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Cleaner energy for cleaner production: modelling, simulation, optimisation and waste management

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ABSTRACT

Energy supply and its efficient use in production are key to ensuring the healthy functioning of the world economies. Based on that, to ensure sustainability, the supply and use of energy have to apply the principle of minimising negative environmental impacts and even improving the environment through net-regenerative development. In this context, ensuring cleaner energy is the cornerstone for cleaner production, especially for reducing the emissions of greenhouse gases and other pollutants, which are directly related to the types and loads of the energy sources used. This introductory article presents a review of the main lessons recently learned in the area of more efficient energy use, cleaner fuels and biofuels, cleaner production, CO_2 capture, optimisation and waste management. This article provides the readers with ideas and technologies that can be incorporated into real world solutions and can serve as the foundations for future research. With firm realisation of the importance of these issues, the 17th conference "Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction – PRES" was held in Prague, Czech Republic, to provide a platform for discussing ideas and devising solutions for cleaner energy supplies that are used more effectively and efficiently. This was followed by comprehensive research that resulted in several high quality scientific contributions published in the Journal of Cleaner Production. The wide topical coverage and the high quality provided excellent directions for future collaborative research of the PRES family – including process level emission minimisation, self-sufficient regions, and industrial symbiosis for optimizing usage of waste heat and waste material flows.

1. An overview and introduction

The issues, which are discussed in this introductory article to the Special Volume (SV) for PRES 2014, are related to key tasks in cleaner and sustainable production (Klemeš, 2015). One of those issues has been the loss of energy during conversion and transportation. To illustrate the magnitude of the losses, Fig. 1 presents a Sankey diagram by EIA (2013a) for electricity in the US in 2014. It is striking to observe that the conversion losses account for more than the electricity generated by renewable, nuclear and natural gas power stations combined. Those figures highlight where one of the future research and implementation efforts should be targeted in all countries. This is one of reasons a substantial portion of this Special Volume (SV) is devoted to improvements in energy use efficiency at many levels of society.

The following part deals with Cleaner Fuels and Biofuels. The available statistics reveal that coal continues to be one of the major sources of energy including for power and heat generation – see e.g. Figs. 2 and 3. However they are various ways by which society can covert to cleaner and renewable energy sources.

There are several answers to this problem, among them being cleaner fuels and biofuels. Cleaner fuels are gaining in importance in parallel with renewables. Biofuels are increasingly directly competing with fossil fuels in price and when the fossil CO_2 emissions are considered, they are net positive with regard to climate change reduction potential. This stems from the fact that although biofuels are also fossil fuels, they have substantially shorter lifecycles from the viewpoint of GHGs because they

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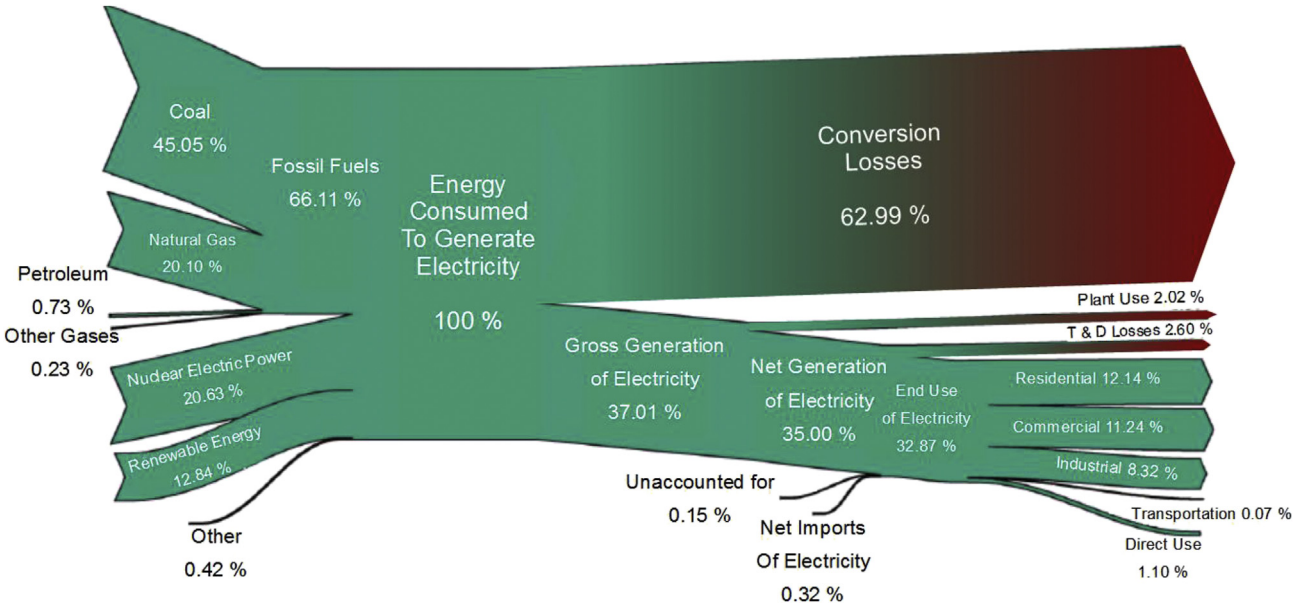

