BIOMASS CONVERSION COURSE

Doctoral School
EPFL

Introduction

What is biomass ?

- **<u>Biomass:</u>** Any organic, *i.e.* decomposing, matter derived from plants or animals available on a renewable basis. Includes wood and agricultural crops, herbaceous and woody energy crops, municipal organic wastes as well as manure (IEA 2012).




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Biomass-based energy is the oldest source of energy known to mankind, and is still today the largest source of renewable energy (10% of world total primary energy).

Traditional biomass : use of wood, charcoal, agricultural residues and animal dung for cooking and heating in the residential sector.

Source: IEA Technology Roadmape Bioenergy for Heat and Power, 2012.

Problem : often sourced unsustainably, leading to forest degradation.

Open fires or simple stoves show very low conversion efficiency (10% to 20%) and can cause severe problems of smoke pollution, as well as black carbon emissions with considerable global warming potential.

Globally around 2.6 billion people – 40% of the world's population – still rely on traditional biomass (wood, crop residues, dung, etc.) to meet household cooking needs (IEA 2012)

Source: Carrie et al. *ASSESSING THE CLIMATE IMPACTS OF COOKSTOVE PROJECTS SEI* Stockholm Environment Institute, 2013

Ethiopia, the Democratic Republic of Congo, Tanzania, Uganda and Bangladesh: over 90% of the population relies on these traditional cooking fuels

Indoor air pollution :

- responsible for an estimated 2 million deaths per year (WHO 2011).
- fuelwood collection can also pose risks to personal safety and keeps women and children away from school or income-producing work.

Two women cooking with firewood in Guatemala. Photo © by Rodney Rascona, used courtesy of The Paradigm Project.

Source: Carrie et al. *ASSESSING THE CLIMATE IMPACTS OF COOKSTOVE PROJECTS SEI* Stockholm Environment Institute, 2013

Potential improvements:

Small investments ($5 to $8 per tCO2e) in new, more efficient biomass stoves for cooking or heating, can lead to significantly improved efficiencies.

Reduce fuel use and improve indoor **air quality**, while providing **employment** in the stoves supply chain stove

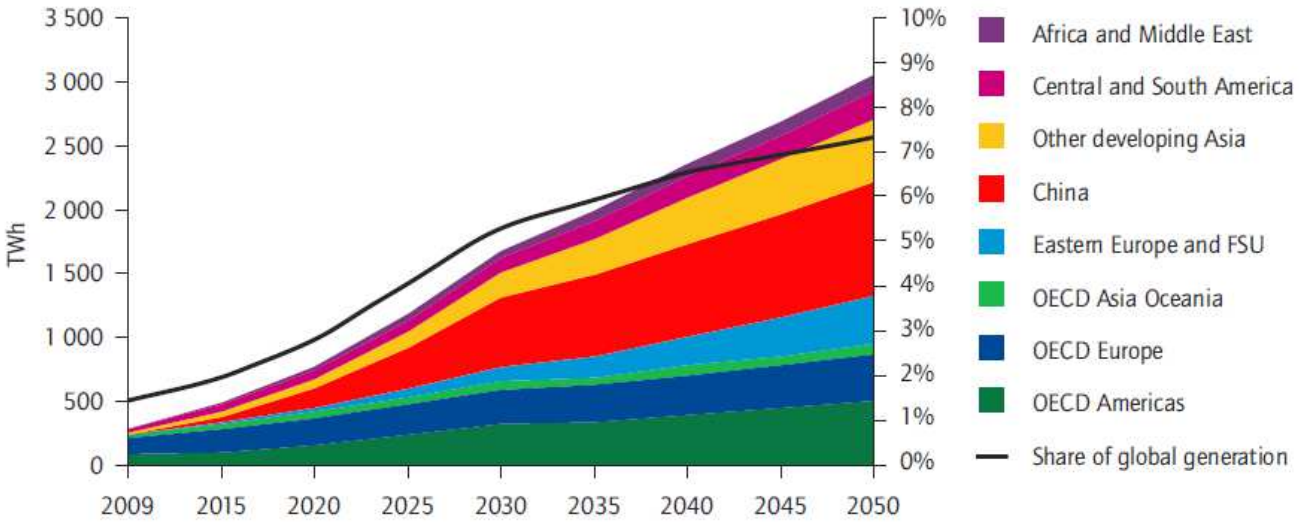
A woman uses an improved cookstove in Kenya. Photo © by Rodney Rascona, used courtesy of The Paradigm Project.

