

Biomethane, the renewable and domestic automotive fuel

- technology, market dynamics and potential

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Biomethane potential

Waste, residual products and energy crops

Cities (urban)



Sewage sludge
Household organic waste
Industrial organic waste
Landfill gas

Agriculture



Manure
Residual products
Energy crops

Forestry



Residual products from
forests and industry

The biofuel with the highest potential through its high
substrate flexibility and its superior conversion and
surface efficiency!

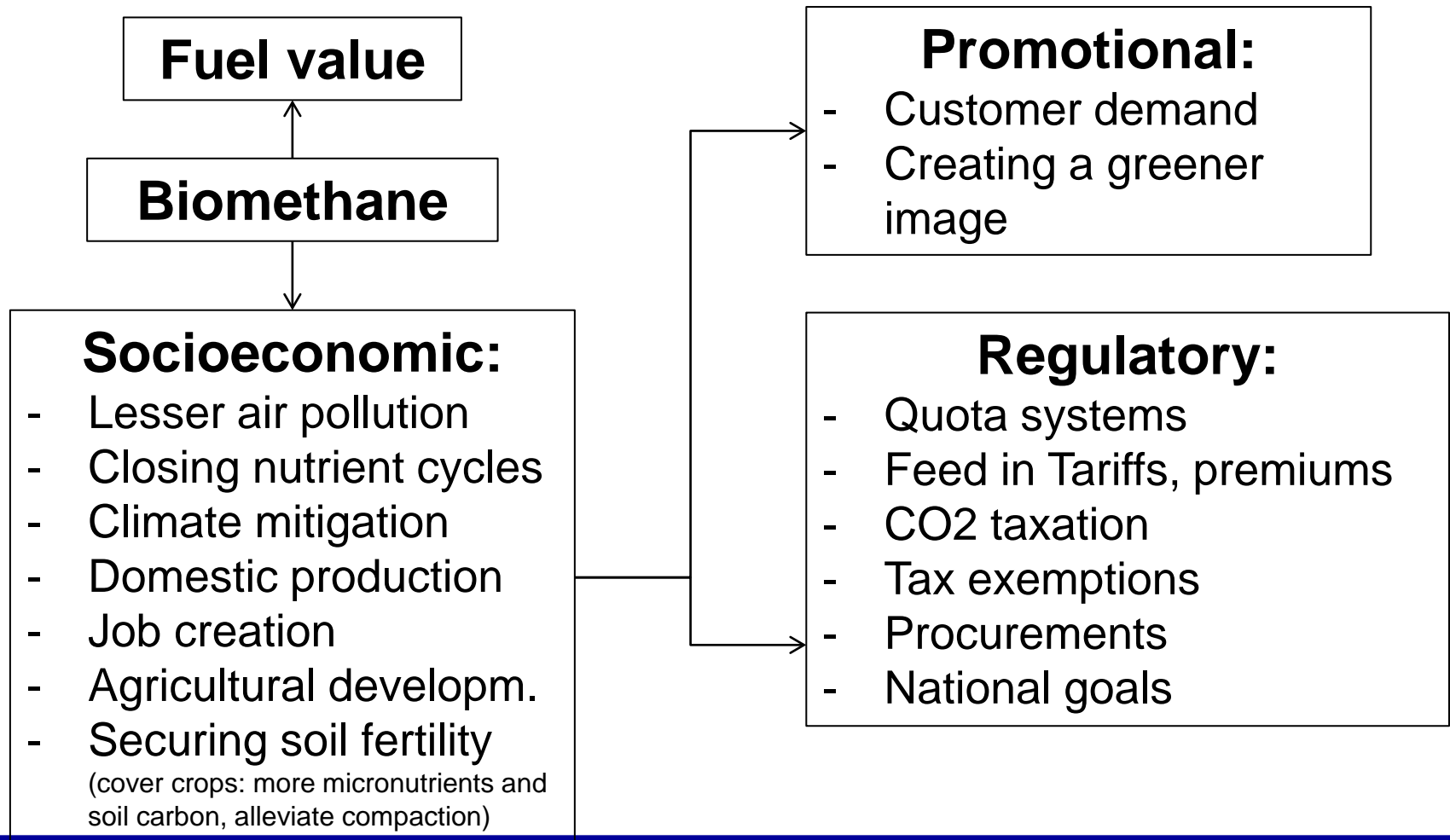
Why biomethane in transports?

