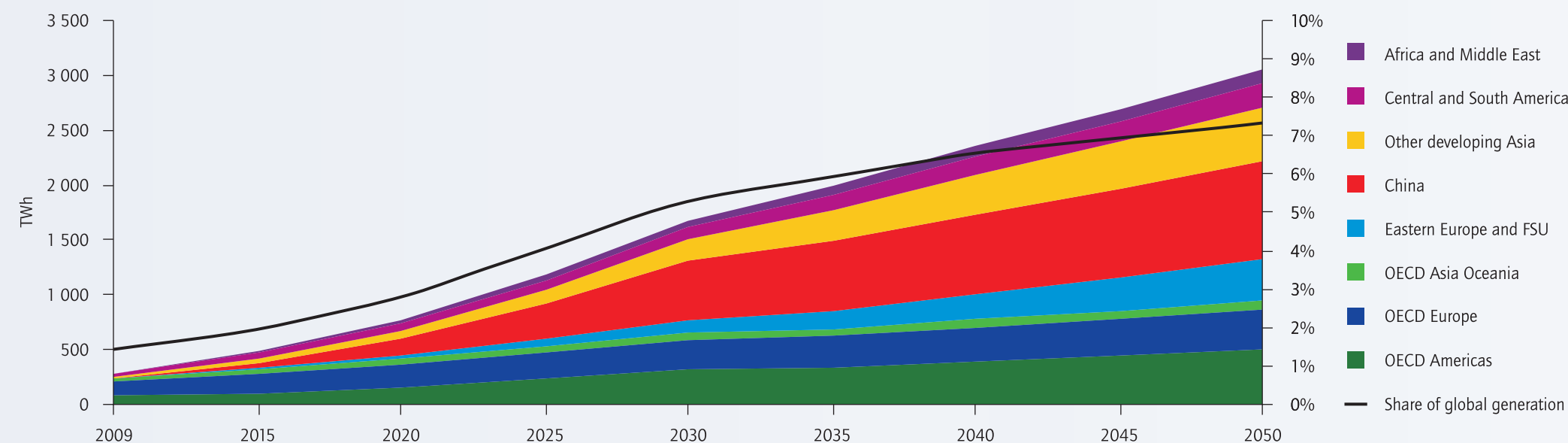


Key findings

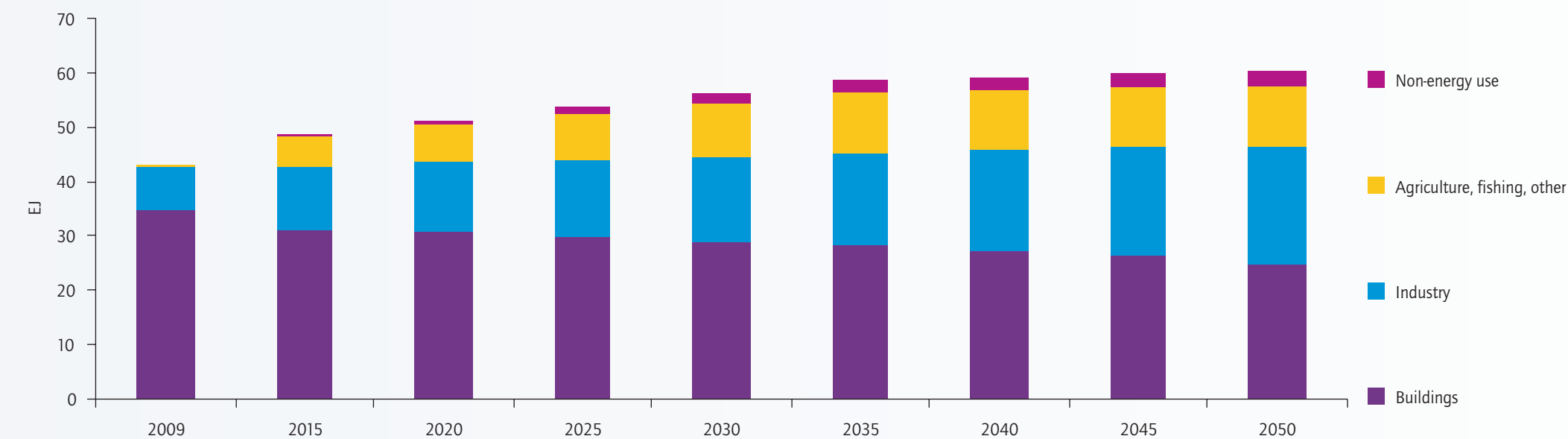
- ▶ This roadmap envisages world total primary bioenergy supply increasing from 50 EJ today to 160 EJ in 2050, with 100 EJ of this for generation of heat and power.
- ▶ This roadmap aims at the deployment of advanced biomass cookstoves and biogas systems to 320 million households in developing countries by 2030, as part of a sustained effort to provide universal access to clean energy.
- ▶ By 2050 bioenergy could provide 3 000 TWh of electricity, i.e. 7.5% of world electricity generation. In addition heat from bioenergy could provide 22 EJ (15% of total) of final energy consumption in industry and 24 EJ (20% of total) in the buildings sector in 2050.
- ▶ Bioenergy electricity could bring 1.3 Gt CO₂-eq emission savings per year in 2050, in addition to 0.7 Gt per year from biomass heat in industry and buildings, if the feedstock can be produced sustainably and used efficiently, with very low life-cycle GHG emissions.
- ▶ Large-scale (>50 MW) biomass power plants will be important to achieve this roadmap's vision, since they allow for electricity generation at high efficiencies and relatively low costs. Smaller-scale (<10 MW) plants have lower electric efficiencies and higher generation costs, and are best deployed in combined heat and power mode, when a sustained heat demand is available.
- ▶ Biomass heat and electricity can already be competitive with fossil fuels under favourable circumstances today. Through standardising optimised plant designs, and improving electricity generation efficiencies, bioenergy electricity generation costs could become generally competitive with fossil fuels under a CO₂ price regime.
- ▶ Around 100 EJ (5-6 billion dry tonnes) of biomass will be required in 2050, in addition to 60 EJ (3-4 billion dry tonnes) for production of biofuels. Studies suggest such supply could be sourced in a sustainable way from wastes, residues and purpose grown energy crops.
- ▶ International trade in biomass and biomass intermediates (pellets, pyrolysis oil, biomethane) will be vital to match supply and demand in different regions and will require large-scale development of biomass and its intermediates.
