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Driving forces and barriers in the development and implementation of coal-to-liquids (CtL) technologies in Germany

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Abstract

Because of a growing global energy demand and rising oil prices coal-abundant nations, such as China and the United States, are pursuing the application of technologies which could replace crude oil imports by converting coal to synthetic hydrocarbon fuels—so-called coal-to-liquids (CtL) technologies. The case of CtL is well suited to analyse techno-economic, resources-related, policy-driven and actor-related parameters, which are affecting the market prospects of a technology that eases energy security constraints but is hardly compatible with a progressive climate policy. This paper concentrates on Germany as an example—the European Union (EU)'s largest member state with considerable coal reserves. It shows that in Germany and the EU, CtL is facing rather unfavourable market conditions as high costs and ambitious climate targets offset its energy security advantage.
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1. Introduction

Facing a growing global energy demand and rising oil prices, coal-abundant nations, such as China and the United States, are aggressively pursuing the application of technologies which could replace crude oil imports by converting coal to synthetic hydrocarbon fuels—so-called coal-to-liquids (CtL) technologies. In the US, 14 CtL plants are being planned. The Chinese government intends to achieve an annual CtL production capacity of 152 million barrels (BBL) in the coming 5–10 years in order to reduce oil imports by 5–10%. These initiatives have been encouraged by positive experiences in South Africa where, since the 1950s, South African Coal Oil and Gas Corporation (Sasol) is operating the world's only commercial CtL plants, producing about 28% (160,000 BBL per day) of South Africa's automotive fuels (Southern States Energy Board, 2006).

A diffusion of CtL technologies would extend coal utilisation to the transport sector. Doing, so, the case of CtL is well suited to analyse techno-economic, resources-related, policy-driven and actor-related parameters which are affecting the possible diffusion of a technology that eases energy security constraints but is hardly compatible with a progressive climate policy as it indicates a high carbon intensity.

This paper concentrates on Germany as an example—the European Union (EU)'s largest member state with considerable coal reserves. It shows that in Germany and the EU, CtL is facing rather unfavourable market conditions since high costs and ambitious climate policy targets offset its energy security advantage.

The analysis and identification of diffusion parameters is based on the technological system approach by Carlson and Hughes and more than 30 expert interviews as well as an extensive study of regulations, policy papers and technology studies.

2. The recurring relevance of synthetic fuels from coal

2.1. Technical principles of CtL processes

Synthetic fuels are generally referred to as any liquid or gaseous fuels derived from the conversion of coal, natural

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gas or different kinds of biomass. Depending on the utilised feedstock, the process for the production of synthetic fuels is known as CtL, gas-to-liquids (GtL) or biomass-to-liquids (BtL). As Fischer-Tropsch synthesis is the most commonly applied process for the conversion of all these feedstocks, the process is often denoted as X-to-liquids (XtL).

2.1.1. Coal gasification

With regard to coal, the Fischer-Tropsch conversion path is also termed as indirect coal liquefaction[1] since coal is transformed into a synthesis gas ("syngas"), mainly consisting of carbon monoxide (CO), hydrogen and carbon dioxide (CO_2), via coal gasification before it is converted into a liquid fuel. (Fig. 1)

During coal gasification, the feedstock is fed into a reactor (gasifier) where the coal reacts with air or oxygen and steam. Depending on the type of gasifier, coal gasification involves pressures of 30–50 bar and temperatures in the range from 500 °C up to 1200 °C (Miller, 2005). In order to obtain an optimal gas constitution for the Fischer-Tropsch synthesis, additional processes need to be carried out to raise the hydrogen content and to clean the gas from undesirable by-products, especially SO_2 (sulphur dioxide) and CO_2. The gas cleaning procedure is crucial as both SO_2 and CO_2 inhibit an optimal performance of the Fischer-Tropsch process. Producing a relatively pure and concentrated stream of CO_2, coal gasification allows capturing of CO_2 at rather low costs and energy intensity.

