Fortieth Annual INTERNATIONAL PITTSBURGH COAL CONFERENCE

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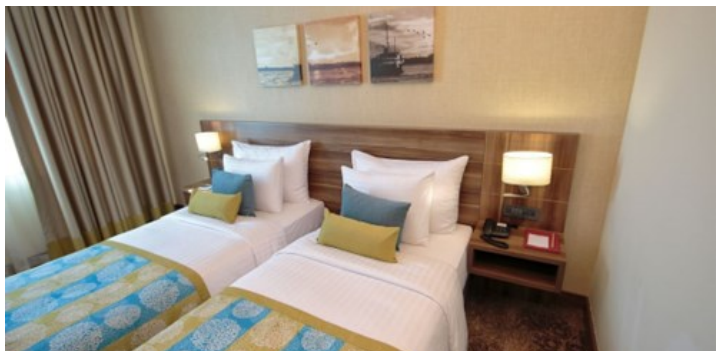
ABSTRACTS BOOKLET

Technology Innovation and Solutions for Clean Energy



TÜYAP Exhibition and Convention Center, Istanbul, TÜRKİYE

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Hosted by:

REPUBLIC OF TÜRKİYE
MINISTRY OF ENERGY AND
NATURAL RESOURCES

GENERAL DIRECTORATE OF TURKISH COAL ENTERPRISES ANKARA

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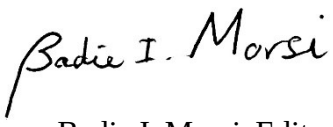
A NOTE TO THE READER

This Abstracts Booklet is prepared solely as a convenient reference for the Conference participants. Abstracts are arranged in a numerical order of the oral sessions as published in the Final Conference Program. In order to facilitate the task for the reader to locate a specific abstract in a session, each paper is given two numbers: the first designates the session number and the second represents the paper number in that session. For example, Paper No. 2.1 is the first paper to be presented in the Oral Session #2.

It should be cautioned that this Abstracts Booklet is prepared based on the original abstracts that were submitted unless the author noted an abstract change. The contents of the Booklet do not reflect late changes made by the authors for their presentations at the Conference. The reader should consult the Final Conference Program for any such changes. Furthermore, updated, and detailed full manuscripts, published in the Conference Proceedings, will be sent to all registered participants following the Conference.

On behalf of the Thirty-Ninth Annual International Pittsburgh Coal Conference, I wish to express my sincere appreciation and gratitude to Ms. Nicole Drebsky for her guidance of the entire conference. My profound gratefulness goes to Mr. Rui Wang for his crucial assistance and dedication in preparing this Abstracts Booklet and the Final Conference Program.

Thank you,



Badie I. Morsi, Editor
Professor and Executive Director of the Conference

FOUNDATION FOREWORD

The Turkish Mining Development Foundation was established with the mission of developing local mining. The organization of congresses and conferences as well as the publication of books and periodicals are part of its activities. The Foundation is organizing the International Pittsburgh Coal Conference in Türkiye for the second time. The conference is conducted under the Directory of Pittsburgh University. We would like to express our thanks to the Conference executive director Professor Dr. Badie MORSI and his colleagues for their contributions. We would like to express our gratitude to Turkish Republic Energy and Natural Resources Ministry, Turkish Coal Enterprises and Mineral processing Department of Istanbul Technical University. We wish to thank the local steering committee, the staff of the foundation and the University. We also wish to express our sincere appreciation to the sponsors and the exhibition attendees.

Kind regards,

On behalf of the Turkish Mining Development Foundation
Prof.Dr. Güven ÖNAL
President

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SESSION 1 (16:00 – 17:40)
GASIFICATION TECHNOLOGIES – 1
Dr. Aleksander Sobolewski, Prof. Dr. Hasan Can Okutan

1.1 (16:00-16:20) Development and Characterization of Densified Biomass-plastic Blend for Entrained Flow Gasification

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Jameson Hunter, Research Engineer Assistant, University of Kentucky, UNITED STATES OF AMERICA
Dimitrios Koumoulis, Senior Research Engineer, University of Kentucky, UNITED STATES OF AMERICA
Heather Nikolic, Research Program Manager, University of Kentucky, UNITED STATES OF AMERICA