- ▶ To achieve the targets in this roadmap, total investment needs in bioenergy electricity generation plants globally are around USD 500 billion between 2012 and 2050. In addition, considerable investments in bioenergy heating installations in industry and buildings are required. Total expenditures on feedstocks are in the range of USD 7-14 trillion in 2012-2050, depending on feedstock prices.
- ▶ In the next 10-20 years, cost differences between bioenergy and fossil derived heat and power will remain a challenge. Economic support measures specific to different markets will be needed as transitional measures, leading to cost competitiveness in the medium term.

Roadmap vision of bioenergy electricity generation by region



Note: In 2050 Brazil accounts for 80% of total bioenergy electricity generation in Central and South America, India accounts for 45% of the total in Other developing Asia, and Russia accounts for 60% of total generation in Eastern Europe and FSU.

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 IEA roadmap.

Policy actions and milestones

Technology and RD&D

- Foster transition of traditional biomass use to more efficient and sustainable energy access by deploying advanced cookstoves and provide access to clean fuels (biogas, bio-ethanol)
- Increase share of co-firing, and refurbish existing boilers to accept higher biomass shares in order to achieve short-term CO₂ reductions and avoid "lock-in"
- Gradually replace standing coal-fired assets with high efficient, utility-scale electricity and CHP biomass plants to ensure efficient CO₂ reductions
- Commercial-scale demo plant for torrefaction, pyrolysis and bio-SNG
- R&D and demonstration of biomethane use in fuel cells and micro turbines, and other cost-efficient small-scale generation options
- Deploy small-scale CHP systems with high electricity generation and overall cost-efficiency
- Increase research efforts on development of bioenergy feedstocks and establish large-scale field trials to identify the most promising feedstock types and locations for future scale-up
- Continue RD&D efforts on promising feedstock species and innovative cultivation methods
- Focus on efficiency (logistics and waste reduction) and productivity of agriculture, livestock production, and sustainable forest management, and develop integrated biomass supply chains that can supply food, fibre and fuels in a cost- and resource-efficient manner

