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Opportunities in the Use of Coal for Chemicals Production

1. Introduction

Coal products find numerous applications in markets beyond power generation and cokemaking. Prominent among these markets is the production of chemicals and carbon products, with coal-derived chemicals in turn serving as feedstocks for the production of fertilizers, fuels, carbon and graphite materials, sealants, and, ultimately, numerous consumer products.

The discussion presented here is the result of a high-level review related to opportunities for closer cooperation, among the subsidiary bodies the UNECE Committee on Sustainable Energy, for closer cooperation in the field of chemicals production from coal. There are three topics related to chemicals production in this context: combined heat and power (CHP), gasification, and chemicals. While this document is focused on the last of these (chemicals), the nature of chemicals production is such in some cases, opportunities for improvements under the CHP and gasification topics are also present.

As such, crosscutting opportunities under the CHP and gasification topics will be discussed, as well as the following within the context of chemicals production from coal:

- Example best practice opportunities with respect to heat integration and emission reductions
- How carbon capture, utilization, and storage (CCUS) can be integrated with some chemicals technologies, and
- Where advanced fossil fuel technologies and related energy enhancing measures can fit within a best practices-driven chemical production project.

2. Background on Coal-to-Chemicals

a. Routes

i. Thermal Processing (Carbonization)

The production of chemicals from coal is dominated by three types of process, the first, thermal treatment of coal, or carbonization, involves destructive distillation, producing hydrocarbons that are in gaseous or liquid states under ambient conditions, as well as a char or coke.

The dominant traditional outlet for coal using carbonization has been cokemaking. While this activity is not focused on metallurgical use of coal (largely the coke/blast furnace ironmaking route), cokemaking itself is relevant to this discussion due to byproducts of the process, which can include nitrogen and sulfur compounds, as well as tars which are further processed to produce naphthalene, creosote, and pitch, the latter two in turn being used for the production of carbon and graphite materials.

Heat integration and emissions reductions can be concurrently accomplished in carbonization processes, notably in cokemaking. This can include the generation of heat and power from

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integrated cokemaking, where coke oven gas is used for the generation of electric power, with attendant heat recovery steam generation. This practice can lend itself to retrofitting to existing byproduct coke plants. A recent example (under development) has recently been announced by U.S., Steel at the Clairton Coke Works in Pennsylvania.

There are also examples of non-recovery cokemaking, where byproduct chemicals are not produced. Processes of this type can co-generate electric power.

ii. Syngas

The production of chemicals from coal-derived syngas includes commercially proven technologies that can produce methanol, urea and fuels, the latter is an application for Fischer-Tropsch (F-T) technology (the indirect coal liquefaction, or ICL, process). Common to these routes for chemical production are gasification technologies, gas cleanup processes, and reaction and gas separation systems to adjust syngas composition, and reactors that produce the desired chemical products from the syngas components. Gasification technologies can also require tonnage oxygen from air separation units (ASUs).

Coal gasification-based chemical production shares technology requirements with fossil-fuel based power systems, notably those based on the integrated gasification combined cycle (IGCC) process, but also with more conventional steam cycle power equipment. Examples include the need to separate gases from mixtures, compress gas streams, and efficiently generate power from steam. These requirements offer opportunities for efficiency improvements involving individual components in the syngas-based chemical production process, such as acid gas units, steam- and power generation equipment associated with syngas cooling and reactor systems, and compressors, notably associated with ASUs.

Adjustment of the chemical composition of reactor feeds in syngas-based chemical production also offer opportunities for the application of CCUS technologies. The production of reactor feeds can require CO_2 removal from syngas streams ahead of reactor systems. The result is the generation of a relatively pure CO_2 byproduct stream which is an inherent requirement in the plant design.

iii. Chemical Extraction

While they may have seen less commercial application than carbonization or syngas-based processes for chemical production, solvent extraction processes that produce chemicals from coal have nonetheless seen some application, and newer technologies can offer opportunities for extending the range of both coal types that can be used economically for chemicals production and the types of chemicals that can be produced.

Direct coal liquefaction (DCL) technologies can extract the organic portion of coal and hydrogenate the resultant extracts for the production of fuels and chemicals. More recent developments related to this family of processes include system development for the conversion of low rank coal directly to liquids, avoiding efficiency and reliability issues associated with the ICL alternative, which would require low rank coal gasification.

Chemical extraction processes can require efficient heat integration and, as is the case with syngas-based technologies, gas separation, compression and power generation technologies.

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Here, there are also opportunities for high-efficiency components that have originally been developed for fossil fuel-based power generation, including steam generation, compression, and steam turbine systems.

b. Best Practice Opportunities with Respect to Heat Integration and Emissions Reductions

All three coal-to-chemicals routes present can present opportunities for best practices technology applications that can improve efficiencies, and possibly allow for CCUS opportunities. A condensed set of opportunities can be summarized as follows:

Carbonization Processes

- The use of advanced fuel-flexible gas turbine technologies to maximize power production from gaseous carbonization products (for example, coke oven gas).
- Application of state-of-the-art heat recovery steam generation (HRSG) technologies to allow for operation of combined cycle power systems, allowing for optimized bottoming cycle efficiencies and possibly cogeneration.

