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The potential for renewable energy in industrial applications

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ABSTRACT

To date, insufficient attention has been paid to the potential of renewable energy resources in industrial applications. Our analysis suggests that up to 21% of final energy demand and feedstock-use in the manufacturing industry sector could be of renewable origin by 2050, a five-fold increase over current levels in absolute terms. This estimate is considerably higher than other recent global scenario studies. In addition, if a 50% share of renewables in power generation is assumed, the share of direct and indirect renewable energy use rises to 31% in 2050. Our analysis further suggests that bioenergy and biofeedstocks can constitute three-quarters of the direct renewables use in this sector by 2050. The remainder is roughly evenly divided between solar heating and heat pumps. The potential for solar cooling is considered to be limited.

While low-temperature solar process heat can reach cost-effectiveness today in locations with good insolation, some bioenergy applications will require a CO_2 price even on the longer term. Biomass feedstock for synthetic organic materials will require a CO_2 price up to USD 100/t CO_2, or even more if embodied carbon is not considered properly in CO_2 accounts. Future fossil fuel prices and bioenergy prices in addition to the development of feedstock commodity markets for biomass will be critical. Decision makers are recommended to pay more attention to the potential for renewables in industry. Finally, we propose the development of a detailed technology roadmap to explore this potential further and discuss key issues that need to be elaborated in such a framework.

Contents

1. Introduction

It is clear that renewable energy is a key tenant of sustainable development. Today renewable energy accounts for 13% of global primary energy use. This includes an 18% share of electricity generation, 10% of heating, about 30% of cooking (largely traditional biomass) and 3% of transportation fuels [14,16,26,30]. Renewables account for 9% of industrial energy use. Its use is growing rapidly, driven by rapidly growing demand, technology advances, cost reductions, supply security concerns and environmental concerns. Governments around the world share this vision. As evidence of this, 149 of them have established the International Renewable Energy Agency (IRENA), a new intergovernmental organization. The goal of this agency is to accelerate growth of renewable energy use worldwide across all sectors in order to meet policy targets for energy access, economic growth, energy security and environmental sustainability. Countries have agreed to develop

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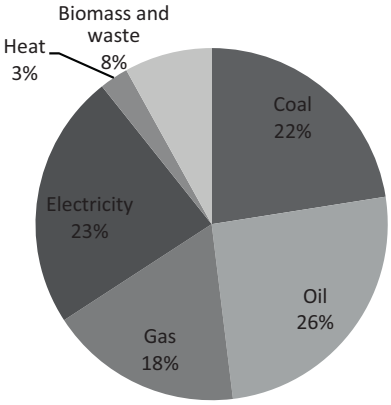

Fig. 1. Industrial energy mix in 2035, WEO 450 ppm scenario [14].

a roadmap for renewable energy in the industry sector [21]. The United Nations Industrial Development Organisation (UNIDO) is working in the demonstration and deployment of renewables in industry, including various projects in the area of solar heating and bamboo feedstock for energy and materials [36]. There is consensus that renewable energy use will grow significantly in the coming decades. For example the IEA World Energy Outlook 2010 (WEO) suggests that, by 2035, the use of renewables can grow to 27% of primary energy use [14]. By 2035, the IEA analysis sees the use of traditional and non-traditional bioenergy can double compared to 2008. In the current IEA new policies scenario industrial energy use is projected to grow from 98 EJ in 2008 to 156 EJ in 2035. In the 450 ppm scenario it rises only to 130 EJ in 2035 due to higher efficiency. This consumption excludes feedstock for the production of synthetic organic materials. Non-energy use for industry is projected to grow from 31 EJ in 2008 to 43 EJ in 2035 (excluding bitumen and lubricants). So inclusion of non-energy use raises industrial energy use by about one third. Industrial energy use in the WEO 450 ppm scenario in 2035 amounts to 168 EJ. When losses in electricity generation are considered, industry accounts for approximately one third of primary energy use in this scenario (Fig. 1).