Biomass and plastics have been extensively studied as alternative, carbon-rich feedstocks in many gasification technologies. These fuels have not been considered in entrained flow gasifiers due to the constraint of water slurry feed method that commercial-scale gasifiers of this kind utilize. This method is incompatible with biomass because its porous structure and hydrophilic nature cause slurries to become too viscous for pumping at low solid concentrations. This study seeks to explore the potential of encapsulating densified biomass particles with plastic to increase the concentration of biomass within a slurry for entrained flow gasification. The biomass-plastic blend of torrefied wood and high-density polyethylene is prepared through co-extrusion using a 27 mm twin screw extruder at an HHV ratio of 61:39 (weight ratio of 2:3). The resulting material was reground into particulates and showed a less than 10% weight increase from water uptake over eight hours of soaking compared to an over 100% weight increase in ground biomass over the same period. FTIR analysis was done on the material to ensure encapsulation of the torrefied woods hydroxyl groups by the plastic. The extruded material was used to create a slurry with 60 solid weight% constituted of 70 weight% coal fines and 30 weight% of the extruded material. This slurry had a viscosity in a pumpable range and was less viscous than a coal-water slurry of 55 solid weight%. Simulations of slag formation with a 70 weight% coal and 30 weight% biomass-plastic blend indicates two distinct slags from each component, with the coal slag having significantly higher production. The ash fusion temperatures of this coal-biomass-plastic mixture was calculated to be within 20 °C of coal. Thermal kinetic studies on the extruded material show minimal interactions between the material at temperatures over 1000 °C and similar carbon conversion percents with the inclusion of water vapor.

1.2 (16:20-16:40) Pressurized Gasification of Low Rank Turkish Coal in a Pilot Scale Bubbling Fluidized Bed Reactor with Air, Oxygen and Steam Agents and Syngas Cleaning

Ersin Üresin[1], Emir Aydar[2], Ömer Orçun Er[1], Fehmi Akgün[2], Hakan Karataş[2], Namık Ünlü[1], Tahsin Bahar[1], Mahmut Ateş[2], Bayram Subaşı[3], Orhan Koşdaş[3], Mert İskenderoğlu[3]

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2. TÜBİTAK Marmara Research Center, Hydrogen and Fuel Cell Technologies Research Group
3. TKİ, General Directorate of Turkish Coal Enterprises

In this work, low rank coal gasification and gas cleaning have been investigated in a pilot scale pressurized bubbling fluidized bed reactor, which was operated with 81–101 kg/h coal feed rate. The mixture of air, steam and oxygen was used as gasification agent with different ratios. The operating pressure of the gasifier in this experiment was between 2.2 and 3.2 barg. The effects of equivalence ratio (ER), steam/carbon ratios on syngas composition, cold gas efficiencies were investigated. Syngas composition was analyzed using online gas analyzer through experiments.
To clean the contaminants - particulates, carbonyl sulfide (COS), hydrogen sulfide (H2S), tar - in syngas, a gas cleaning system is integrated into the gasification system. Ceramic candle filters were used to remove particles. For COS removal, commercial Alumina catalyst was used in a hydrolysis reactor to convert the COS to H2S. NaOH solution with a pH of 12 was used in two packed bed scrubber columns operated in series for H2S removal. Water at a temperature of 8-10°C was sprayed to syngas in a spray column to remove tar compounds.
As a result of the studies, >95% efficiency in COS removal and 99% efficiency in hydrogen sulfide removal was obtained.

Keywords: pressurized gasification, low rank coal, syngas cleaning, contaminants removal efficiency

1.3 (16:40-17:00) An Experimental Study on Underground Coal Gasification of Soma Basin Coals

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Anıl Soylu, Istanbul Technical University, TÜRKİYE
İsmail Hakkı Sarıçam, Turkish Petroleum Corporation, TÜRKİYE
Samet Bozdoğan, Istanbul Technical University, TÜRKİYE
Murat Çınar, Istanbul Technical University, TÜRKİYE
Abdullah Fişne, Istanbul Technical University

The energy demand that emerged with the industrial revolution was first met with coal. In the last century, beside of coal, oil and natural gas have come to the fore in meeting this huge energy demand. Underground coal gasification(UCG) provides utilization of unmined coal seams due to various limitations. Production of syngas by in situ gasification of coal with production wells can be done and utilized as an energy source. This laboratory study was performed in order to understand the physical and chemical properties of the underground coal gasification process by simulating certain aspects. Soma basin sample from Western TÜRKİYE were used in two experiments. In these experiments in which dry air and oxygen-enriched air (40% O_2) were injected, the experimental setup was designed to have near zero heat losses, but the reactor used was not an adiabatic reactor. H_2S filter was used to reduce/block H_2S production during the experiment. These experiments were carried out by adapting the methods used for in situ combustion analysis of oil fields. It was aimed to determine the content of syngas released during gasification. Also, proximate analysis is conducted to characterize samples. Temperature history data, gas composition and proximate analysis results are shared and explained.. Experiment with dry air yields 3.56 % H_2 and 15.93 % CO beside of 1.25 % CH_4, 23.84 % CO_2 and other hydrocarbons with higher carbon amounts. 3.08 MJ/Nm^3 energy output is calculated from parameters of produced gas. Experiment with 40 % O_2 yields 5.92 % H_2, 32.55 % CO, 1.77 % CH_4 and 19.33 % CO_2 with other hydrocarbons with low concentrations. 5.87 MJ/Nm^3 energy output is calculated.