Source: Carrie et al. *ASSESSING THE CLIMATE IMPACTS OF COOKSTOVE PROJECTS SEI* Stockholm Environment Institute, 2013

Power Production

- By 2050 bioenergy could provide 3 000 TWh of electricity, *i.e.* 7.5% of world electricity generation.

Figure 9: Roadmap vision of bioenergy electricity generation by region



Source: IEA Technology Roadmape Bioenergy for Heat and Power, 2012

Power Production

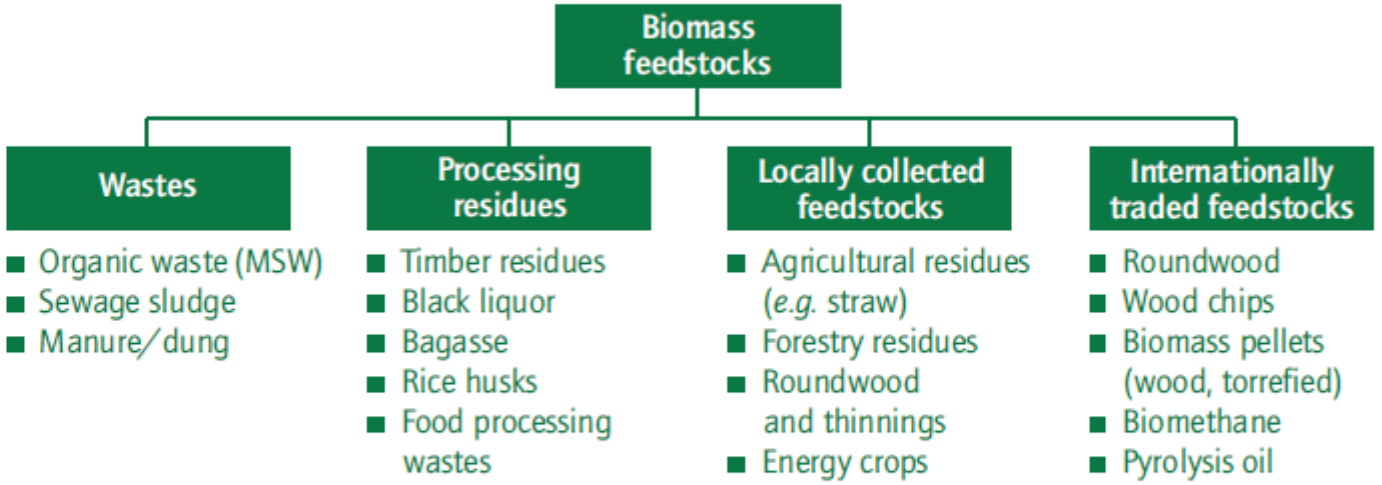
Large-scale biomass combustion based plant to produce heat and power is a **mature technology**.

Heat generated is **competitive** with that produced from fossil fuels.

- Efficient wood log, chips, and pellet burning stoves
- Municipal solid waste (MSW) incineration
- Use of biogas plants

Source: IEA Technology Roadmape Bioenergy for Heat and Power, 2012.

Figure 4: Examples of different biomass feedstocks, typical feedstock costs, and plant capacities



Typical feedstock costs (USD/GJ)	negative to 0	0 – 4	4 – 8	8 – 12
Typical plant capacity (MW electric)	0.5 – 50	0.5 – 50	10 – 50	> 50

Source: IEA Technology Roadmape Bioenergy for Heat and Power, 2012.