Most oil dependent sector (95-100%)

- **Full utilization of energy with solutions available now**
 - Inevitable heat losses in CHP utilization, wind & sun better alt.
 - Commercially available solutions for oil dependent transports of all types (LDV, MDV, HDV, short, medium and long-distant)
 - Natural gas and biomethane: freely intermixed and interchangeable
 - Evident co-distribution and backup synergies (backup for market fluctuations, process failure)
- **Promotional value compensates for added costs**
 - Steadily increasing the renewable share gives true greening

Drivers spelled out

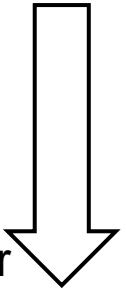
Putting a value on the positive externalities of biomethane



The biomethane market

Complex business in an emerging market

Value
chain



- **Cooperation among many actors**
 - Biomass supplier, biogas producer, digestate receiver
 - Distributors, Refuelling network operators
 - Vehicle manufacturers, auto repair shops, regulatory authorities
 - End customer: From large captive fleets down to the private car owner
- **Barriers to overcome during early formation of market**
 - Weak distribution infrastructure, hen-and-egg situation
 - Low level of knowledge and support, obstructive regulations, weak supportive policies
 - Difficult economics because of high investments
 - Balancing supply and demand
- **→ Formation of regional PPP's (Public – Private – Partnership)**
- **→ Local/regional government as key actors leading the way**

Biomethane through waste management

One solution to meet several urban challenges

- **Giving waste treatment an image boost + saving money!**
 - Decreased treatment costs by producing a high quality energy carrier
 - Increased citizen commitment to recycling by showing tangible results of waste treatment
- **Facilitating fulfilment of urban transport key policy issues**
 - Climate mitigation
 - Fossil fuel dependency
 - Local pollution (PM, NO_x, aldehydes, carcinogens)

“My source-separated food scraps will in 20 days time power my bus ride to work”



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NGV market dynamics of Sweden

Captive bus fleets essential niche* of emerging market
Today: Backbone of the market (ca 50% gas volumes)

- **Converting to NG buses to solve local pollution problems**
 - 90's: NG companies searching for a new market segment
 - Biomethane solution for non-grid cities
 - Today: 1.5 TWh (58% renew.), 47,000 NGV's

The future: 24 m biomethane powered hybrid bus in Malmö



The intercity bus sector is also under "gasification" in Sweden

© Kasper Dudzik, www.kasper.se

*Sandén, B., Jonasson, K. Variety Creation, Growth and Selection Dynamics in the Early Phases of a Technological Transition: The Development of Alternative Transport Fuels in Sweden 1974-2004. pp. 76, 2005.

Biomethane in road transport

Most common in Europe, Sweden forerunner country

- **Big fleet operations outside Europe; US future no.1?**
 - USA, maybe 0,8TWh (2014: 3,9TWh expected!)
 - Driver: 20% renewables by 2022 in RFS* program
- **Changing patterns in Europe**
 - Sweden, Netherlands, Germany and Switzerland current biomethane market leaders (900-100 GWh)
 - New subsidy systems: UK, France, Italy and Denmark
- **Small but quickly growing market**
 - World guesstimate: 3TWh (2014: 6 TWh?)
 - Pilot projects: India, Canada, Thailand, China, South Korea, South Africa, Brazil

* Renewable Fuel Standard

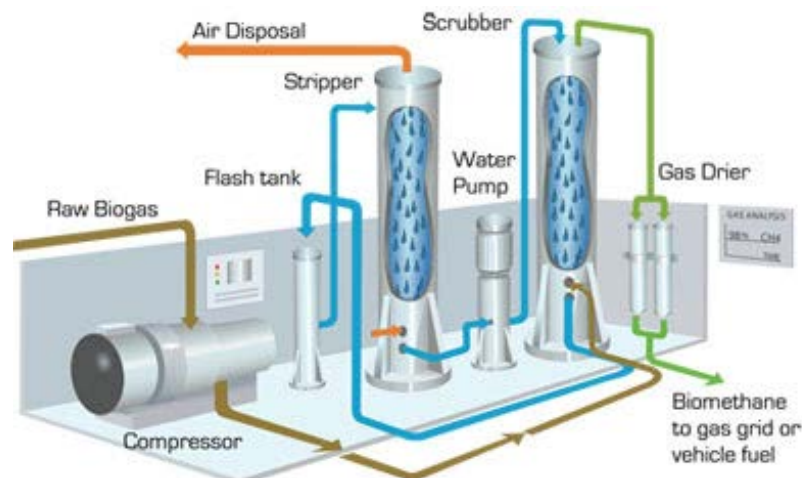
The driving forces that co-create NGV markets

- Oil-dependent transport identified as a major challenge
- Corporative: Gas companies looking for new markets, clients wanting renewable transport products
- National, regional and local interest and policy making
 - National policies, regional public procurement and long-term commitments to fulfill environmental goals
- → **Public-private partnerships and supportive national policies are key in building a biomethane powered NGV market!**
 - Long-term policy commitment, preferably % market size!
 - The whole value-chain need to be involved from the beginning!