1.4 (17:00-17:20) Synthesis Gas Production From Eskişehir Alpu Lignite Reserve with Underground Coal Gasification: Techno- Economic Assessments

Hasan Can Okutan, Prof. Dr., ITU Synthetic Fuels and Chemicals Technology Center, Istanbul/TÜRKİYE

Alper Sarıoğlan, Assoc. Prof. Dr., ITU Synthetic Fuels and Chemicals Technology Center, Istanbul/TÜRKİYE

UCG is a gasification process for coal resources that are not economically viable, e.g. low grade, too deep mines in a thin stratum profile. UCG process converts coal in situ into a product gas by using oxygen/ steam mixture (air, oxygen enriched air, oxygen/vapor). Here the coal beds react as a chemical reactor, thus gasification process is maintained underground in opposition to conventional gasification. In this process; coal, steam and oxygen are brought together under gasification conditions giving a synthesis gas in a mixture of CO, H2, CH4, CO2 and H2O. UCG offers many advantages over the conventional mining and gasification processes. Some of these advantages are; reduced capital investment expenses by eliminating the necessity of successor processes such as transport, storage, crushing, grinding and gasification on the ground. UCG has favorable conditions for occupational safety and health as well. There is no need for ash disposal or landfill. The low particulate matter emission and less noisy operation are its other plus. Thanks to the exploration activities of the Mineral Research and Exploration Institute (MTA) for the discovery of new lignite reserves since 2005, Turkish lignite reserves, known as 8 billion tons, have been updated to 19 billion tons. The newly discovered and important coal reserves are in geographic location of Konya-Karapınar and Eskisehir-Alpu with an estimated capacity of 1.83 billion and 1.45 billion tons of lignite, respectively.

In this study, the applicability of the underground coal gasification technology to Eskisehir-Alpu lignite reserve has been evaluated both technologically and economically. To do this, a computer aided design work has been performed on the configuration of UCG process in line with the characteristics of Eskişehir Alpu lignite reserve field. The parallel and linear controlled retracting injection point (CRIP) as the most favorable technique of gasification of coal in situ has been covered by the model as well as the air separation unit for oxygen supply and syngas clean up unit. A mass balance was established on the UCG process through the computer aided design software and a cost estimation model has been developed for the cost analysis. The calculated size of the equipment has been reported together with the economic indicators such as fixed

and working capitals and also manufacturing expenses. The ultimate syngas cost has been estimated as well for comparison with the conventional coal gasification.

1.5 (17:20-17:40) Feasibility of Methane Production from Elbistan Lignite Using Termite Enzymes: a Numerical Analysis

Cemil Koyunoğlu, Assistant Prof. Dr., Energy Systems Engineering Department, Engineering Faculty, Central Campus, Yalova University, 77200, Yalova, TÜRKİYE