Regulatory framework

- Adopt medium- and long-term targets for sustainable bioenergy supply
- Set clean energy access targets and pursue those vigorously by providing a supportive framework for private sector investments
- Introduce differentiated economic incentive schemes, linked to sustainability certification, for both electricity and heat – to be phased out over time
- Introduce international technical standards for biomass and biomass-intermediates to enhance biomass and biofuel trade
- Further improve framework for international biomass and biofuel trade

Sustainability framework

- Demonstrate sustainability of industry through active engagement together with governments, multilateral bodies, and NGOs in developing and adopting sustainability certification schemes
- Adopt instruments for the promotion of sustainable land use, such as sustainability certification schemes, effective legal regulations, and agriculture development programs, as well as support measures that promote integrated feedstock production systems and efficient processing technologies
- Monitor implementation of sustainability criteria and audit systems, and promote adaptation of solid sustainability certification for other energy sources (fossil and renewable), and in other sectors (agriculture, forestry)
- Re-design agricultural policies in particular in developing countries based on sustainable land-use management
- Align bioenergy sustainability policies with agricultural, forestry and rural development policies
- Foster regional capacity building to promote best practices in the agricultural and forestry sectors in developing countries

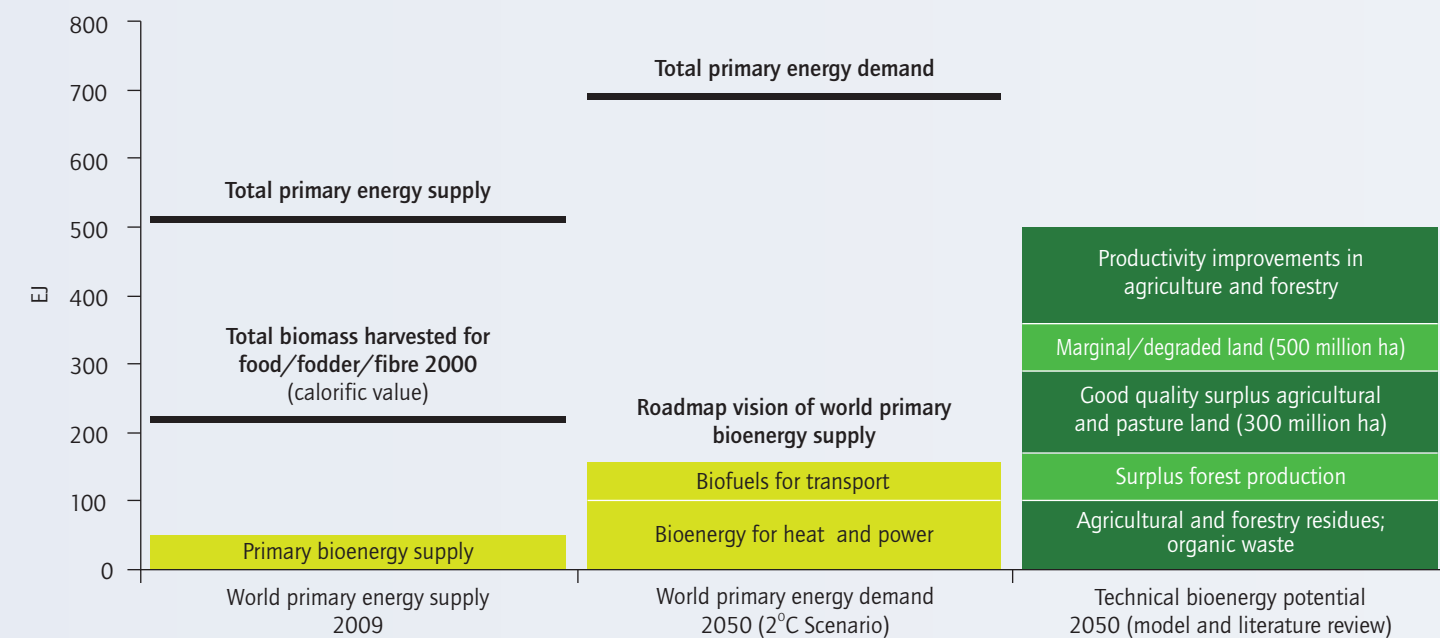
Stakeholders:

