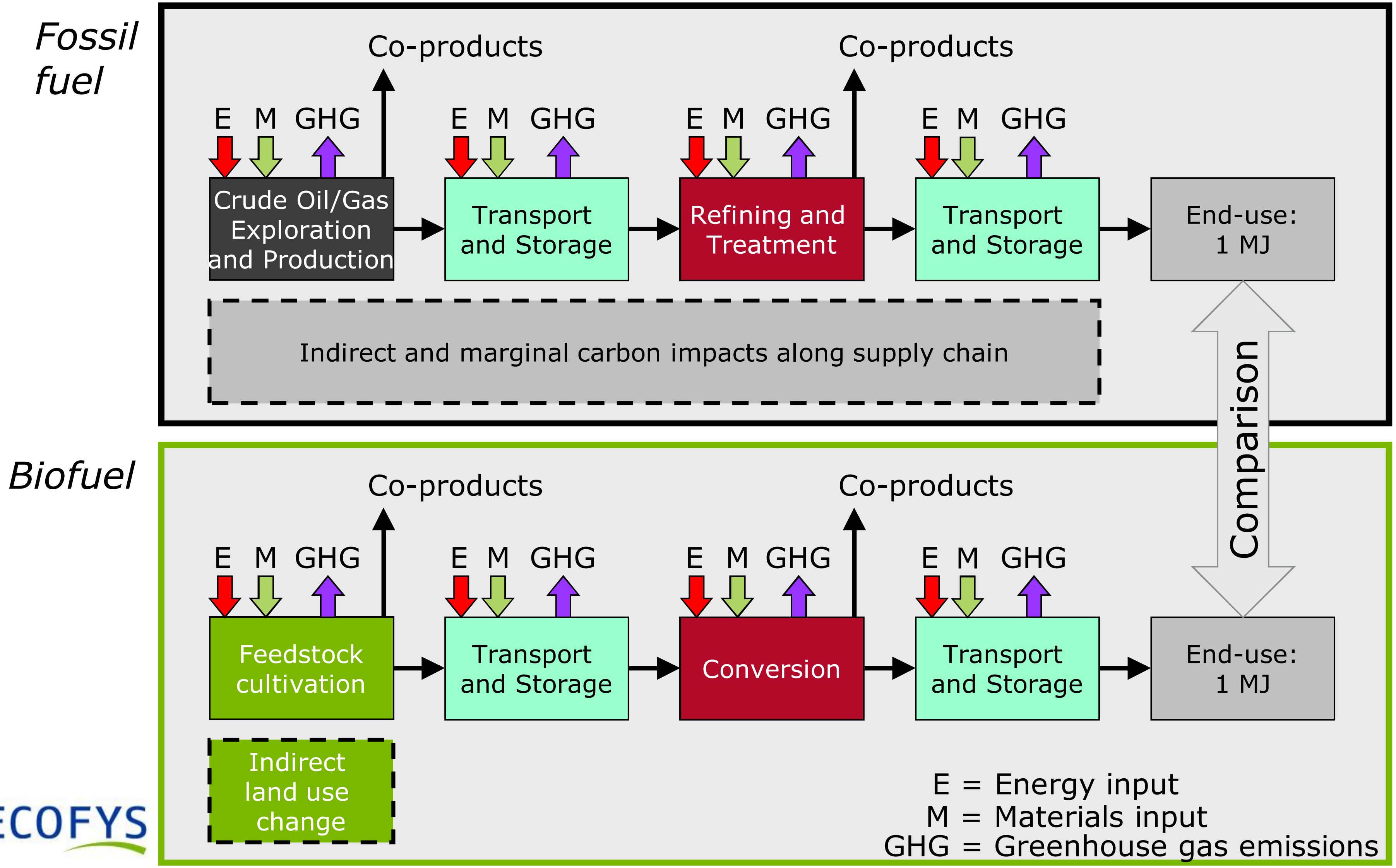
... well almost

- Energy is needed to drive the supply chain
  - Harvesting, transport, processing, etc.
  - Energy use leads to CO_2 emissions
- Fertiliser production and application emits N_2O
- Land use change can decrease carbon stock

... although it could also be more

- Selected felling increases forest carbon uptake
- Manure digestion avoids methane emissions (strong greenhouse gas)
- Reduced tillage in agriculture can increase soil organic carbon
- Biomass combined with CCS can remove CO_2 from atmosphere

- If done smart, bioenergy could contribute to carbon removal solutions



Fossil fuel
Co-products
Co-products
E M GHG
E M GHG
E M GHG
E M GHG
Crude Oil/Gas Exploration and Production
Transport and Storage
Refining and Treatment
Transport and Storage
End-use: 1 MJ
Indirect and marginal carbon impacts along supply chain
Comparison
Biofuel
Co-products
Co-products
E M GHG
E M GHG
E M GHG
E M GHG
Feedstock cultivation
Transport and Storage
Conversion
Transport and Storage
End-use: 1 MJ
Indirect land use change
E = Energy input
M = Materials input
GHG = Greenhouse gas emissions