Ahmet Arısoy, Prof. Dr., Mechanical Engineering Department, Faculty of Mechanical Engineering, Gümüşsuyu Campus, 34469, Istanbul, TÜRKİYE)
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This paper presents a feasibility study on the utilization of termite enzymes to produce methane from Elbistan lignite, with a focus on quantifying methane yields and evaluating economic viability. The study explores the potential of harnessing termite enzymes to convert Elbistan lignite, a regionally abundant low-grade coal, into methane gas. The assessment incorporates numerical analysis to determine both the technical and economic feasibility of termite enzyme-based methane production. Laboratory experiments were conducted under controlled conditions to measure the efficiency of termite enzyme activity in converting Elbistan lignite into methane. The methane yield from termite enzyme activity was determined to be 0.1 kg CH4/kg lignite, with a reaction rate of 0.03 mol CH_4/mol enzyme/hour. Based on these findings, the daily methane production from Elbistan lignite was calculated to be 0.03 kg CH4/day, resulting in a total methane production of 0.9 kg CH4 over a 30-day monitoring period. The economic analysis included an assessment of the initial investment costs required for establishing termite colonies, enzyme extraction, and lignite processing, with the total investment cost estimated at $8,000. Considering the market price of methane and the volume of produced methane, the analysis indicated a total revenue of $13.50 USD from methane sales. However, the return on investment (ROI) showed a negative value of -40.63%, indicating that the revenue falls short of covering the investment costs. The study concludes that termite enzyme-based methane production from Elbistan lignite demonstrates potential methane yields, but the current economic feasibility is limited. Further research is recommended to optimize the process, enhance methane production efficiency, and reduce investment costs. Additionally, exploring potential uses for by-products and valorizing them could contribute to improving the overall economic viability of this technology. In conclusion, this feasibility study offers valuable insights into the potential of termite enzyme-based methane production from Elbistan lignite. While the results indicate promising methane yields, addressing economic challenges is crucial to making this innovative approach a sustainable and cost-effective biogas production method. Continued research and development efforts are essential to unlock the full potential of this technology for renewable energy generation and to harness the vast reserves of Elbistan lignite.

SESSION 2 (16:00 – 18:00)
VALUE-ADDED PRODUCTS FROM COAL – 1
Dr. Ahmed Aboudheir, Mr. Ayhan Kandemir

2.1 (16:00-16:20) Upgraded Coal and Coal Waste to Graphite for Lithium-Ion Battery Applications

Alexander Azenkeng, Assistant Director for Critical Materials
Nicholas E. Stanislowski, Research Scientist
Jason D. Laumb, Director of Advanced Energy Systems Initiatives

University of North Dakota Energy & Environmental Research Center
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018 USA

Graphite is currently considered a critical mineral because of its importance as an active material for fabricating the anode of lithium-ion batteries (LIBs). Global trends in the manufacture of electric vehicles (EVs) are rising steeply, but the supply of graphite, which constitutes the largest component in a LIB by mass, is limited. In addition, natural graphite mines around the world that have been the traditional source of commercial graphite are limited, and the few existing mines may be subject to complicated geopolitical dynamics. To assist in meeting the global graphite supply limitations, this study aims to investigate efficient ways to synthesize high-quality graphite from abundant coal and coal waste resources that exist in many areas around the world. A recently developed upgraded coal-to-products (UCP) process has shown great promise in the ability to reduce coal-borne impurities and produce a graphitizable product that yields good quality graphite for LIB applications. Preliminary results show that the quality of coal-derived graphite obtained by the UCP process is similar to that of commercial LIB-grade graphite. Available results are presented and discussed as well as maturation plans and flexibility of the UCP technology.

2.2 (16:20-16:40) Novel Processes for Converting Coal to High-Value and Lower Carbon-Footprint Products

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Sr program Director, Battelle Memorial Institute
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Dan Garbark
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Battelle has developed several, patented processes for making high-value, liquid and solid products employing biomass-derived solvents and other additives. A range of products, including jet fuel, diesel, marine fuel, and polyurethane (PU) foam can be produced in the desired proportions. The biomass-derived solvents/additives are functionally superior to conventional coal solvents and help significantly lower the carbon footprint of the products. The high effectiveness and efficiency of these solvents/additives also contributes to reduction in capital and operating costs. For production of distillate products, such as jet fuel or diesel, the biomass-derived solvents/additives employed in Battelle's coal-to-liquids (CTL) process provide highly effective and efficient hydrogen-donor function, allowing coal to be liquefied and partially refined without needing molecular hydrogen (H_2), thus also avoiding high pressures. This process won an R&D 100 Award in 2017. In a related process, coal can be co-liquefied with waste biomass to produce fuels with a much lower carbon footprint than for producing the same from petroleum crude.

In another patented process, a variety of coal-derived liquids, such as from Battelle's CTL process or from conventional pyrolysis processes, are converted to polyols as an intermediate via ozonation. These coal-derived polyols can be substituted for petroleum-derived polyols for making PU foams. The process represents a breakthrough in innovative utilization of U.S. coals, does not require any advanced preparation of coal, and is applicable to bituminous as well as sub-bituminous coals. The resulting PU foam products are projected to have an extremely high value (over $5,000/tonne), with up to 90% of coal-based carbon being utilized. The bio-based content of the PU foams from this process ranges from 32 to 44%. The products represent an extremely large (over $80 billion/year), existing (PU foam) market. The initial target applications for these foams will be insulation, packaging, and energy absorbing foams, which could expand into making coatings and adhesives. The presence of aromatics in coal-derived liquids helps increase the final foam rigidity. The process can help reduce petroleum imports, while improving the economics of PU foam production. The process won an R&D 100 Award in 2022.