Biogas upgrading technology

Biogas upgrading technologies

Water/chemical scrubber



Water Scrubbing Flow Diagram

Source: Greenlane Biogas

Membrane



Source: Air Liquide

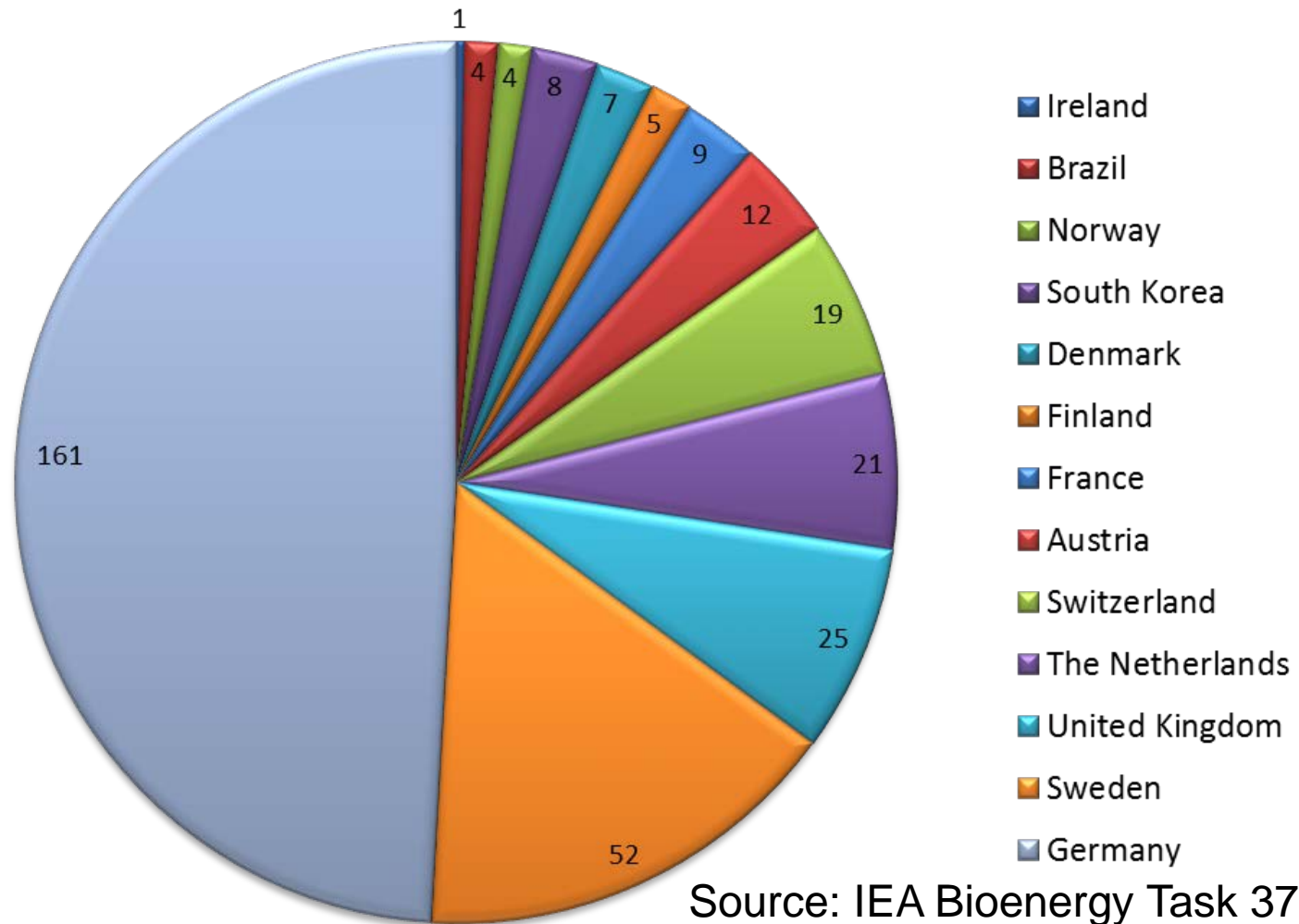
PSA





Biogas upgrading plants in operation

- 328 in IEA Bioenergy Task 37 member countries (1404)