Principles of greenhouse gas calculations in the EU renewable energy directive

> Three key elements

> Typical and default factors

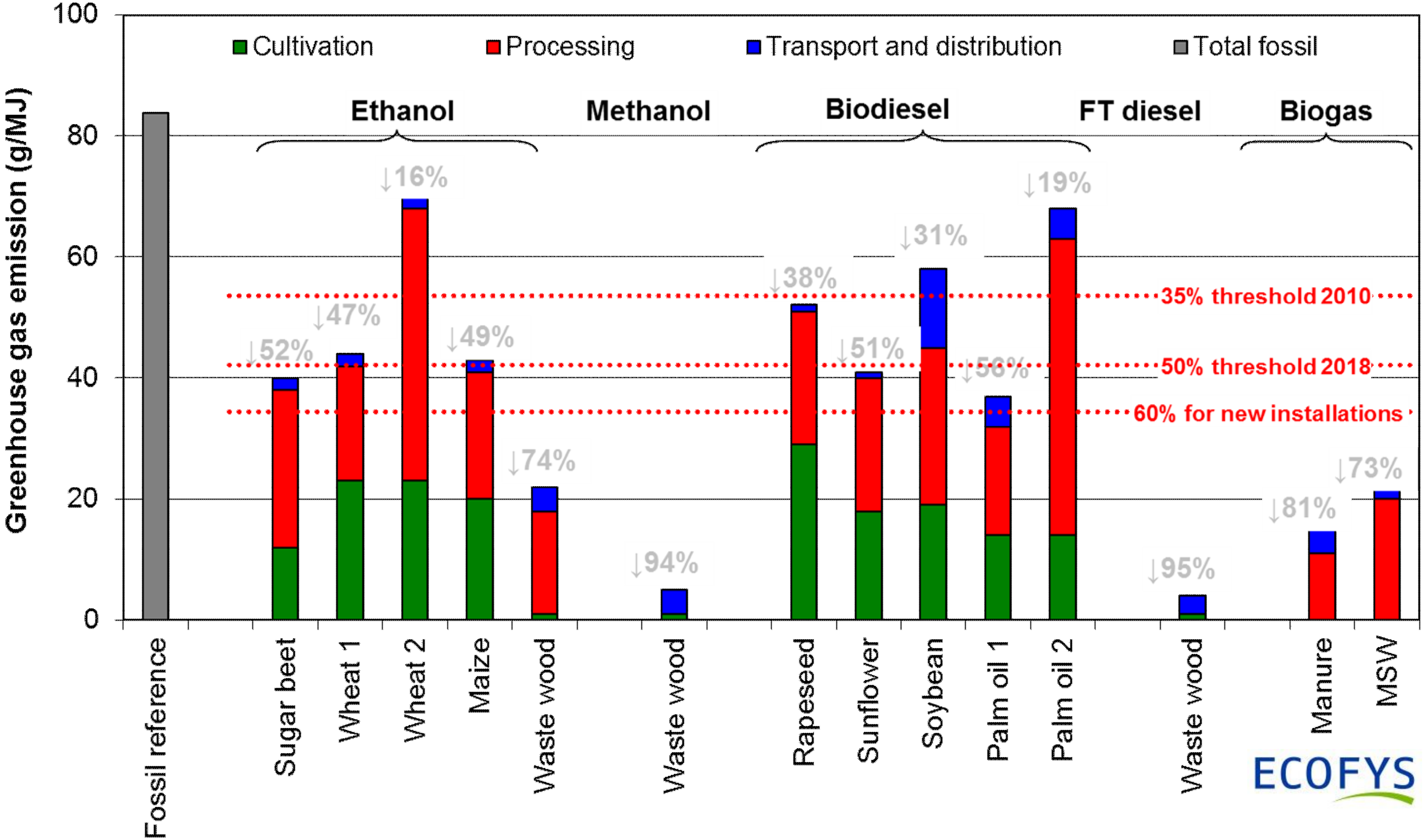
> Standard rules for accounting

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee},$$

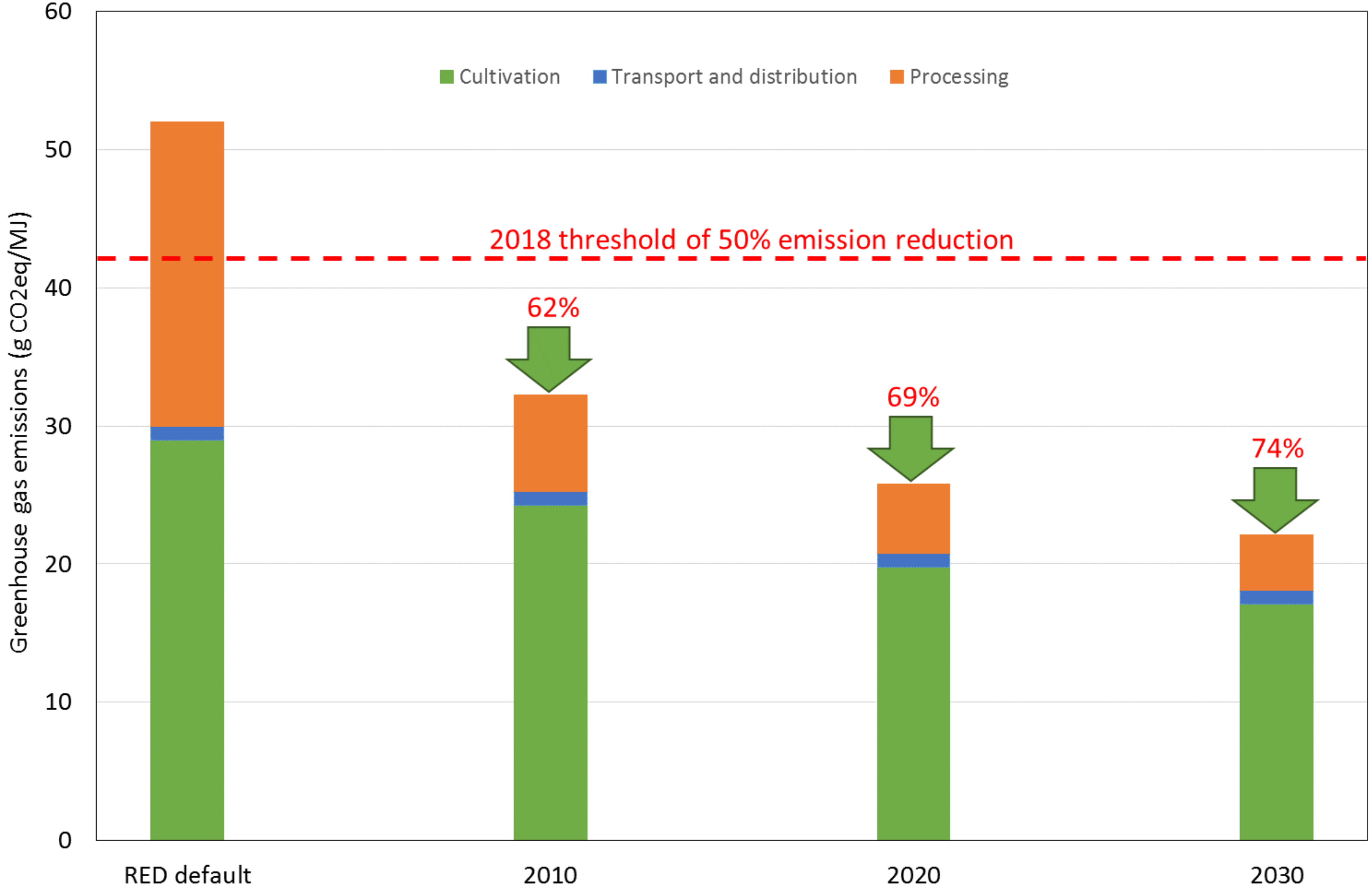
> Fossil comparator

> RED methodology is a political concept, necessary to distinct between various supply chains in a pragmatic manner – but not suitable to draw conclusions on the real greenhouse gas impact from all biofuels together