- Government
- Industry
- IGOs and NGOs

Key actions over the next ten years:

- This roadmap suggests the following key actions should be undertaken over the next few years:
- Create a stable, long-term policy framework** for bioenergy to increase investor confidence and allow for private sector investments in the sustainable expansion of bioenergy production.
 - Introduce efficient support mechanisms** for bioenergy that effectively address the specifics of both electricity and heat markets.
 - Increase research efforts on development of bioenergy feedstocks and land suitability mapping** to identify the most promising feedstock types and locations for future scaling up.
 - Replace traditional biomass use through more efficient stoves and clean fuels** (e.g. biogas) by the creation of viable supply chains for advanced biomass cookstoves and household biogas systems.
 - Support the installation of more pilot and demonstration projects**, including innovative concepts for small-scale, high-efficiency combined heat and power (CHP) plants, including their complete supply chains.
 - Set medium-term targets for bioenergy** that eventually lead to a doubling of current primary bioenergy supply (i.e. to 100 EJ) by 2030. This will help to establish supply chains, assess the impact on sustainability and identify options for effective integration of bioenergy in biomass value chains.
 - Implement internationally agreed sustainability criteria, indicators and assessment methods** for bioenergy. These should provide a basis for the development of integrated land-use management schemes that aim for a more resource efficient and sustainable production of food, feed, bioenergy and other services.
 - Introduce internationally aligned technical standards for biomass and biomass intermediates**, in order to reduce and eventually abolish trade barriers, enhance sustainable biomass trade and tap new feedstock sources.
 - Support international collaboration on capacity building and technology transfer** to promote the adoption of best practices in sustainable agriculture, forestry and bioenergy production.

Comparison of primary bioenergy demand in this roadmap and global technical bioenergy potential estimate in 2050



Source: Adapted from IPCC (2011) and supplemented with data from IEA.

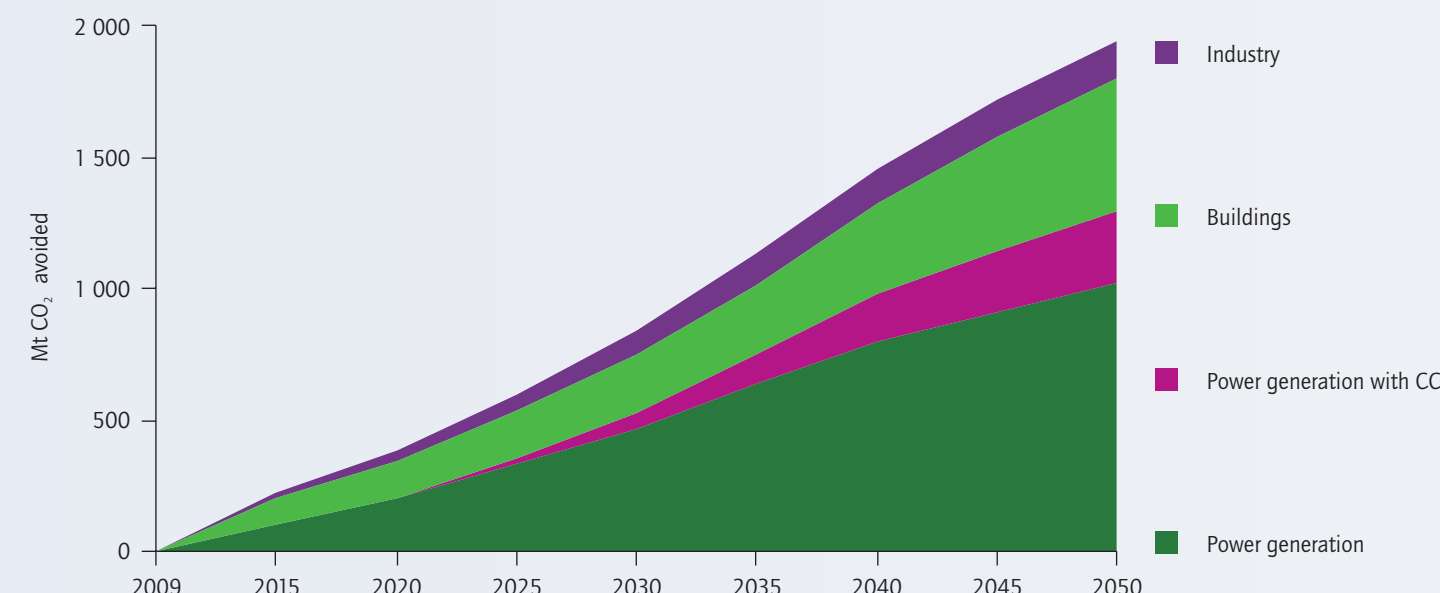
Around 100 EJ, i.e. 5-6 billion dry tons of primary biomass is needed for bioenergy production in this roadmap, in addition to 60 EJ needed for biofuel production. Analyses suggest a solid potential exists to source this from wastes, residues and purposely grown energy crops in a sustainable manner.