This paper will provide key details of two of these novel processes, including results from continuous testing and data on product properties, as well as present the process economic analyses.

2.3 (16:40-17:00) Novel PRB Coal Based Asphalt

Jeramie J. Adams, Vice President of Asphalt and Petroleum Technologies, Western Research Institute, 3474 North 3rd Street, Laramie, WY 82072, USA
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J.-P. Planche, Y. Kumbargeri, J. Rovani, Western Research Institute, 3474 North 3rd Street, Laramie, WY 82072, USA

A novel coal-to-chemicals conversion process was recently introduced that uses biobased solvents to liquefy subbituminous coal and lignite. Here we present results on the application of the new coal derived feedstock in asphalt pavement formulation and as an asphalt extender by blending with traditional paving grade asphalt. Powder River Basin (PRB) coal extract, as the coal-based asphalt binder, was prepared at pilot scale. Coal extracts were subsequently used to prepare a compacted asphalt mixture sample. Coal extracts were further blended with conventional asphalt binders, biobased and petroleum-based oils at various levels to obtain samples for rheological characterization according to Superpave asphalt standards. USAT RTFO/PAV aging was performed to evaluate aging behavior. The coal extract was modified with common SBS polymers at 3 wt%, similar to traditional asphalt modification. These polymer modified blends were analyzed by the multiple creep recovery test which showed high compatibility and activation of the polymers.
The coal extract consisted of about 55% PRB coal and the remainder was biobased. PRB coal production has a much lower carbon footprint than crude oil, so using PRB coal extract could reduce emissions over conventional asphalt use. The high biobased content in the coal-derived asphalt could significantly reduce emissions associated with pavement construction.

2.4 (17:00-17:20) Is It Time to Utilize Coal as Value Added Material: Carbon Fiber

M.F. Can[1], A. Kılıç[2], A. Sarıoğlan[3], F. Boylu[4], S. Gürmen[5], H. Okutan[3], M.S. Çelik[4]

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[5] Istanbul Technical U. Metallurgical Eng. Dept.

Effective utilization of coal and particularly of low-rank coals is of utmost importance as the concern over gas emissions and climate change is growing rapidly. Despite their high reactivity, the utilization of low-rank coals in direct liquefaction is limited by their high oxygen and moisture contents because large amounts of hydrogen and energy are required for oxygen and water removal, respectively. However, syngas (or CO) and H_2O may be used as a hydrogen source for liquefaction together with introducing some catalysts and solvents can convert low-rank coals into fuels and value-added chemicals in the conditions of hydrogen-poor gas and drying, thus resulting in the whole cost reduction under appropriate reaction under certain temperatures and pressures.

More interestingly, Hydrocarbon extraction by supercritical carbon dioxide technology not only is able to produce gases and hydrocarbon liquids but can be also used in utilizing large quantities of CO_2 and thus help in reducing green-house gas emissions. Various hybrid methods with some liquid solvents like toluene are used to increase the efficiency and selectivity of extraction process. In this context, Coal to Carbon Fiber–Novel Supercritical CO_2 Solvated Process (MUSCL) Terra Power's pyrolysis test loop utilizes supercritical CO_2 in a closed loop to obtain asphaltenic pitch from Benzene Soluble pitch (BSP) as a potential precursor for mesophase pitch development.

2.5 (17:20-17:40) General Directorate of Turkish Coal Enterprises Leonardite Projects

Murat KURT, General Directorate of Turkish Coal Enterprises, Coal Products and Technologies Manager,

In today's world, where global warming-based agricultural transformation is taking place, countries are taking steps to increase the decreasing organic matter content of agricultural soils due to incorrect fertilization and soil cultivation, and to regulate the use of chemical fertilizers.
The General Directorate of Turkish Coal Enterprises (TKİ) aimed to contribute to the economy by evaluating Leonardite, which is processed as coal waste in lignite fields, in the agricultural sector since 2009, anticipating this change.
Leonardite is a substance that is formed after a humification process that 60 million years, and it is located in the surface areas of the lignite mines in an oxidized state. Leonardite is a natural product that contains high levels of "Organic Matter and Humic + Fulvic Acid" and can be used as a raw material in agriculture and many industrial sectors through direct or derivative products.
Leonardite generally converts plant nutrients in an unfavourable form in the soil into a usable form by increasing soil organic matter and enhancing microorganism activity. In this way, it enhances the effectiveness of chemical fertilizers, prevents excessive fertilizer use, prevents excessive irrigation by increasing water-holding capacity and helps protect the environment, as well as contributing to the economy.
TKİ has conducted R&D and field trial studies with many institutions and organizations to produce Leonardite and derivative products. As a result of these studies, it has produced "Liquid Organic Soil Regulator Humic Acid" and established a production facility with an annual capacity of 1,500,000 liters in Kütahya under the brand name TKİ-Hümas, which is sold commercially in the market. The General Directorate of TKİ, which speeds up production and facility activities to increase the amount of organic matter in Turkish agricultural soils, reduce the use of chemical fertilizers, and increase agricultural productivity, plans to carry out the following activities between 2023-2024 in the "Organic Source Fertilizer" sector to increase its market share;