Default emissions
Specified by Renewable Energy Directive



Biodiesel supply chain greenhouse gas emissions

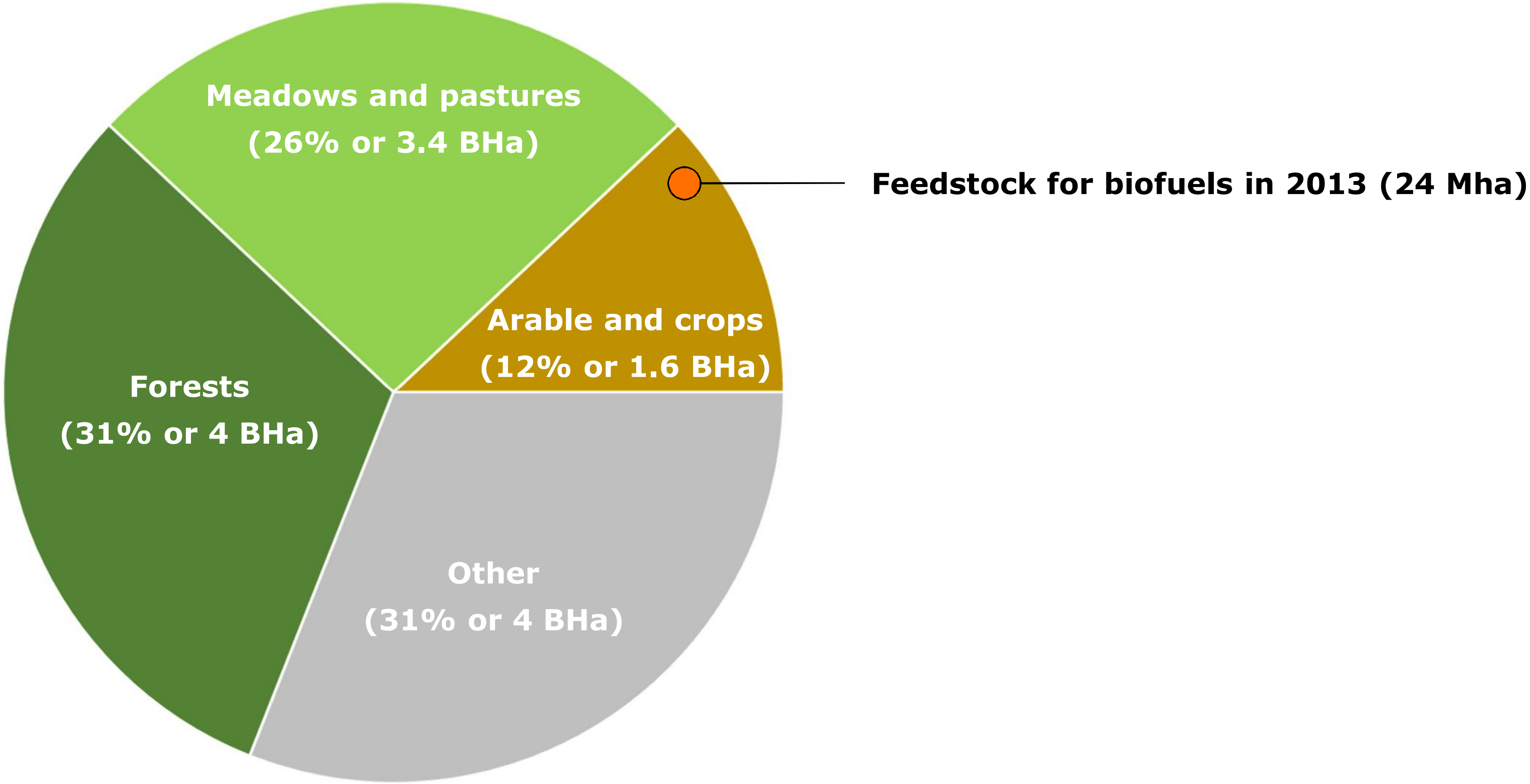


#6
The climate performance of biofuels continuously improves – by law

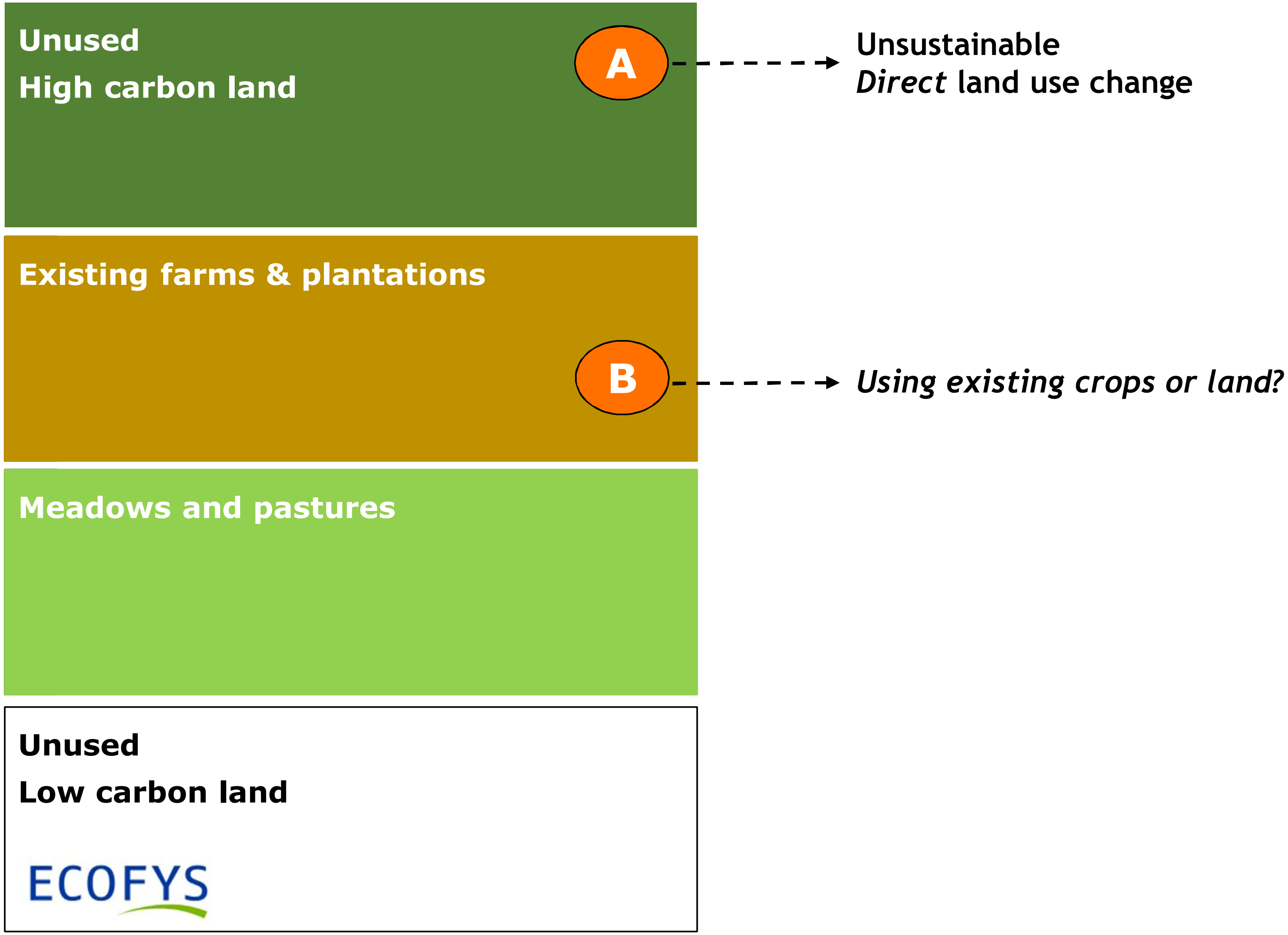
Emissions from
Indirect Land Use Change (ILUC)

Global agricultural land use

> World land area: 13 billion hectare
> Agricultural land: 5 billion hectare



ILUC concept: indirect land use change (simplistic explanation)