Syngas-Based Processes

- The use of acid gas removal (AGR) tail gas for CCUS applications. Examples would include relatively pure streams of CO2 produced by physical- (Rectisol, Selexol) and chemical (amine) solvent AGR systems.
- The use of advanced fuel-flexible gas turbine technologies, in conjunction with state-of-the-art HRSG and steam turbine technologies to produce power from reactor byproducts (example: Fischer-Tropsch tail gas), as an alternative to recycling this gas stream within the plant. This concept is called a “once through” F-T system and may also be applicable to byproduct gas streams in other syngas-based chemical production processes.
- Syngas-based chemical production processes can have significant in-plant loads associated with gas compression needs. The application of advanced compression and intercooling technologies can mitigate these load requirements and render the processes more efficient.

Chemical Extraction Processes

- The use of advanced fuel-flexible gas turbine technologies, possibly in conjunction with state-of-the-art HRSG and steam turbine technologies to produce power from low molecular weight reactor products and other gaseous byproducts that might otherwise be flared.

c. How CCUS can be Integrated with Chemicals Technologies

Opportunities for CCUS vary among the countries that are members of the UNECE, and those countries with the potential for enhanced oil recovery (EOR) projects may present the earliest economically viable opportunities for CCUS application to chemicals production.

An additional use for CO_2, applied in chemicals production from natural gas, is the recycling of process CO_2 to the reformer. This concept, called “dry reforming”, may also provide an opportunity as a CO_2 utilization concept in coal-to-chemicals systems.

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d. Where Advanced Fossil Fuel Technologies and Related Energy Enhancing Measures can Fit within a Best Practices-Driven Chemical Production Project.

Fuel Flexible Gas Turbine Use in Combined Cycle Power Systems

Byproduct gas streams in chemicals production can represent a significant source of potential fuel for heat and power production. In some cases, these streams are used as such, although there may be opportunities for efficiency improvements through the use of newer technologies (more efficient gas turbines, for example). In other cases, these gas streams may simply be flared.

Advanced Compressor Technologies

Some processes, notably those that are based on syngas, have significant compression requirements, which can manifest themselves as in-plant power loads. Reductions in these loads can make plants less expensive to operate, and, where the plant is a net exporter of power, increase the amount of power that can be placed in the grid, without the requirement for additional fuel.

CCUS Technologies

As mentioned previously, coal-to-chemicals production systems can produce relatively pure CO_2 streams as part of their process requirements. Advances that have been made within the UNECE membership, regarding carbon capture technologies, may lend themselves to application to chemicals production. Coal-to-chemicals projects can offer opportunities for the demonstration and early adoption of these technologies, in addition to their potential to improve efficiencies in plant operations.

3. Sustainability: Environmental Performance and Byproduct Energy Use

The application of advanced fossil fuel technologies to chemicals production can present a best practices opportunity for plant optimization from the standpoints of both environmental performance and energy efficiency. Within the carbon emissions picture, there are items of interest. The first is that, where a plant is a net power exporter, reductions in in-plant loads and improvements in power equipment efficiencies can increase the amount of power that the plant can export, without the need for additional fuel. This offsets the requirement for dedicated power generation capacity in the grid, resulting in CO_2 emissions reductions.

The second item of interest with respect to CO2 emissions is that coal-to-chemicals processes can produce relatively pure CO2 streams with the equipment required for their processes. Where this is the case it represents opportunities for (1) CCUS projects and (2) demonstration and early commercial adoption of carbon capture technologies designed for fossil fuel systems.

The adoption of advanced fossil fuel technologies, notably advanced fuel-flexible gas turbines in combined cycle operation, may, in addition to improving plant efficiency and possibly increasing net export power, may also allow for the use of byproduct gas streams that would otherwise be flared, representing both an emissions reduction and an efficiency improvement. The use of state-of-the-art HRSG systems and steam cycle equipment can also help in this area, along with

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presenting additional opportunities for the export of steam and hot water (cogeneration) for CHP-style district heating use.

4. Summary and Recommendations

A variety of chemical products can be produced from coal. The production of chemicals from coal includes thermal processing (such as used in carbonization processes), syngas-based processes where gasification is used, and chemical extraction processes. Best practices opportunities exist across all three of these process types, leading in turn to technologies transfer opportunities for advanced fossil energy technologies. These opportunities are found across the entire spectrum of coal-to-chemicals processes, and include CCUS technology application, the use of advanced gas turbine technologies to generate heat and power from byproduct gas streams, and the application of advanced compressor technologies to reduce in-plant power loads and allow for the increased export of power from a chemicals installation.

Individual UNECE members will have different perspectives on this topic, including resource drivers such as the availability of domestically produced coal and any EOR opportunities that might provide outlets for CCUS applications, as well as policy drivers, that will result in varying levels of interest among the group. With respect to those UNECE members with higher levels of interest, it is recommended that a panel of experts be convened to assess any common interests with respect to technology transfer and best practices opportunities. The following are recommended inclusions in the work product of the panel:

1. The views of the members on opportunities for coal-to-chemicals projects in their countries.
2. A set of technologies that are of interest to the group.
3. The state of technology transfer within the UNECE group, and recommendations for improvements.
4. A set of recommendations for overcoming barriers to deployment of advanced chemicals technologies in UNECE member countries.