- Granular Organomineral Fertilizer Production Facility/Kütahya (30,000-90,000 Tons/Year),
- Potassium Humate Powder Production (Kütahya 50 Tons/Year),
- Powder/Granule Leonardite Production (Kütahya-Bursa-Kahramanmaraş 200,000 Tons/Year),
- Powder/Granular Gidya Production (100,000 Tons/Year in Kahramanmaraş)

is planned to be carried out, aiming to increase its market share in the "Organic Source Fertilizer" sector.

Keywords: Leonardite, Humic Acid, Fulvik Acid, Organic Fertilizer, Coal, Produce, Organomineral

2.6 (17:40-18:00) Development Studies for Construction Chemicals Using Humic Acid

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İffet Yakar Elbeyli, Assoc. Prof. Dr., TUBITAK Marmara Research Center, Chemical Process Technologies Research Group, Barış Mah., Dr. Zeki Acar Cad.,No:1, P.K. 21, 41470, PK 21, Gebze-Kocaeli, Türkiye.

Construction industry has sustainability all over the world by effective using raw material sources. It is forecasted that in 2030 construction industry value will be reach to 17.5 billion USD by increasing from 11.4 billion USD in 2019. Concrete will be most important material in construction industry comparing with steel, wood, prefabricated materials. Chemical admixture industry as a side supplier for cement and concrete production processes are developing new technologies. In 1960 lignosulphonates were main plasticizers than in 1980's the melamine and naphthalene sulphonates were developed and the high-rise buildings using polycarboxylates by Japan was dominated the chemical industry. Under the light of sustainability, the use of value added materials is the main aim of scientists.
TKI Humas is a natural organic soil conditioner product containing humic and fulvic acids. It is produced from leonardite by General Directorate of Turkish Coal Enterprises (TKI) for agricultural use. In the present study, TKI Humas was modified by different chemical methods and converted to water reducing agent for uses in concrete production. The modified products were evaluated comparatively with respect to commercial superplasticizers. The results suggest that TKI Humas should be considered as eco-efficient superplasticizers due to the similar performance on workability and other properties of cementitious systems when compared to lignin-based and/or polycarboxylate type of superplasticizers. Interdisciplinary studies have an opportunity for reach and development projects to create network.
Keywords: construction, chemical admixtures, humic acid, superplasticizer.
Acknowledgments: The authors greatly acknowledge to Turkish Energy, Nuclear and Mining Research Council (TENMAK) and General Directorate of Turkish Coal Enterprises (TKİ) for supporting of the ''Development of Construction Chemicals Containing Humic Acid'' project (Project No.522RA01) in which this study was carried out.

SESSION 3 (16:00 – 18:00)
COAL SCIENCE – 1
Prof. Atsushi Ishihara, Prof. Dr. Mehmet Sabri Çelik

3.1 (16:00-16:20) Comparing of the Estimation Reserve Results with after Mining Operation Rom Results in Çivilicam Open Pit Panel in Garp Lignite Enterprise

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Aycan ÇATAL, Mining Engineer/Manager, Turkish Coal Enterprises, Ankara, TÜRKİYE
Kazım BAŞKAYA, Geological Engineer/Manager, Turkish Coal Enterprises, Ankara, TÜRKİYE

Ceren DEMİR, Mining Engineer/Manager, Turkish Coal Enterprises, Ankara, TÜRKİYE
Ali BORA, Mining Engineer/Manager, Turkish Coal Enterprises, Ankara, TÜRKİYE