Source: IEA Bioenergy Task 37



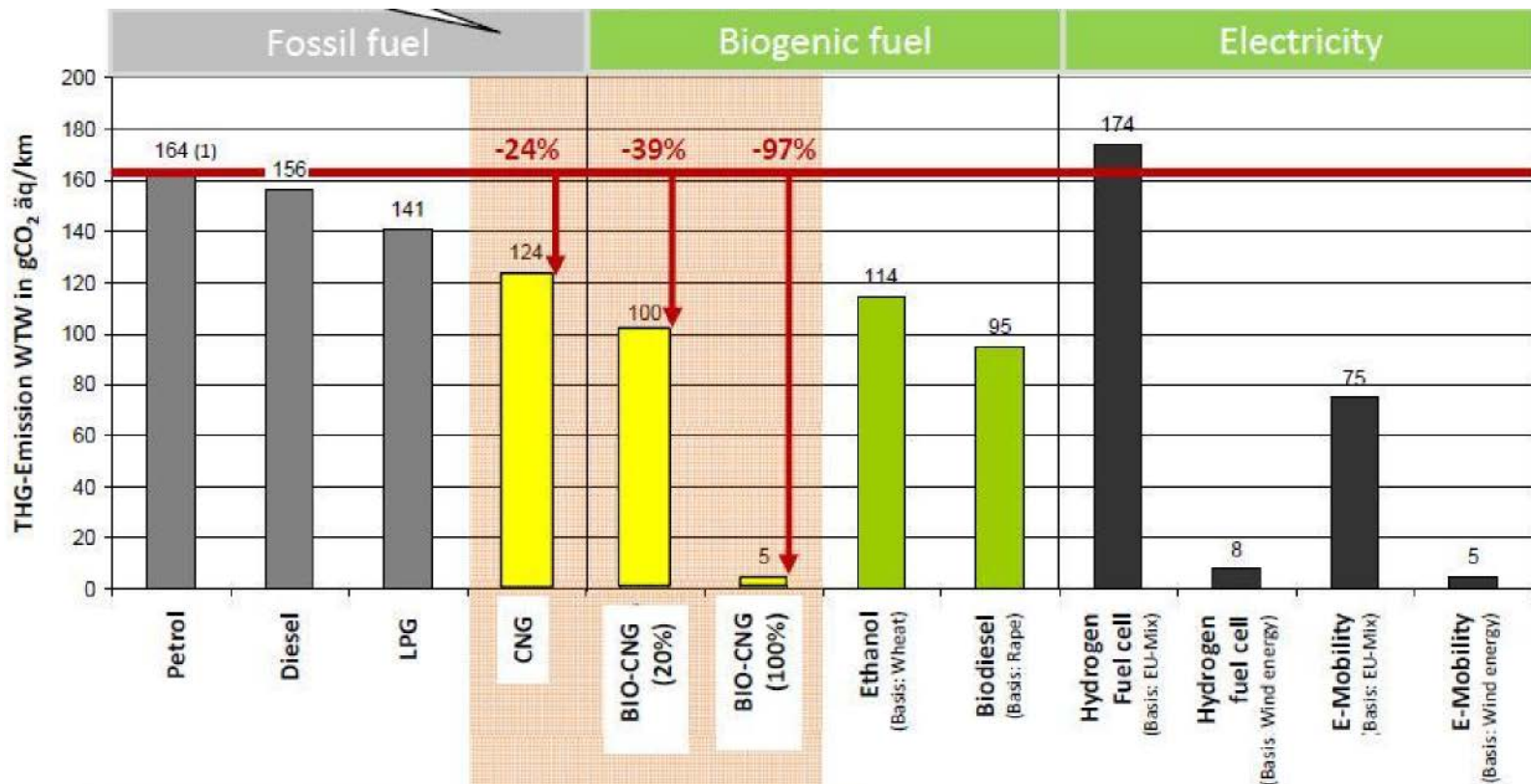
Development

- **Energy consumption has been decreased**
 - Lower pressures, more efficient absorption/adsorption/membranes 0.30-0.35 → 0.25 kWh/Nm³ raw biogas
- **Close competition → similar costs between technologies**
 - Larger standardized units with lower specific investment costs
 - <1,000 Nm³/h: 4,000-2,000 EUR/Nm³
 - 1,000- 2,000 Nm³/h: 2,000-1,500 EUR/Nm³
 - 3,000-5,000 Nm³/h: approx. 1,000 Eur/Nm³
- **Decreased methane emissions (0.5-1% w/o RTO*)**
- **Maturing market → increased availability**