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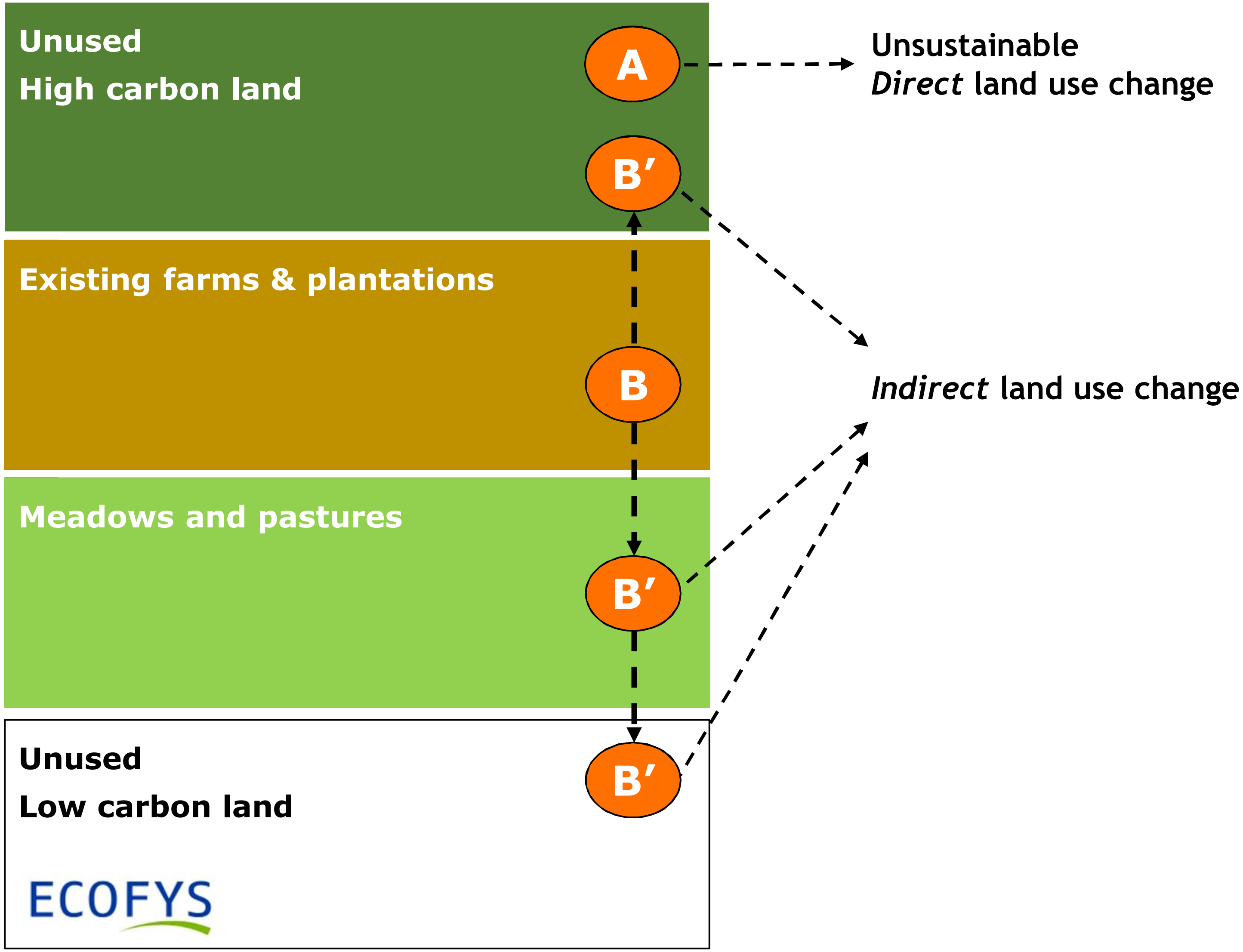
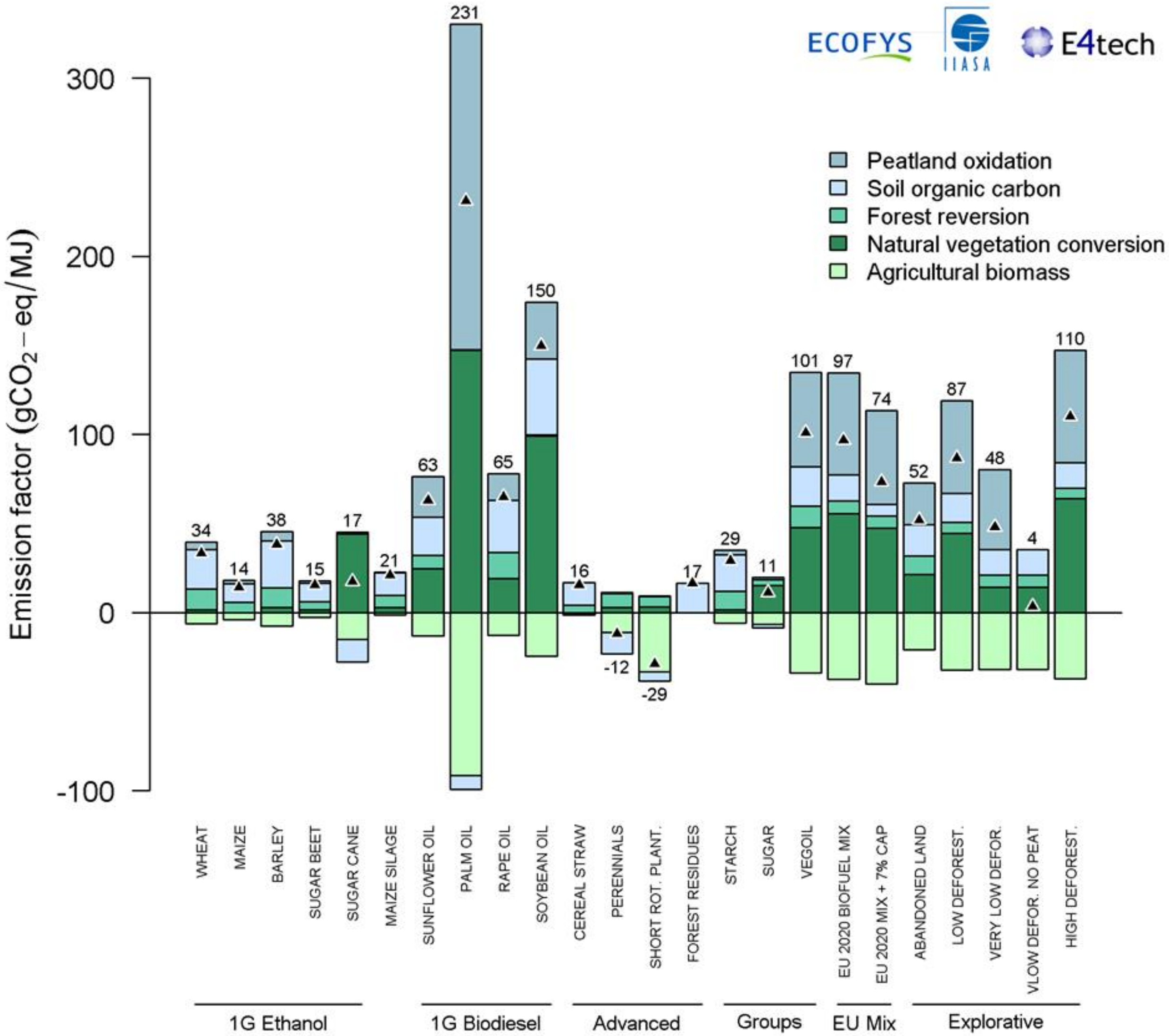