Co-firing Biomass and Coal

Property	Biomass	Coal
Fuel density (Kg/m^3)	~500	~1,300
Particle size	~3 mm	~100 μm
Carbon content[a]	42–54	65–85
Oxygen content[a]	35–45	2–15
Sulfur content[a]	Max. 0.5	0.5–7.5
Nitrogen content[b]	0.1–0.2	1.5–2.0
SiO_2 content[b]	23–49	40–60
K_2O content[b]	4–48	2–6
Al_2O_3 content[b]	2.4–9.5	15–25
Fe_2O_3 content[b]	1.5–8.5	8–18
Ignition temperature (K)	418–426	490–595
Peak temperature (K)	560–575	–
Friability	Low	High
Dry heating value(MJ/kg)	14–21	23–28

Reproduced with permission from [1]

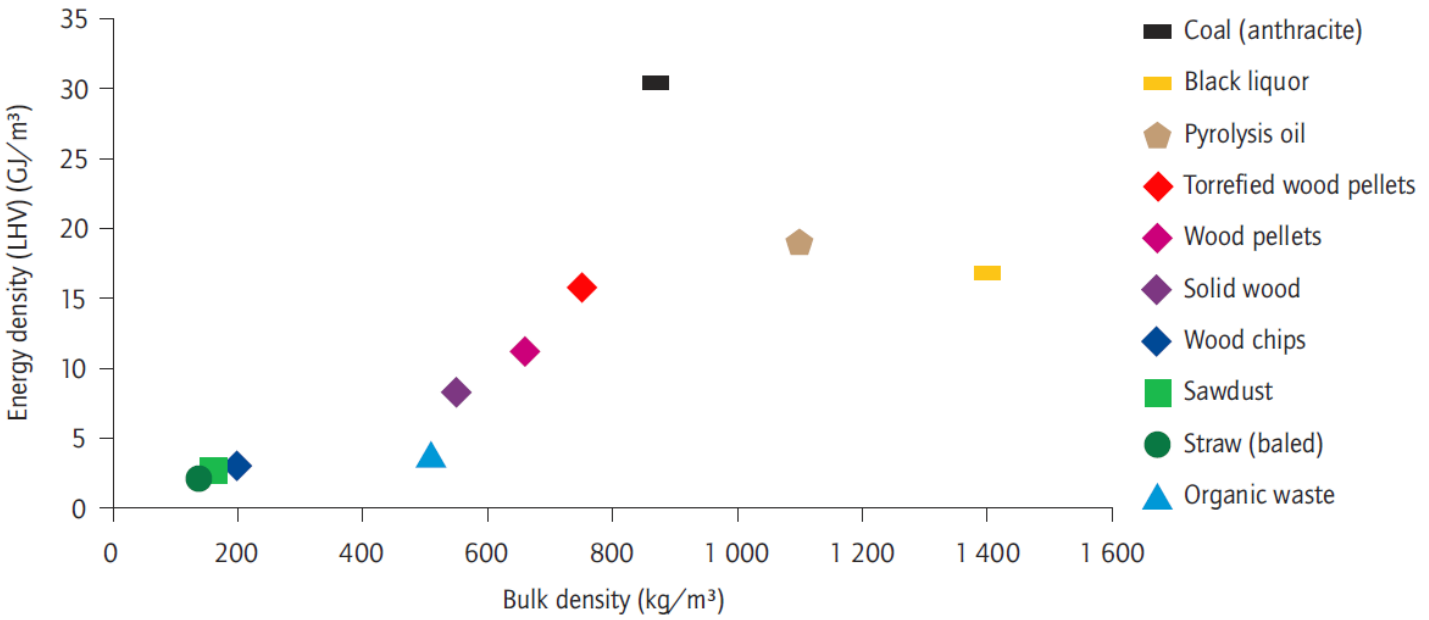
[a] wt% of dry fuel

[b] wt% of dry ash

Source: Baskar et al. Biomass conversion, Ed. Springer, 2012.

Co-firing Biomass and Coal

Figure 5: Comparison of bulk density and energy density of different biomass feedstocks



Source: IEA analysis based on DENA, 2011; FNR, 2011a; IEA Bioenergy, 2011; Kankkunen and Miikkulainen, 2003. For detailed data see Table 6 in Appendix I.