Despite the optimistic overall outlook for renewables in the WEO 2010, the projections for industry are rather sobering. Only 8% of the total final energy use in this sector is of renewable origin, all of it is biomass. The WEO assumes no significant uptake of renewables for feedstocks and no significant direct use of other forms of renewable energy such as solar heating. In fact the share of renewables in this ambitious scenario is on par or slightly below the share of renewables in industry today.

These scenario results are consistent with other sources, including the IEA Energy Technology Perspectives [15]. They indicate that the prospects for renewable energy growth in general are good, notably in power generation, if proper ambitious climate policies are put in place. However uptake in end-use markets remains a concern and should be accelerated further. This paper assesses the options for industrial use of renewable energy, and outlines element of a roadmap to achieve this. (Production of electricity from renewable sources is outside the scope of this paper.)

2. Statistical issues

Renewables account for 9% of industrial final energy use. Within industry, bioenergy use dominates total renewable energy use. It includes use of residues in the wood processing industry and pulp and paper industry. Also significant amounts of bioenergy are used on traditional industries in developing countries. This category is not properly measured, which results in considerable uncertainties in the statistics.

While there is plenty of literature regarding the proper definition of renewable energy use for power generation, also for industry statistical issues exist that have not received the same level of attention. Wood is used as feedstock for pulp production. Wood is also used as a building and construction material, where it competes with other materials. Agricultural crops are used as feedstock for chemical products, notably so-called oleochemicals and natural fibres such as cotton.

We estimate that in the order of 12 EJ of biomass feedstock end up in industrial products that are not counted as renewable energy and feedstock use (700 Mt oven dry matter wood in 2009 plus around 50 Mt natural oils, natural fibres and starch) [8]. Only a small fraction that is incinerated with energy recovery is counted as energy use in the IEA energy statistics. In contrast 42 EJ of non-energy use of fossil fuels is included in the primary energy use, of which 31 EJ are used in industry.

If both renewable electricity use and biomass feedstock were accounted as described, the share of renewables in industry would be substantially higher [29]. We estimate that it would raise the share of renewables in industry to 18% in 2008. This would double the share of renewables. This is important as it suggests that renewables already play an important role today, which reduces the challenge for future growth.

3. Options and trends

Total fossil fuel and feedstock use in industry amounted to 117 EJ in 2008 (IEA Statistic Database, as of September 2010). This includes blast furnaces, coke ovens and non-energy use. Industrial use of fossil fuels can be split into:

- Heat – about 75 EJ of fuel yielding about 50 EJ of useful heat;
- Carbon and hydrogen for chemical reactions (iron making, ammonia) – about 12 EJ yielding 928 Mt iron (50–55% conversion efficiency) and 153 Mt ammonia (65–70% conversion efficiency);
- Carbon as feedstock for synthetic organic materials (plastics, fibres, bitumen, etc.) – about 30 EJ yielding 245 Mt plastics, 90 Mt other petrochemical products and 89 Mt bitumen.

We consider these market segments independently. The yields are important because they indicate significant losses in the transformation of fossil fuels into useful energy. The losses may be substantially different in case renewable energy is used. This paper analyzes the potential for renewable energy use primarily in four areas, namely:

- Biomass for process heat;
- Biomass for petrochemical feedstocks;
- Solar thermal systems for process heat; and
- Heat pumps for process heat.

Unlike combustible fossil fuels, not all of the required temperature levels can be provided by all of the renewable energy sources and technologies. Different types of biomass feedstock can cover the full temperature range required by industrial processes, including high temperatures. To achieve higher temperatures, preprocessing might be needed (i.e. from wood to charcoal, for use in blast furnaces).

On a laboratory scale it has been shown that solar thermal can provide temperatures above a thousand degrees Celsius, but in practice today this is limited to less than 150° for flat plate systems and less than 350° for parabolic trough collector systems [39]. However, in general, costs go up as the temperature level