2.1.2. Fischer-Tropsch synthesis

After the gasification and cleaning processes, the clean synthesis gas is sent to the Fischer-Tropsch unit where, by using a catalyst, carbon monoxide and hydrogen are converted into hydrocarbons of various forms. Fischer-Tropsch processes operate at 25 bar and 200–250 °C (low-temperature Fischer-Tropsch synthesis) or 320–350 °C (high-temperature Fischer-Tropsch synthesis). They generate a broad set of hydrocarbons, including liquids such as gasoline, diesel or jet fuel, gases such as fuel gas or liquefied petroleum gas (LPG) and waxy substances like soft or hard waxes. The share of middle distillates produced via Fischer-Tropsch conversion may reach up to 75% of the obtained product mix, including 80% diesel and 20% kerosene (Wuppertal Institute/Research Centre Jülich, 2006). Fischer-Tropsch diesel indicates high-quality characteristics. It burns more completely and leads to significantly lower emissions of CO_2 (−4%), NO_x (−13%) and particulates (−52%) than conventional diesel fuels (WMPI, 2007).

[1]Coal hydrogenation (also called the Bergius process) is referred to as direct coal liquefaction and represents an alternative coal liquefaction path. It includes the conversion of coal into a slurry that is reacted with hydrogen under high pressure and heat in order to form hydrocarbons. However, with the exception of China, all current coal liquefaction activities apply indirect coal liquefaction which is why direct coal liquefaction will not be considered in further detail in this paper.

2.2. A new wave of CtL on the horizon?

Current trends indicate that, notwithstanding the intense debate on climate change, the share of coal within the global total primary energy supply (TPES) is likely to increase. Due to growing and volatile oil and gas prices, coal has been the world's fastest growing hydrocarbon fuel during the last 2 years. In 2006, global coal consumption rose by 4.5%, which is well above the 10-year average whereas oil consumption increased by only 0.7%—the weakest growth since 2001. Gas production rose at a rate of 3%, slightly beyond the 10-year average (BP, 2007).

2.2.1. CtL in business-as-usual scenarios of the International Energy Agency

Recent business-as-usual scenario calculations of the International Energy Agency (IEA) confirm that if current trends are extrapolated to the year 2030 or 2050, respectively, coal consumption will experience a rapid growth which is partly due to CtL utilisation. The reference scenario of the *World Energy Outlook 2007* projects that global coal demand will rise from 2892 million tonnes of oil equivalent (Mtoe) in 2005 to 4994 Mtoe in 2030 at an average annual rate of 2.2% until 2030, cumulating to a growth of 73% in 2030 compared to 2004 (IEA, 2007a). Despite this increase, coal demand from CtL plants is assumed to remain marginal until 2030 since CtL unit costs remain too high compared with conventional refinery products (IEA, 2006a).

However, the business-as-usual projection of the *IEA Energy Technology Perspectives 2006* scenarios points out that the production of synfuels from coal might "increase dramatically after 2030" (IEA, 2006b) due to oil supply shortages and high oil prices. In 2050, nearly 1800 Mtoe of coal would be consumed by CtL plants, being equivalent to 42% of the current global coal demand. In combination with increasing coal demand entailing from rising gas prices and rapid economic development in developing countries, the extensive production of coal-derived fuels is estimated to lead to an overall coal consumption of 7532 Mtoe in 2050 (IEA, 2006b) which supersedes today's consumption rate by 160%. Consequently, a diffusion of CtL is a likely scenario unless there is a significant change of policy in the coming decades.

2.2.2. The history of CtL technologies in Germany

The question if under current circumstances CtL technologies might experience a revival in Germany is of high relevance since the country is the EU's largest member state with considerable coal reserves and functioned as an initial CtL frontrunner in the early 20th century. In order to achieve independence from foreign oil imports to fuel the German military fleet during World War II, the Nazi regime was operating nine Fischer-Tropsch plants, mainly yielding diesel, waxes and lower quality gasoline, and 12 coal hydrogenation plants, producing high-quality aviation and motor gasoline. Supported by aggressive subsidies,

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