Assuming one-third of biomass demand for heat and power could be met with residues and wastes, an additional 2.5-4.5 billion tons of biomass from lignocellulosic energy crops would be needed to meet this roadmap's targets. With an average yield of 15 dry tons/ha/year between 170 Mha and 300 Mha of energy crop plantations would need to be established, corresponding to 4%-6% of total agricultural land today. With higher energy crop yields, or enhanced use of residues and wastes, total land demand would be significantly lower.

Some uncertainty exists, however, regarding aspects like logistics, costs, biodiversity, and other socio-economic impacts. An intermediate target of sourcing a total of 100 EJ for heat, power and biofuels under a strict sustainability framework, is thus suggested to establish supply chains, and evaluate the feasibility of such large-scale biomass supply.

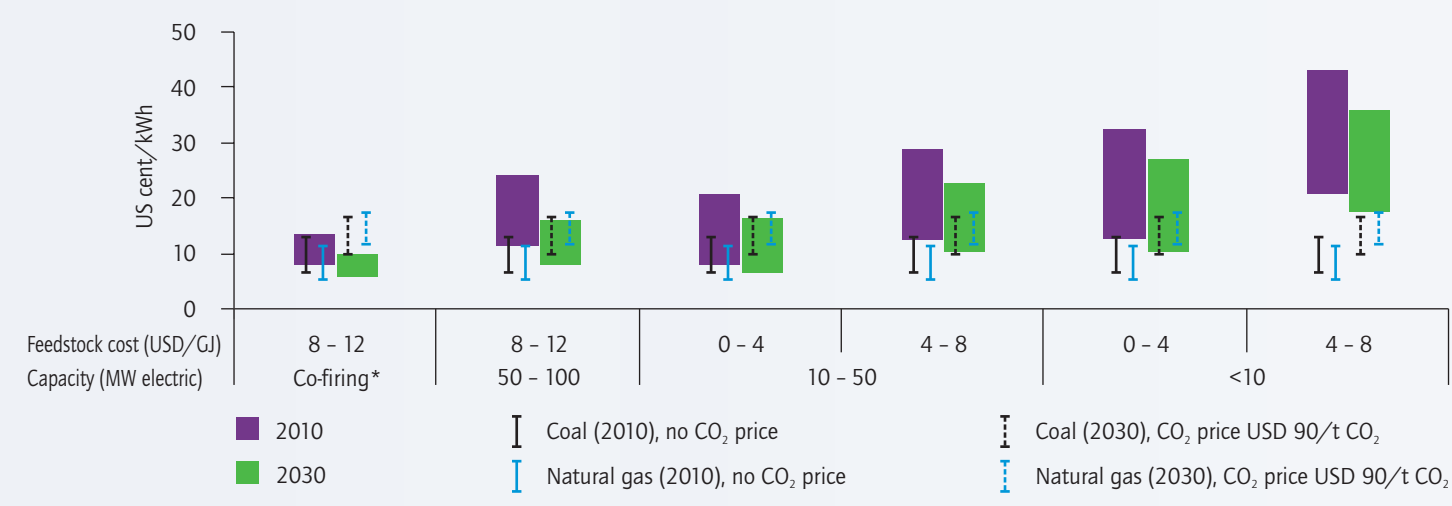
A key element to achieve the targets in this roadmap will be a strong policy framework that balances the need for energy with other important objectives such greenhouse-gas reduction, food security and biodiversity, stimulates positive socio-economic development where possible, and mitigates negative impacts where such are unavoidable.