*Regenerative Thermal Oxidation

Carbon footprint of biomethane

Green House Gas (GHG) performance of biofuels

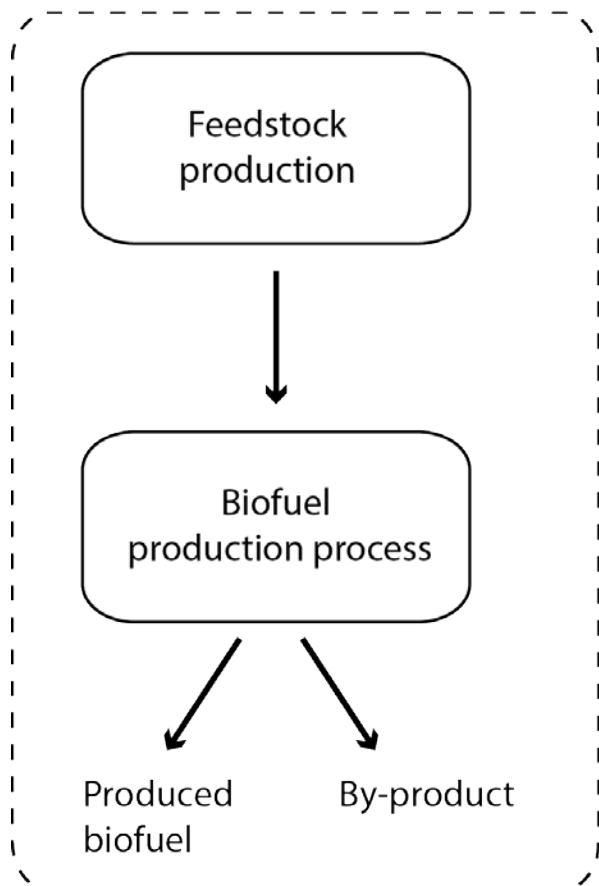


(1) Basis: (Petrol, naturally aspirated engine), Fuel-consumption: 7l/100km

