Model based evaluation of industrial greenhouse gas abatement measures

Industrie

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Motivation and research gap

In 2016 the German industry sector accounted for 34 % of total energy related CO_2-emissions (polluter principle) [1], [2], [3]. To achieve deep decarbonization in the heterogeneous and complex industry sector a combination of measures is required (e.g. energy efficiency, electrification). Depending on the selected transformation path, the systemic effects of the industrial energy transition as well as the costs resulting from the implementation of decarbonization measures can vary significantly. In this paper the sector model industry (SMIND) is constructed in order to analyze the costs and effects of implementing selected decarbonization measures.

Methodology

Core elements of the Matlab based SMIND are the load curve, industry structure, measure implementation and results module. Furthermore, SMIND embedded in a larger model landscape to which it is connected through the FREM database [4]. Main output is the industrial load curve, which builds the basis for assessing the impact of industrial decarbonization measures on the energy supply side. The model is structured according to application areas (e.g. process heat <100 °C, process heat 100 – 500 °C, lighting, mechanical energy, etc.), industry branches (e.g. Food and Tobacco, Iron and Steel, etc.) and energy carriers. A core component are the application-energy-matrices (AEM) which show the share of energy carriers by application in each industry branch. AEM's are calculated annually and vary according to structural changes in the respective industry branch or decarbonization measure implementation.

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\mathrm{AEM}_{\mathrm{Fuel,Paper,2015}} = \begin{matrix} (\%) \\ Coal \\ Oi \\ Gae \\ Non\text{-}RE\text{-}Fuels \\ Dist.\ heat \\ RE\text{-}Fuels \\ H_2 \\ Syngas \end{matrix} \begin{bmatrix} Mech & PH100 & PH500 & PH500+ & H\&HW \\ 0{,}0 & 1{,}8 & 6{,}9 & 0{,}0 & 0{,}2 \\ 0{,}0 & 0{,}1 & 0{,}5 & 0{,}0 & 0{,}0 \\ 1{,}0 & 10{,}4 & 39{,}0 & 0{,}0 & 1{,}4 \\ 0{,}0 & 0{,}4 & 1{,}4 & 0{,}0 & 0{,}0 \\ 0{,}0 & 3{,}9 & 14{,}7 & 0{,}0 & 0{,}6 \\ 0{,}0 & 3{,}6 & 13{,}5 & 0{,}0 & 0{,}5 \\ 0{,}0 & 0{,}0 & 0{,}0 & 0{,}0 & 0{,}0 \\ 0{,}0 & 0{,}0 & 0{,}0 & 0{,}0 & 0{,}0 \end{bmatrix}
$$

AEM:	Application energy carrier-matrix	PH100:	Process heat below 100°C
RE	Renewable	PH500:	Process heat between 100°C und 500°C
Mech:	Mechanical Energy	PH500+:	Process heat above 500°C
Dist.	District	H&HW	Heating and hot water

Figure 1: Exemplary fuel AEM for the paper industry in 2015 [5]

The model time frame is 2015 to 2050. Greenhouse gas abatement measures are implemented based on external scenario configuration. Hereby the effects on energy intensive industries are modelled bottom-up based on production figures and specific energy demands. Non-energy intensive industry branches are modelled top-down based on energy and gross domestic product data.

Results and conclusion

SMIND can be used to quantify the effect of 90 decarbonization measures in the industry branches food and tobacco, paper, iron and steel, basic chemicals, glass and ceramics, non-metallic minerals and non-ferrous metals. In addition, 30 measures affecting cross-sectional technologies such as lighting, information, communication technology and low-temperature process heat were evaluated with respect to costs and potential.

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Figure *2* shows the annual greenhouse gas reduction resulting from the implementation of a variety of energy efficiency measures in the steel, paper and cement production. Beginning in 2030 process specific measures are phased in [6]. It is assumed that measures are implemented at times when the existing infrastructure reaches its end-of-life.

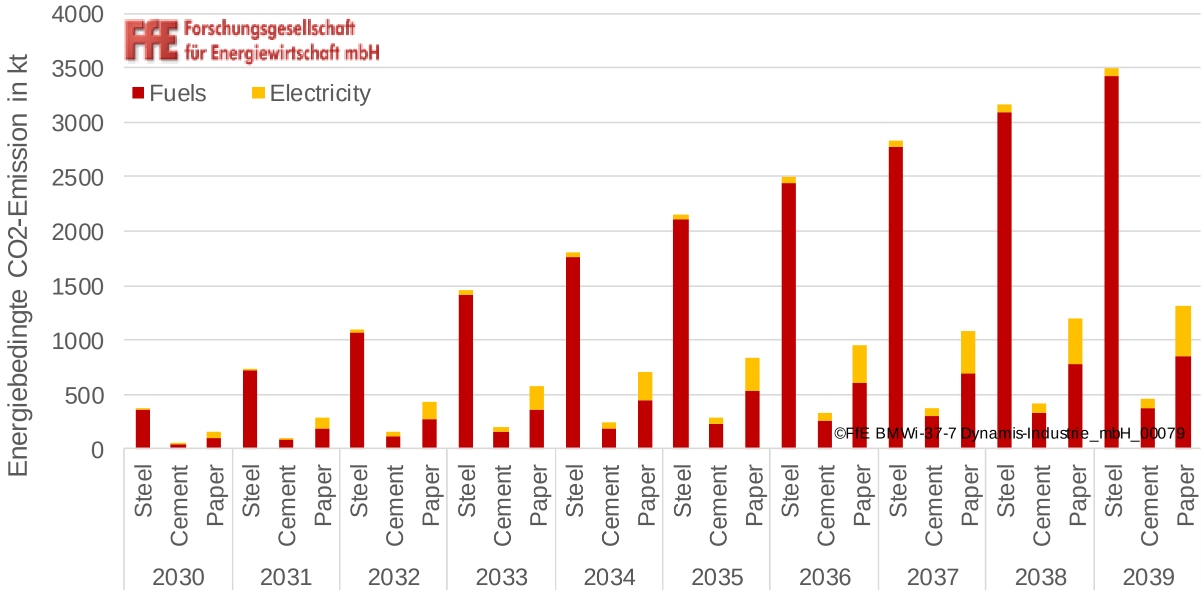

Figure 2: Effect implementing selected energy efficiency measures on energy related CO_2-emissions in the processes steel, cement and paper production between 2030 and 2039

By 2039 an annual CO_2-abatement of 3.5 Mt_{CO2}, 0.5 Mt_{CO2} and 1.3 Mt_{CO2} is achieved in the steel cement and paper production, respectively. Compared to total emissions of 264 Mt_{Co2} in 2016 total emission reduction in 2039 amounts to approximately 2 %.

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