CO₂ emission reductions from bioenergy electricity and bioenergy use in industry and buildings compared to a business as usual scenario (6°C Scenario)



Note: This assumes that biomass is sourced sustainably with very low life-cycle GHG emissions.

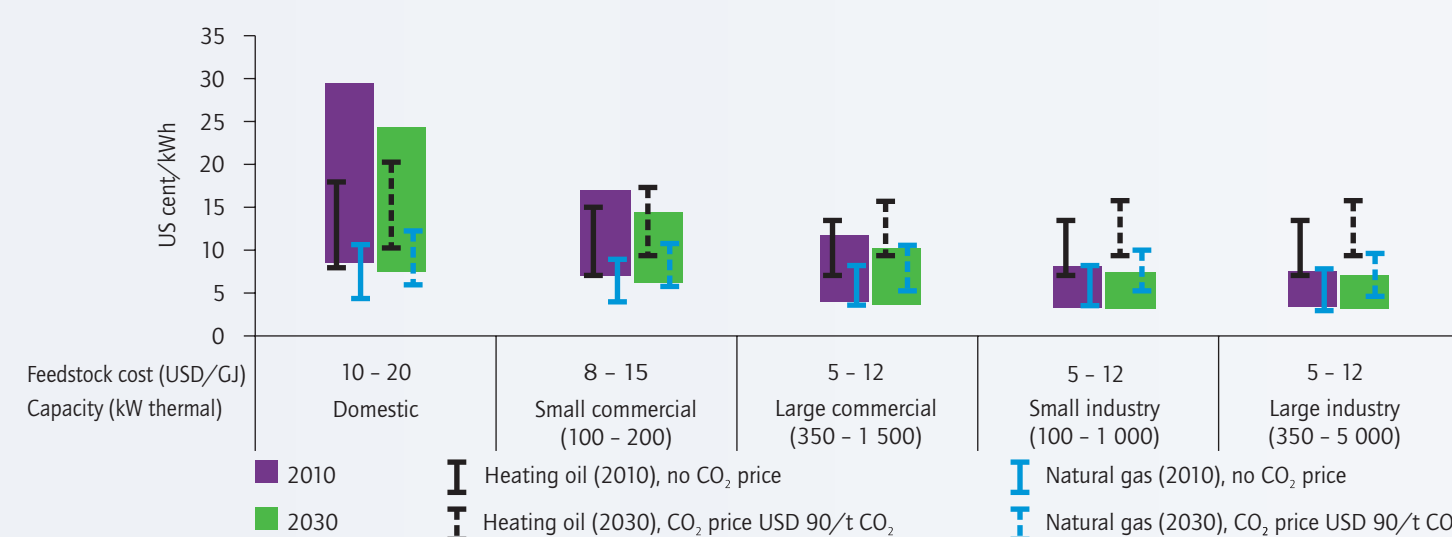
Bioenergy electricity generation costs 2010 and 2030, compared to coal and natural gas based power generation



Note: *Co-firing costs relate only to the investment in additional systems needed for handling the biomass fuels, with no contribution to the costs of the coal-fired plant itself. Fossil electricity generation costs are not capacity specific.

IEA analysis on electricity and heat generation costs clearly indicates that large-scale (>50 MW) biomass power plants allow for low bioenergy electricity generation costs thanks to high electric efficiencies and relatively low capital costs per unit. Smaller-scale (<10 MW) plants have lower electric efficiencies and higher generation costs, and are best deployed in combined heat and power mode in a situation where a good heat sink such as district heating or industry is available.

Bioenergy heat production costs 2010 and 2030, compared to heating oil and natural gas based heat production



Investment needs (billion USD) in bioenergy electricity generation capacity, including co-firing, in different world regions

Region	2010-20	2021-30	2031-50
OECD Europe	21	8	22
OECD Americas	13	11	20
OECD Asia Oceania	4	6	6
Africa and Middle East	7	3	7
China	39	99	54
India	14	8	10
Central and South America	16	5	17
Other developing Asia	12	15	52
Eastern Europe and FSU	3	6	15
World	130	160	202

Note: Numbers may not add up due to rounding.



Bioenergy for Heat and Power

Regional bioenergy electricity generation and final consumption of bioenergy in the buildings sector and industry