The biggest investment item in coal mining project is capital costs. Therefore, estimation of the reserve, coal quality, depth of the seams and amount of overburden is very important in order to find out most suitable mining methods before commissioning mining operation. In this study, modelling and open pit mine design of Çiviliçam panel in Garp Lignite Enterprise that belongs to Turkish coal Enterprise were made with three-dimensional mining software.
All explorational data (geological studies, drilling etc.) and topographic data that belongs to field is transferred to the three-dimensional software program. Coal seams were identified by examining the drilling logs one by one in the three dimensional software program. Then levels of coal seams that can be produced by open pit mining method and amount of overburden was determined. With this method, it has been calculated 1.26 million tons of coal reserve in the field and 24.6 million m^3 of overburden should be removed in order to produce this reserve. In operation phase, production was carried out by the Garp Lignite Enterprise with the open-pit coal production method, 1,03 million tons of coal was produced and 18,1 million m^3 of overburden was done. As a result, this modelling study results has achieved 80% compliance with the actual production results.

3.2 (16:20-16:40) Uysal Madencilik – CS ARGE Coal Drying Plant Project

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Soner AKIN, Mr., CS ARGE INC, Address: Malkara / Tekirdağ / Türkiye, TURKIYE
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Due to the surface moisture generated in the products obtained as a result of heavy medium coal enrichment processes, it may be necessary to apply a number of dewatering methods (centrifugation, filtration, etc.). As the last of the dewatering methods, final dewatering is carried out with dryers. There are many types of dryers used in the mining industry today. The surface moisture content of the coals that are likely to be dried in the rotary type coal drying plant, which is the subject of this study, is between 10% and 25%. As it is known, the moisture in coal changes in inverse proportion to the calorific value. In general, 1% decrease in moisture will result in an increase in calorific value of 40 to 60 kcal/kg, depending on the type of coal. In this project Rotary drying design was made by considering, evaluation of the properties and amount of coal to be dried and determining below parameters ; -The dimensions of the combustion chamber and moving grill dimensions required for the drying process, -The amount and properties of the fuel required for the drying process, -The dimensions of the rotary drum and the design of the lifter blades in it, -The residence time in the drum, -The selection of the fan required to ensure the absorption of steam and gases in the drum.

3.3 (16:40-17:00) The Design and Performance Study of a Coal Sorting Machine Using X-Ray Technology

Erdem KAZAN, M.Sc., CS ARGE INC., Address: Malkara / Tekirdağ / Türkiye, TURKIYE)
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In line with the goal of producing smart and technological solutions for the efficient use of energy and water resources, global trends towards environmentally sustainable mining have led to a significant interest in sensor-based dry processing methods as alternatives to traditional ore processing techniques.
Sensor-based sorting techniques, such as sorting with X-ray, can be performed entirely in a dry manner and are highly efficient in terms of energy. It has been observed that the operational costs of sorting units could be lower than those of traditional mineral processingunits, making sensor-based ore sorters an industry standard for mineral processing circuits. In recent years, successful results have been reported in international studies regarding the use of X-ray sorting systems in coal processes.
The most significant and distinct advantage of dry coal processing is that it eliminates the need for water usage, thus reducing the overall processing costs and making the operation more profitable. In X-ray sorting, the coal remains dry, resulting in a higher-quality product at lower operating costs. Dry processing plants are easy to construct, and their construction time is much shorter compared to traditional wet coal processing plants. Since water circuits and slurry ponds are not required, there are fewer environmental permitting issues. Dry enrichment plants can be made semi-mobile, allowing for quick and easy relocation of these facilities. The addition of sensor-based ore separation to the ore enrichment value chain can have a significant impact not only on unit operations but also on overall economic and environmental considerations.
These beneficial effects can be summarized as follows:
• Increased recoverable reserve quantity.
• Recovery from waste dumps.
• Increased efficiency.
• Decreased energy consumption.
• Absence of water consumption.
• Absence of byproduct waste (magnetite, flocculants, etc.).
• Reduction in transportation costs.
• Decreased labor and maintenance costs.
• Reduction in waste generation.
• Access to additional sources of revenue.
This study discusses the development, performance evaluation, and implementation process of a coal sorting machine using X-ray technology specifically designed for Turkish lignite coals. In line with this objective, Uysal Mining Inc., a lignite mining company, has completed the preliminary designs and prototypes of the X-ray sorting machines. The machines underwent further mechanical and software improvements, and real-world tests were conducted to enhance separation efficiency and increase capacity. Additionally, efforts were made to address any potential issues that could hinder long-term operation. As a result of these efforts, an efficient, environmentally friendly, and Industry 4.0-compliant technological system has been developed for coal reserves in our country.
Within the scope of the study, sensor-based ore sorting technologies, specifically X-ray sorting technology, were addressed. The theory of separation using X-ray transmission (XRT) formed the basis of this research. Dual Energy analysis and algorithms were employed for product and waste assessment. The application focus of the study was on lignite coal as the ore material.
In X-ray sorting technology, the separation process is based on the differential absorption coefficients of X-rays by materials, which depend on their atomic densities. Different substances with varying atomic densities allow X-rays to pass through them to different degrees. This difference enables the separation of materials. The bulk material is passed through a tunnel where X-ray scanning takes place. Image processing technology using specialized software is applied to the scanned objects. The processed images provide information about the organic and inorganic percentages of the objects, and based on these values, they are classified as either product or waste. The decision to separate them from the flow using compressed air is then made.
The X-ray sorting system consists of four main components:
• X-ray Hardware System (X-ray machines, X-ray sensors, X-ray source...)
• Computer and Software System (Artificial vision, image processing, machine and valve control PLC software)
• Compressed Air System (Air valves, nozzles, compressors, dryers...)
• Valve Control and Automation System (Valve control automation modules, PLC cards, communication cards, encoders...)
Within the scope of the study, the following factors primarily affecting separation efficiency and capacity were addressed: Controlled Factors related to Feed Material:
• Material size
• Material shape
• Material structure
• Proportions of fractions within the bulk feed
Pneumatic Controlled Factors:
• Opening and closing time of air valve
• Flow rate and operating pressure
Software Controlled Factors:
• Objects in close proximity
• Delay time
• Coloring algorithms
Mechanical Controlled Factors:
• Type of separator mechanism (air valve, mechanical flap, etc.)
• Angle and position of the separator platform
• Angle and position of the nozzle platform
• Feed platform (vibratory feeder, sliding plate, etc.)
• Screening platform (crusher and sieve)
• Belt conveyor speed
Within the study, a high-speed camera capable of slowing down the recorded videos by 10 times was used to detect faulty separations. Periodic tests were conducted in the operating laboratory to determine the quality of the product, which involved analyzing the calorific value, ash content, and moisture content.