Source:: DENA; EUCAR-CONCAWE

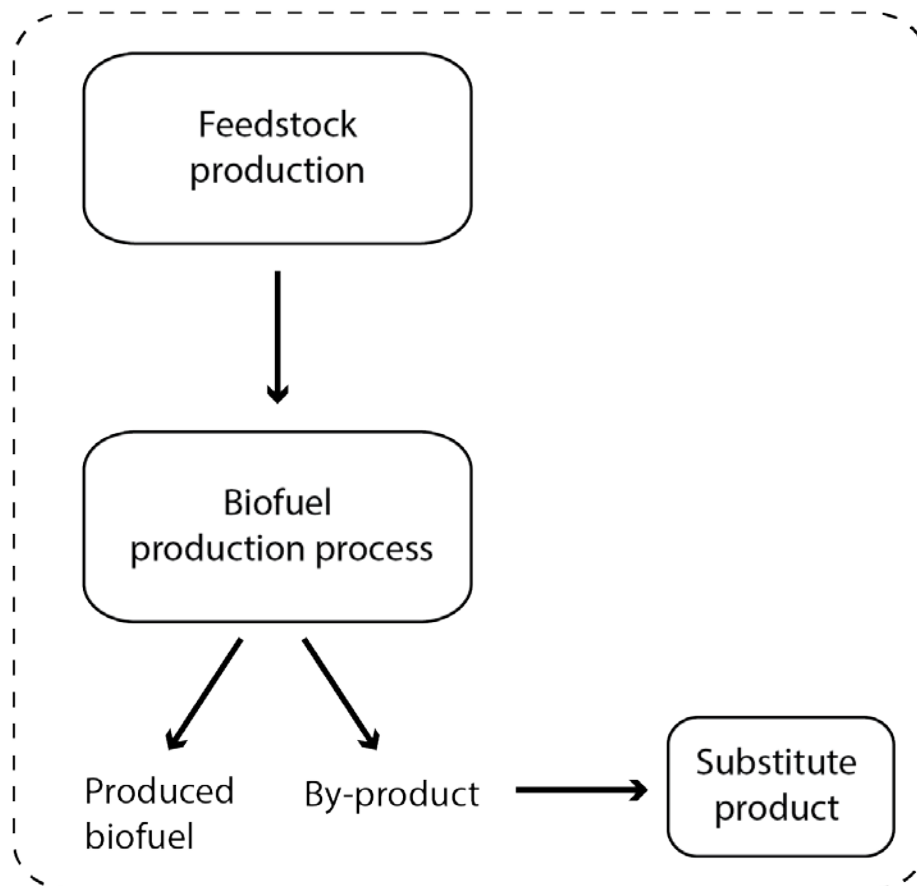
GHG calc. methodology differences

a) System boundary RED



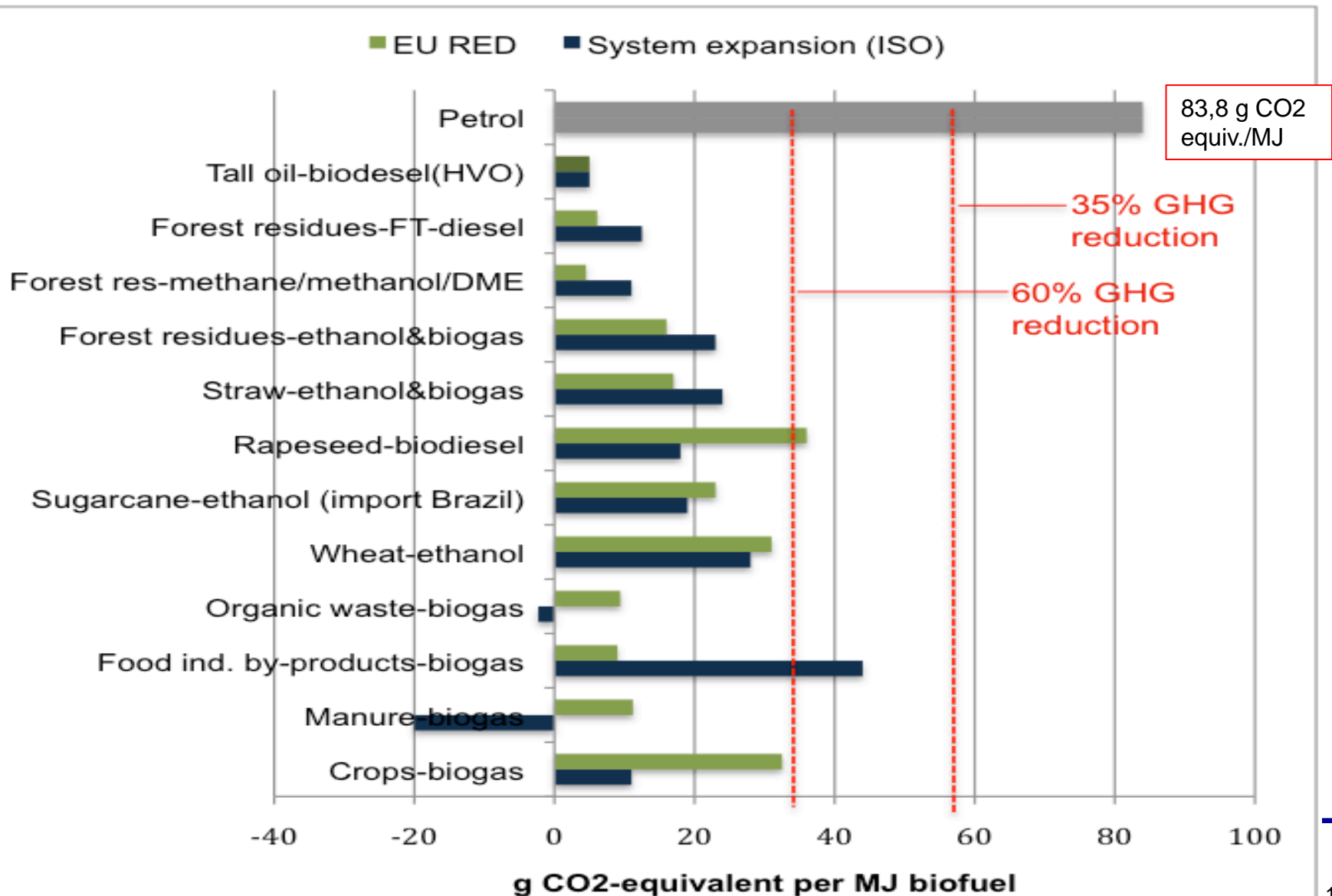
Allocation based on the energy content of products

b) System expansion (ISO 14044)