Fig. 1. A Sankey diagram developed from EIA (2013a) report for the electricity generation and use in the US in 2014.

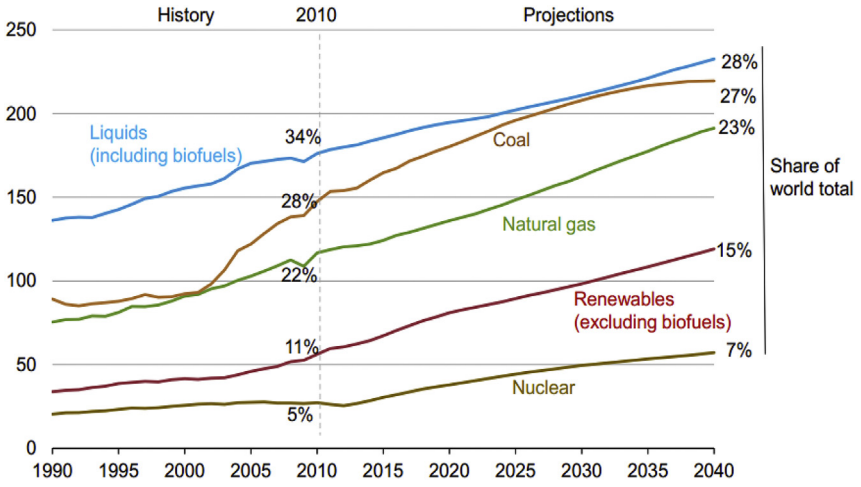

Fig. 2. World energy consumption by energy source (existing and forecasted): 1970–2040 in quadrillion of BTU (EIA, 2013b).

captured CO_2 one to tens of years ago, rather than millions of years ago. From Fig. 4, which presents the live power energy mix in the UK. From this figure it is clear that the share of fossil fuels is still high.

The sources are even more visible from the peak energy values for the UK presented in Fig. 5. The contributions of wind and water pumped storage are around 5% and 3%.

There are other approaches for dealing with GHG. Carbon Capture and Sequestration (CCS) sometimes called "Carbon Capture and Sequestration", which is not exactly correct, as C is not captured, CO_2 is. CCS had received increasing attention in recent years. But when CCS was analysed from a LCA perspective, it became obvious that not all CCS approaches decrease GHG footprints, but as a main benefit some result in enhanced recovery and recovery of crude oil and natural gas (Tzimas et al., 2005).

However, there are some other crucial issues. Some were highlighted by Markovska (2015). Fig. 6 demonstrates that CO_2 from fossil fuels accounts for less than two thirds of the GHG. The remaining more than one third, which also has to be considered, is derived from changes in land use due to deforestation and other land use changes. Additionally, there are GHS gases such as NH_4 and NO_x, which are harmful and which are emitted from agricultural processes including biomass combustion and by diesel-powered vehicles.

The data of Fig. 7 shows the strong increase of CO_2 emissions and substantial increases of NH_4 and NOx emissions.

Cleaner Production is based upon holistic and preventative approaches, which if implemented society-wide can help us to make progress toward more sustainable societies. However as the world population needs to produce a huge variety of products from industrial to agricultural sources, this requires many studies (Klemeš, 2015). The contents of Fig. 8 present information about the industrial sector, which produces the third most 'direct' GHG emissions (21%), however it is the highest when 'indirect' CO_2 emissions are considered (31%). This provides a very strong mandate for the topics addressed in the *Journal of Cleaner Production (JCLP)* and specifically in this SV.