ILUC concept

- Political concern:
  - Increased consumption of biofuels require agricultural expansion at a global scale
  - Marginal land use change causes high carbon emissions
  - This limits greenhouse gas savings from biofuels application
- Policy makers want to understand the larger consequences of their decisions
- Biofuels industry feels unfair treatment – are not cause – have no influence
- Models can shed some light on the land use impact of biofuels
- ILUC quantification:
  For a certain biofuels development, the land use change is quantified worldwide, and compared to counterfactual, i.e. the world without that development

Overview of modeling results



Remarkable results

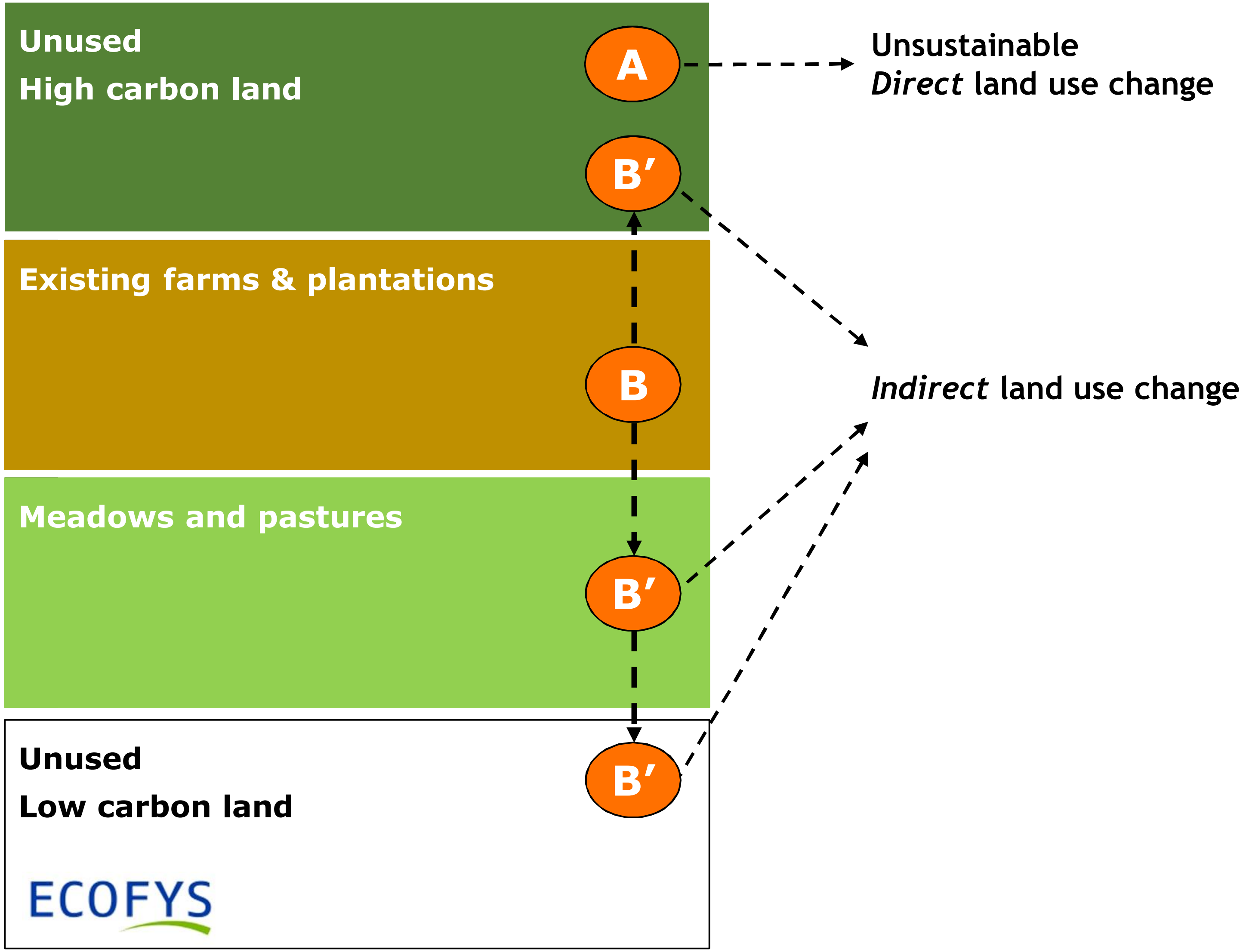
> ILUC is very much a local problem
  - If peatland drainage in Indonesia and Malaysia were stopped, ILUC would reduce dramatically

> Foregone sequestration
  - In absence of biofuels, EU cropland will decrease and partially becomes grassland or forest
  - Use of abandoned land is not per se good, depends on counterfactual
  - Biofuels produced on set-aside land before 2008 ILUC free?