Source: IEA Technology Roadmape Bioenergy for Heat and Power, 2012

Co-firing Biomass and Coal

- Cost-effective **large-scale** means of converting biomass to electricity (and where suitable networks exist, to heat).
- Use of the existing infrastructure - relatively **minor investment** in biomass pre-treatment and feed-in systems.
- **Higher conversion** efficiencies as large-scale coal plants.
- Provides an opportunity for direct carbon savings by directly **reducing the volumes of coal** used

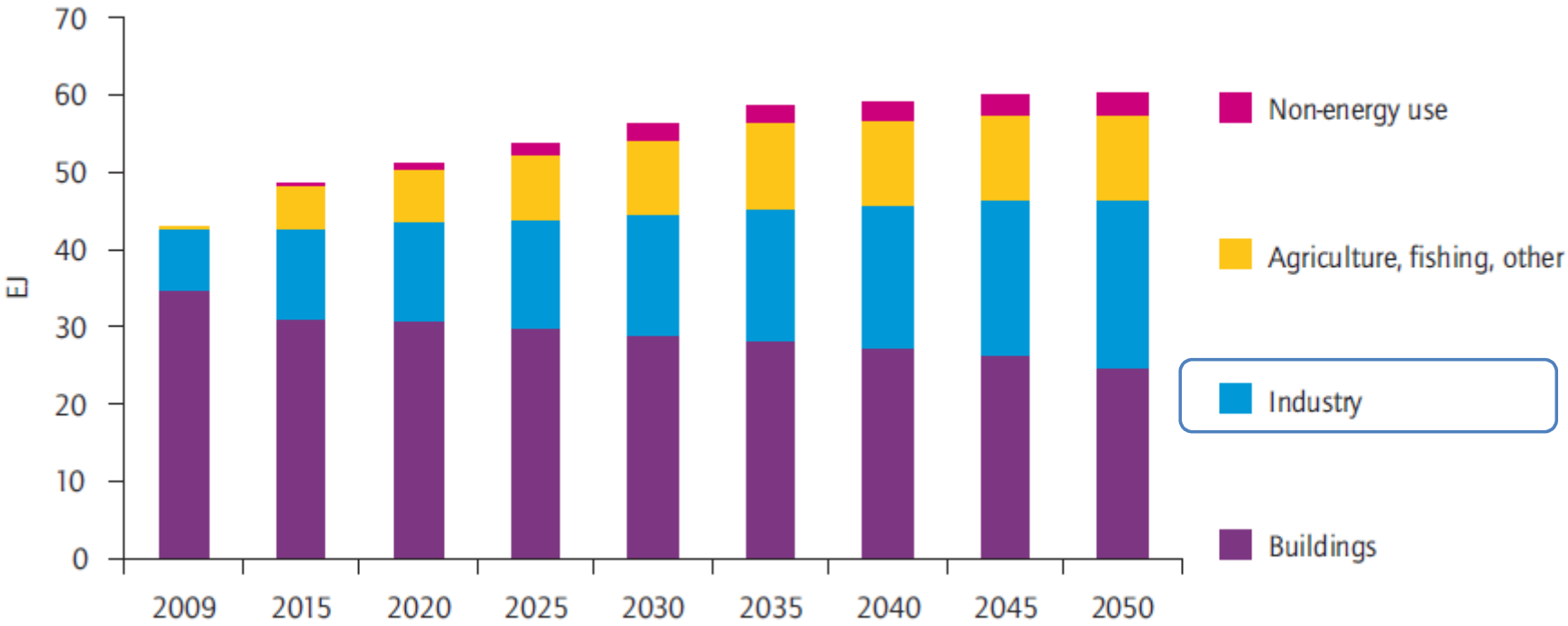
Source: IEA Technology Roadmape Bioenergy for Heat and Power, 2012

Co-firing Biomass and Coal

- **Mixing** solid biomass and coal between **5% to 10%**
- Higher co-firing rates require **modifications**, such as to the fuel pre-treatment (milling).
- Liquid and gaseous biomass fuels such as **tall oil** (a by-product of the Kraft process of pulp and paper production) and **biomethane** can also be used in this way.
- Particularly interesting option, as it can be blended with **natural gas**.