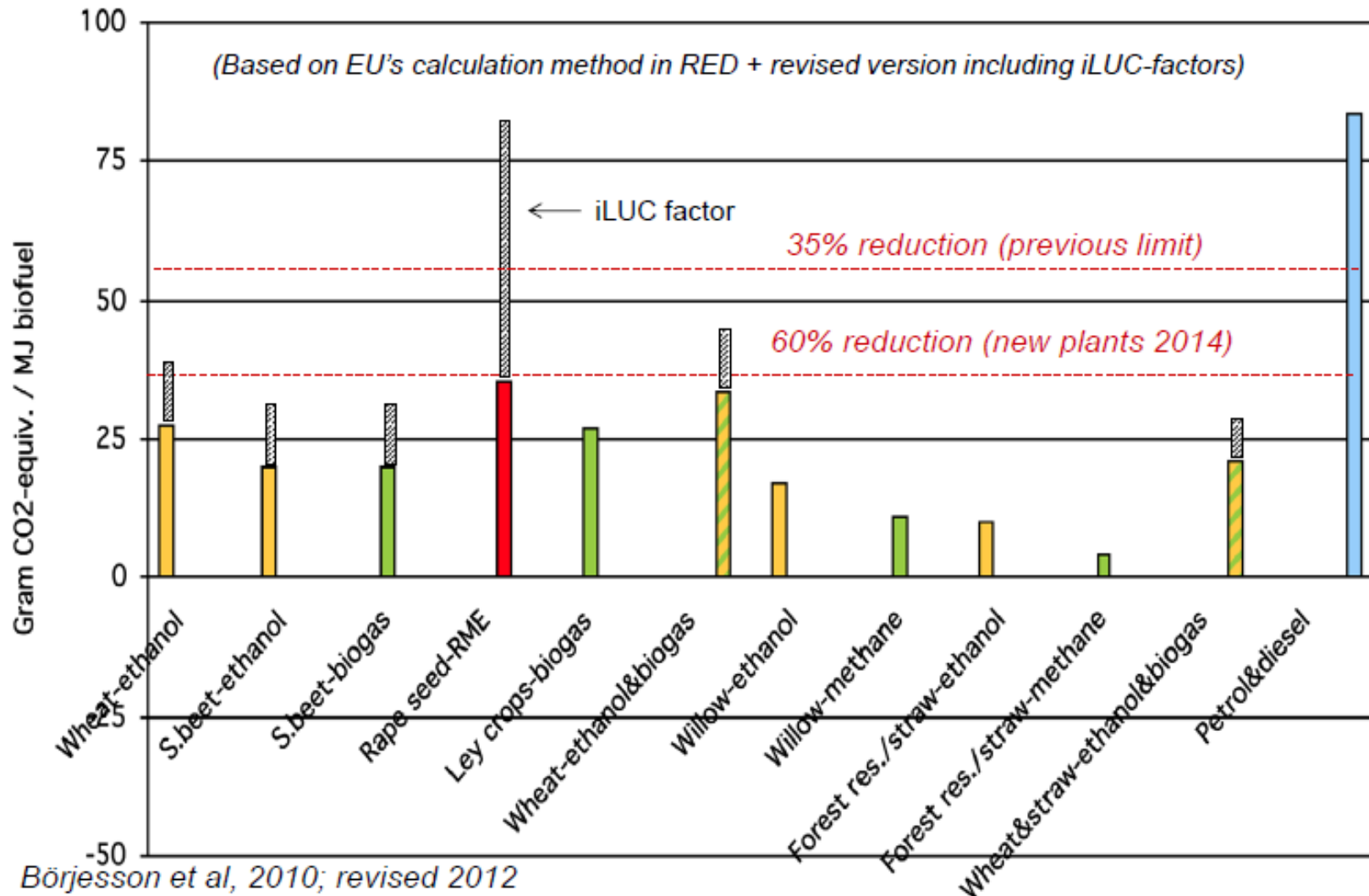
Including indirect benefits due to replacement of alternative product (*e.g. digestate as fertiliser*)

GHG performance biofuels (SWE)



Source: Börjesson, Lundgren, Ahlgren, Nyström (2013)

EU: iLUC stops 1st gen. biofuels



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Thank you! Any questions?

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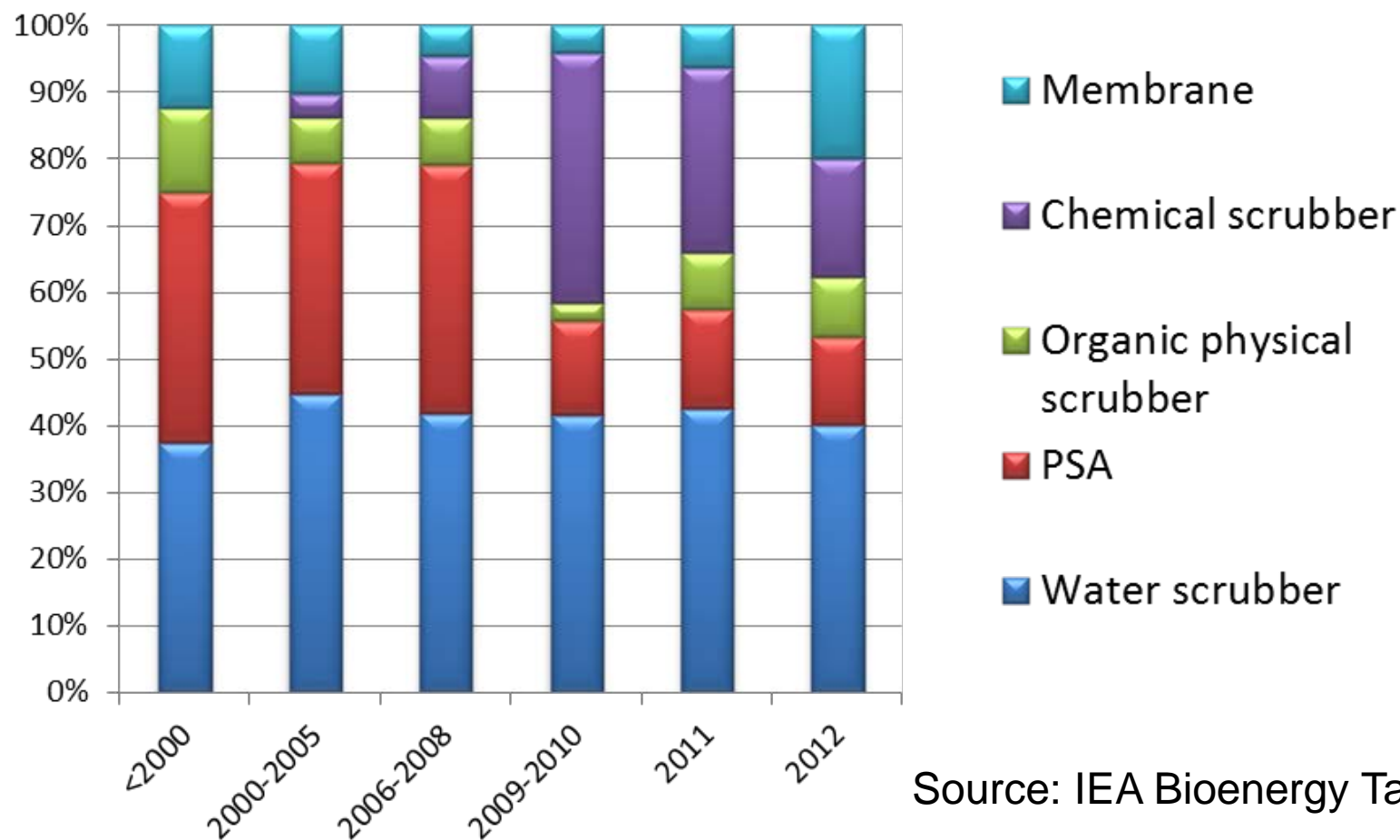