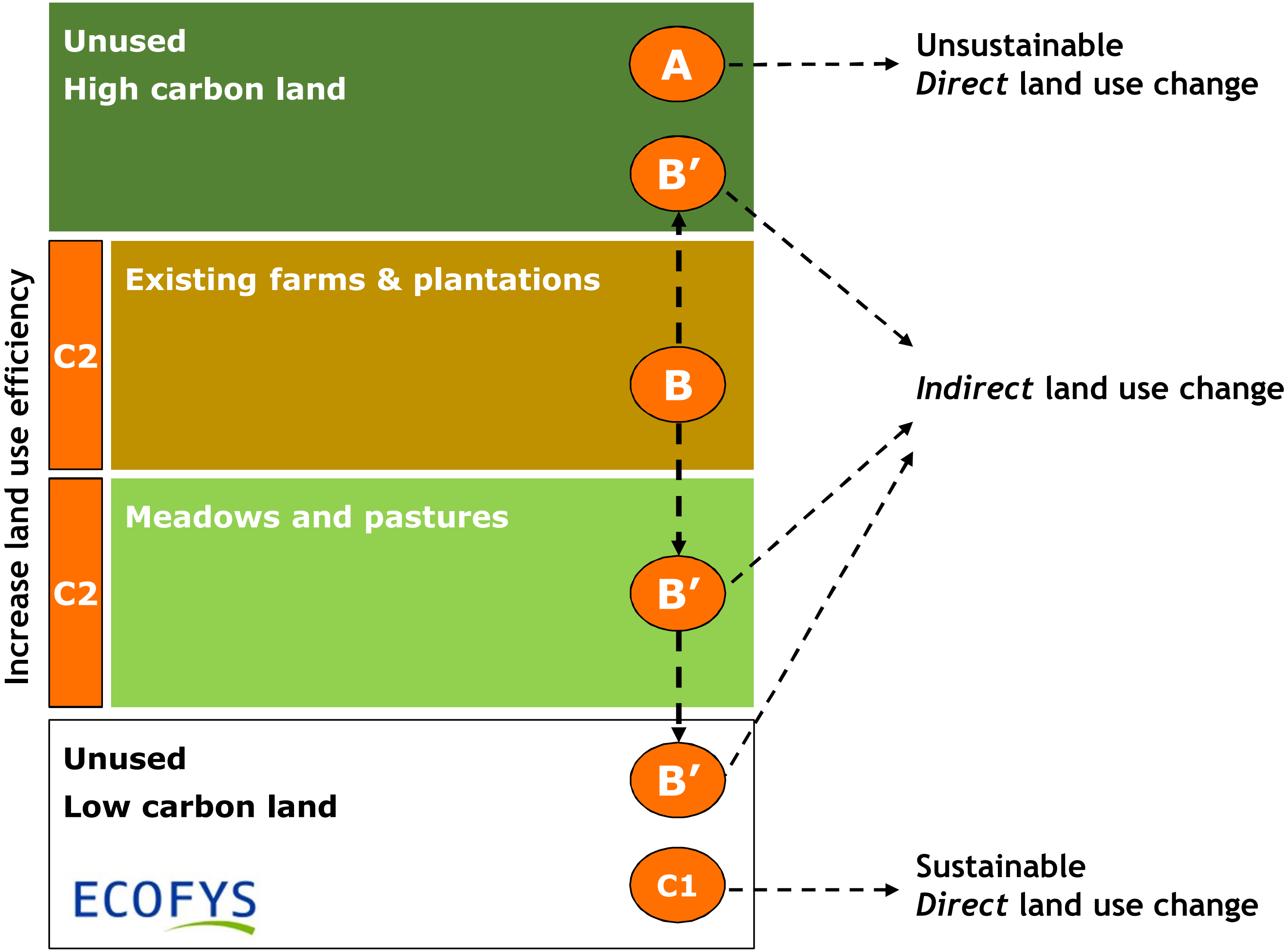
> Co-producing animal feed
  - Leads to decreased soy production in Latin America
  - Leads to increased palm oil production in South East Asia
  - Overall LUC impacts decrease

> ILUC is largely paid back after 20 years – by definition (& Fossil fuels emissions don't pay back!)