Source: IEA Technology Roadmape Bioenergy for Heat and Power, 2012

Figure 8: Roadmap vision of world final bioenergy consumption in different sectors

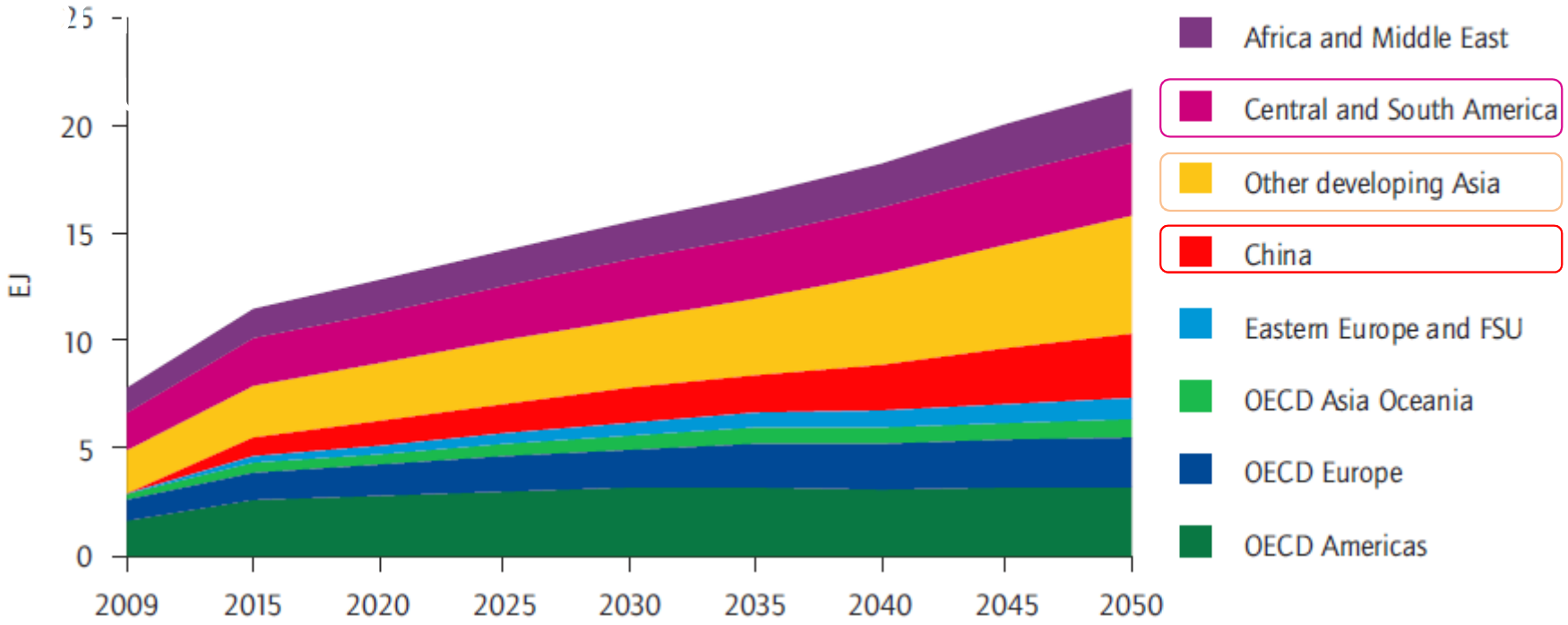


Note: Bioenergy use in the buildings sector is for both heating and cooking. Demand for transport fuels is not shown here since this has been discussed in a previous roadmap (IEA, 2011b).

Source: IEA Technology Roadmape Bioenergy for Heat and Power, 2012.

- Increase of 8 EJ in 2009 to 22 EJ in 2050
- 15% of the industrial sector's total energy

Figure 11: Roadmap vision of final bioenergy consumption in industry



Source: IEA Technology Roadmape Bioenergy for Heat and Power, 2012.