Örnsköldsvik
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- **Welcome to meet up at any of our conferences:**

- GGROS, March 23rd – 25th 2015 www.greengasresearch.se
- Summer school Aug-15 www.gasakademin.se
- IBBA workshop, lignocellulosic substr., Sep-15 www.ibbaworkshop.se
- International Seminar of Gasification, Oct-15 www.gasification.se
- Nordic Biogas Conference, Finland Mar-16 www.nordicbiogas.com

Annual market share



Source: IEA Bioenergy Task 37

Examples US incentives for biomethane

- **Renewable Fuel Standard (FS2 – federal)**
 - Conventional fuel suppliers need to purchase RINs (Renewable Identification Numbers) to fulfil their RVO (Renewable Volume Obligations)*
 - RVO target 2013: 16.55 billion gallons, total 9,63%, including special quotas for cellulosic, advanced and biomass based diesel (conventional share = 6,9%); 2022 goal: 36 billion gallons
 - Blend wall (10% EtOH) effects, cellulosic biofuels waiver credits
 - Biogas from landfill, WWTP or manure digesters = advanced; application for landfill as cellulosic pending! 3-12 USD/mmBTU
- **Low Carbon Fuel Standard (LCFS, California)**
 - Similar market based cap and trade system used in California
 - Demands reduction of carbon intensity, from 0.25% (2011) to 10% (2020), also natural gas and electricity eligible
 - 20-80 USD/ton CO₂ (Source: Harrison Clay, CERF)

* "RINs and RVOs are used to implement the Renewable Fuel Standard"

<http://www.eia.gov/todayinenergy/detail.cfm?id=11511>

Examples of supportive policy measures

- **Fuel tax exemptions**
- **Fringe company car tax reductions**
- **Parking benefits, congestion fee exemptions**
- **Environmental demands regarding fuels and vehicles in regional and local government procurements and contracts**
- **Creation of clean(er) vehicle definition, preferably national**
- **Investment grants, refueling stations and waste biomethane production**
- **Establish national and/or international standards regarding storage, handling, transport and utilisation of biomethane**

Sources: Biofuel Cities Handbook "The local implementation of clean(er) fuel policies in Europe"; Biogasmax project publications; GasHighWay final publication "The GasHighWay - Route to Green Transportation"

Biomethane as an automotive fuel

Not only lower emissions of CO₂ but also particles and SO_x and NO_x

Vehicle type	Present fuel	Liquid bio fuels	Electric	Hybrids	Biogas
Cars	Petrol/Diesel	Yes (%)	Yes	Yes	Yes (CBG)
Delievery trucks	Diesel	Yes (%)	No	Yes	Yes (CBG)
Urban busses	Diesel	Yes (%)	Yes (wired)	Yes	Yes (CBG)
Heavy trucks	Diesel	Yes (%)	No	No	Yes (LBG)
Train	Diesel/Electric	Yes (%)	Yes (wired)	No	Yes (LBG)
Ships	Diesel	Yes (%)	No	No	Yes (LBG)



Example: Biomethane in Sweden

Capital intensive business with still small profit margins
need additional drivers and good framework conditions

- **Tax exemption + high fossil fuel taxes**
 - Upgraded biogas: buy at 0.5-0.8 €/m³, retail at 1.6 (8.5SEK/€)
- **Long-term high-volume contracts securing the market**
 - Waste management + procurement of public transport
- **Substrate costs escalation in harmony with market growth?**
 - Challenge: Starting with free or cheap waste, now followed by more expensive substrates, e.g. energy crops – will fossil fuel prices increase? Will production costs go down further?
- **Missing: Extension of existing policies, no new ones to facilitate production growth**