ILUC can be avoided

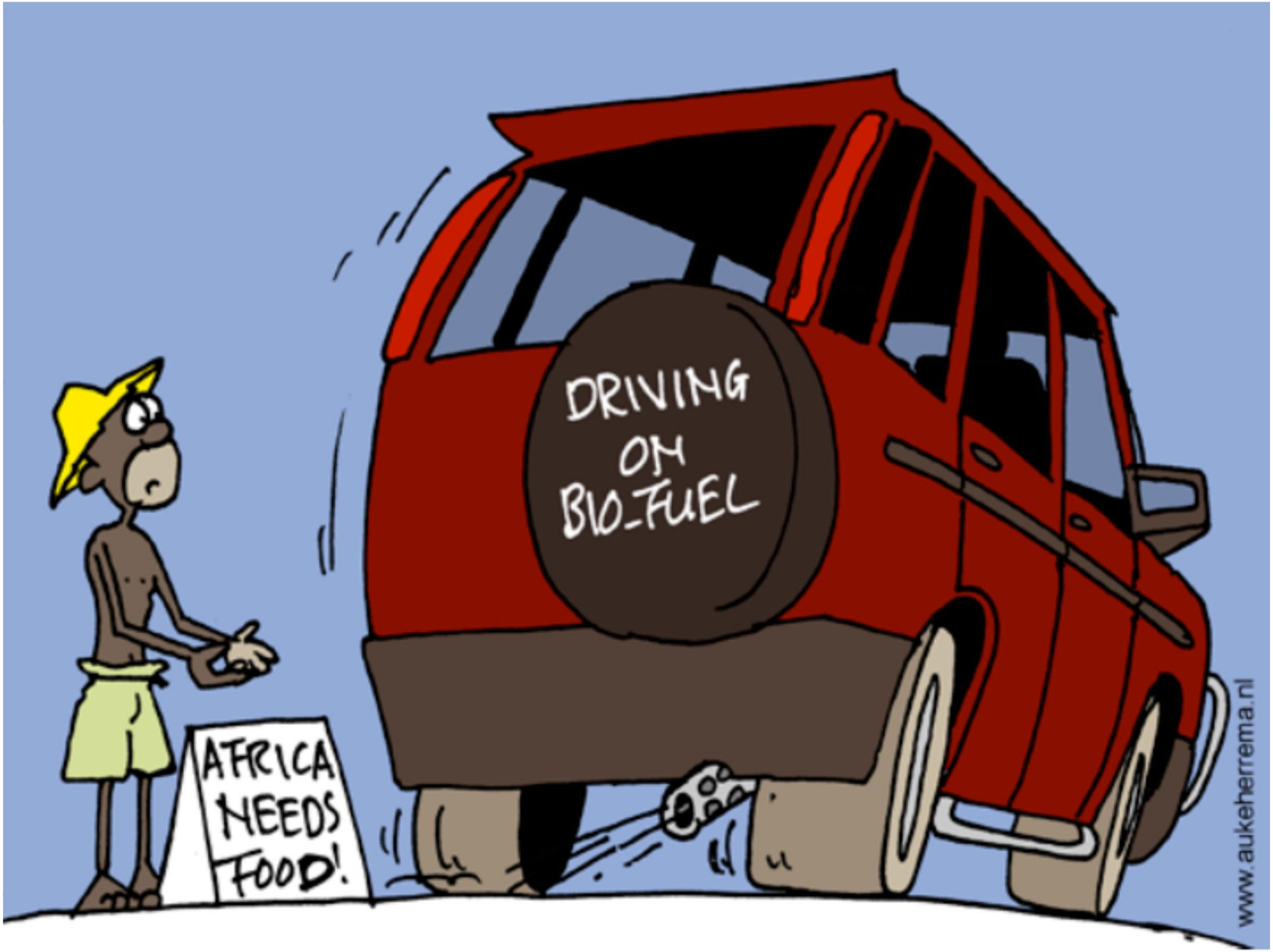


ILUC can be avoided



#7
Indirect Land Use Change: it's complex and relevant, but also manageable

Food security


DRIVING ON BIO-FUEL
AFRICA NEEDS FOOD!
www.aukeherrema.nl

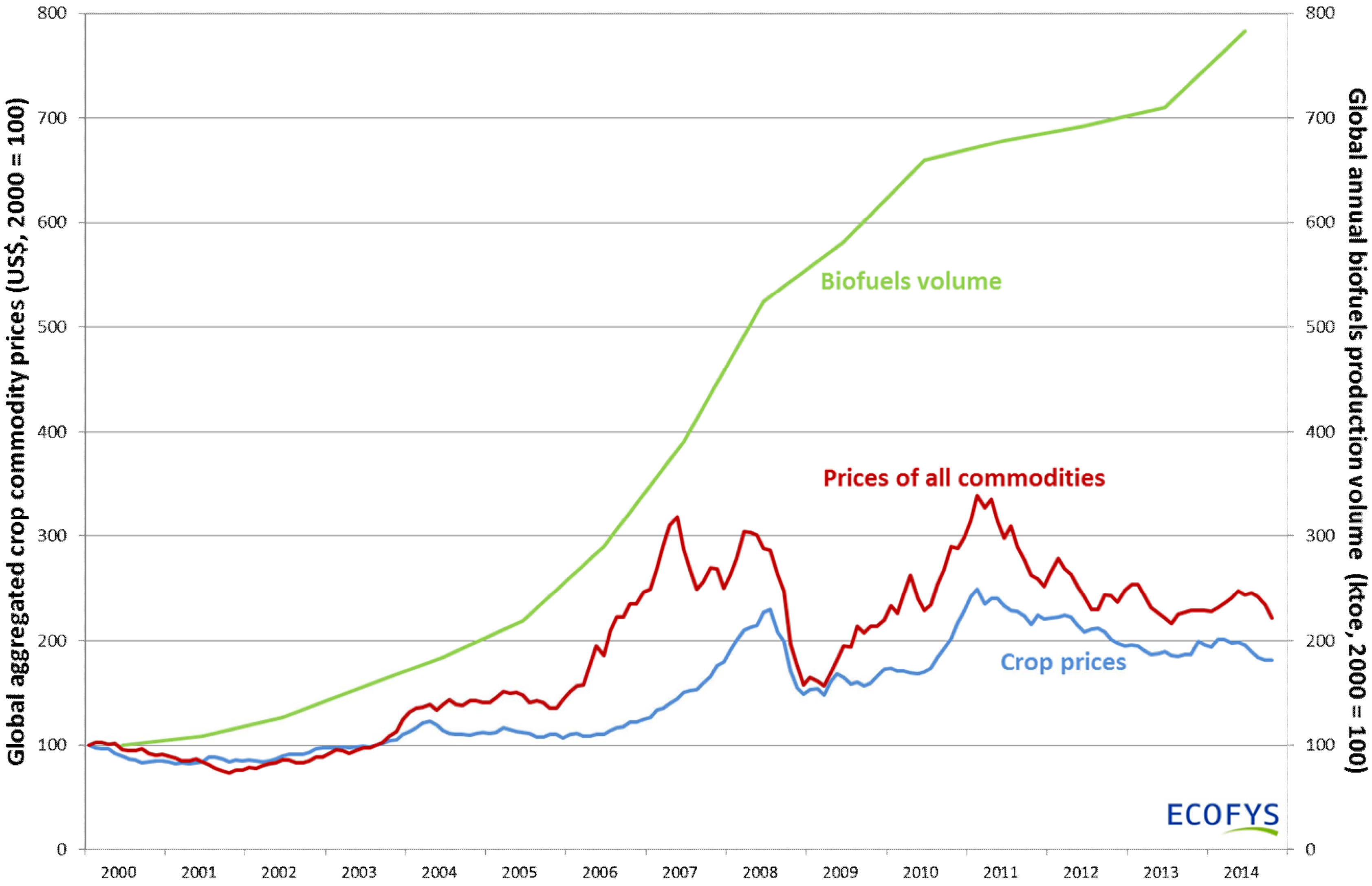
Food security

> Concern:
  - Biofuels use food/feed crops as feedstock
  - Additional demand → The poor face lower supplies and higher prices

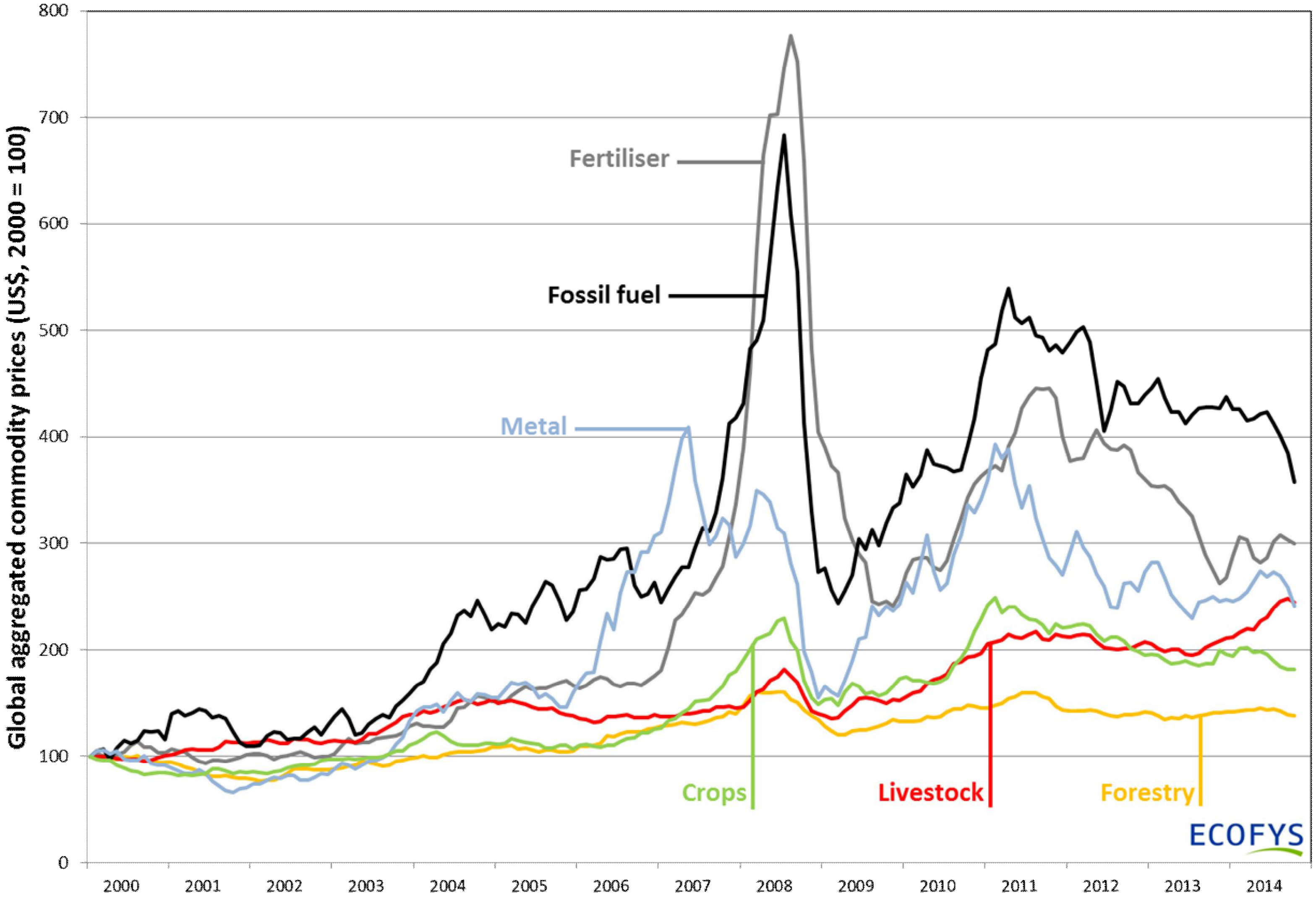
> Hunger in context
  - 2010 crop production was enough to feed 12 billion people and the world can produce more
  - Hunger and poverty continuously decrease
  - Hunger is caused primarily by
    - Suboptimal yields, wastes, absence of (organised) markets, inefficient infrastructure, lack of investments, conflicts, …
  - Not by a reduced supply from developed countries

> The price of food crops mainly depends on the oil price

Global price of products (normalised) and global biofuels volume (normalised)



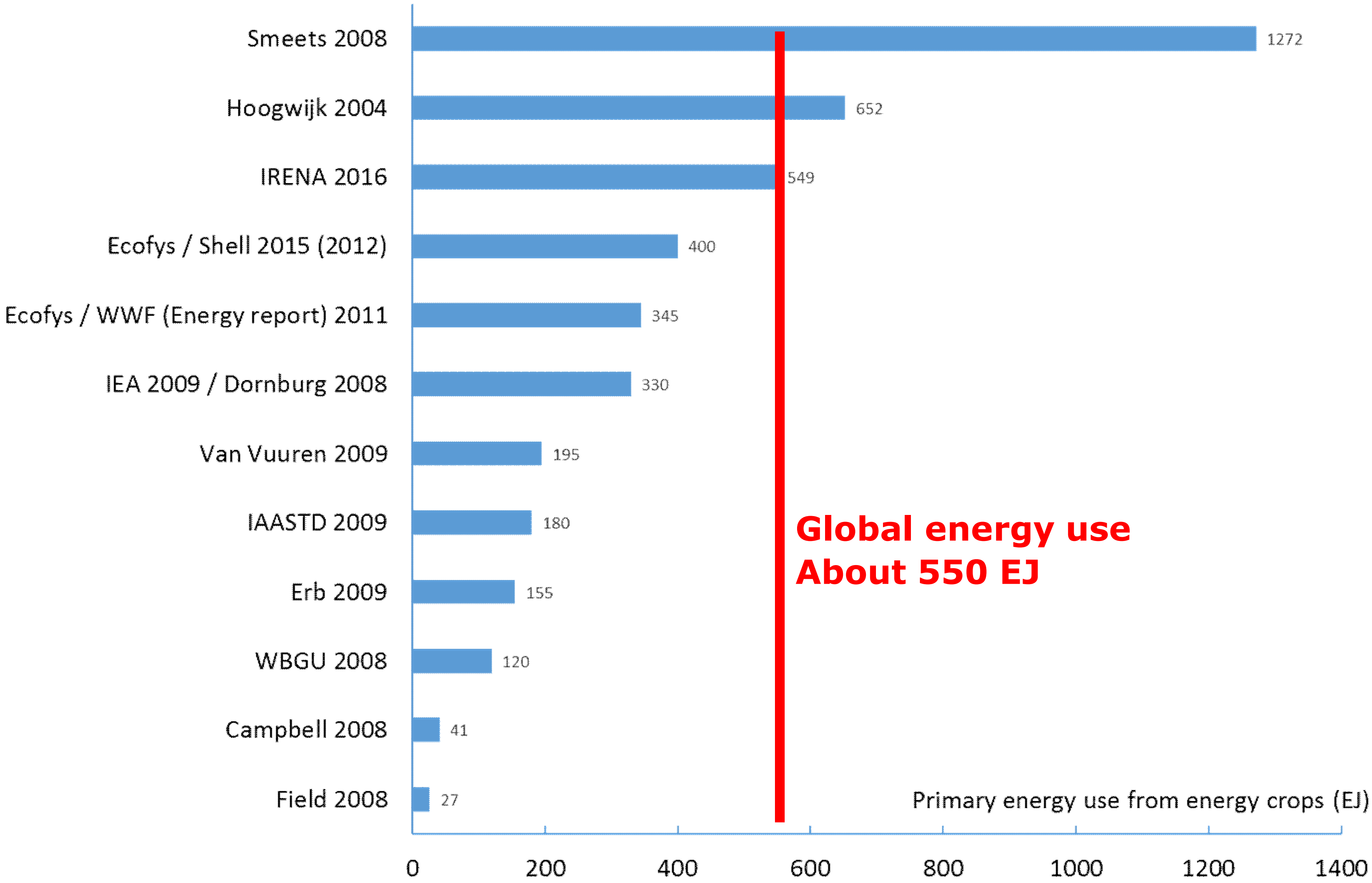
Global price of products (normalised)



#8
Impact of biofuels on food prices is very small

The global biomass potential

Ranges found in literature



Developing countries: improve farm practices and market operation

Charcoal supply chain




- > Sustainable wood
- > Better conversion to charcoal
- > More efficient use in improved stoves (also better for health)

Smarter use of land

- Cane – cattle integration

- Multiple cropping

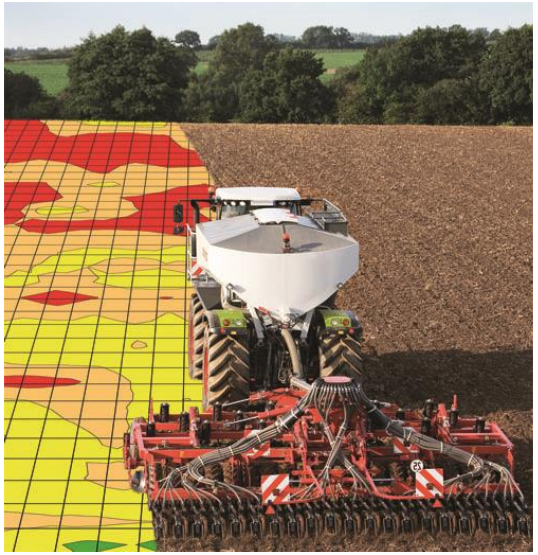
Herbs and vegetables can be grown in urban environment

> Berlin METRO supermarket Herb garden

> Smart greenhouses:

> “Corn field” at Todmore’s police station

Precision farming and smart fertilisation



#9
Biofuels' feedstock could be abundant – but this requires broader action

Conclusion

- Sustainable biofuels are essential for sustainable transport, next to other solutions

- Many types of fuels can be produced from many types of feedstock

- World bioenergy potential estimations range from **<50 to >1000 EJ/yr**
  - Lower estimate considers bioenergy in isolation (only the leftovers)
  - Higher estimate requires that all agriculture becomes more sustainable
- Stimulate synergy between food and fuel, improve the wider agricultural system
- Then the potential for sustainable biofuels becomes very large

- Biofuels are not simply “Good” or “Bad”
- The sustainability of biofuels is complex

- Many concerns are true
- Many concerns are exaggerated
- Many concerns can be avoided
- Mandatory sustainability requirements and certification helps

sustainable energy

for everyone