3.4 (17:00-17:20) Pilot Scale Allair Jig Application on Some Turkish Coals

Feridun Boylu, Dr., Istanbul Technical University Faculty of Mines, Mineral Processing Engineering Department, TÜRKİYE
Yusuf Enes Pural, MSc, Istanbul Technical University Faculty of Mines, Mineral Processing Engineering Department, TÜRKİYE
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Beneficiation of coals are generally performed through dense medium separation for coarse and intermediate feed sizes, gravity concentration for fines and flotation methods for ultrafine coals in hydrophobic nature. However, just because of the environmental problems and need to eliminate water usage in separation circuits, dry beneficiation methods are preferred for the coals in limited sizes up to 45 microns. Although dry beneficiation techniques such as air jigging, pneumatic separators are preferred for the

reasons given above, some requisitions related to the coal characteristics such as feed size and moisture and mainly washability characteristics, those techniques are used for de-shaling process and mainly produce inorganic wastes in reasonable calorific values and propose products in middling character.
The cut densities and probable error for gravity based dry separations are reported as >1.80 g/cm3 and >0.165. So, this I why I called as de-stoning process since the higher densities than 1.85 g/cm3 which are mainly ash forming minerals are reported to tailings with reasonable low calorific value (lower than 700 kCal/kg) whereas lower densities than 1.80 are reported to light product (clean coal product). The light product having comparatively high-density fractions does not allow to have clean coal product and the minimum ash content of clean coal product was controlled by the amount of near gravity materials NGM). In Türkiye, some coals have low amount of NGM and seems to be processes through gravity based dry beneficiation methods. In this study, three coal examples were chosen and processed using Allair Jig with 50 t/h capacity. The results showed that it is possible to have clean coal product with ash content of lower than 20 %.

3.5 (17:20-17:40) Chemical Desulfurization of Low-Rank Muğla-Yatağan and Kütahya-Tunçbilek Lignites

Figen Gündüz, Chemical Engineer, Msc., Chemical Engineering Department, Engineering Faculty, Inonu University, Elazig Road 15th km, Central Campus, Inonu University, 44280, Malatya, TÜRKİYE

Hüseyin Karaca, Prof. Dr., Chemical Engineering Department, Engineering Faculty, Inonu University, Elazig Road 15th km, Central Campus, Inonu University, 44280, Malatya, TÜRKİYE

Impurities present in coal structure, when combusted, release harmful emissions into the environment. Sulfur is a primary impurity in this context. One of the most effective methods for removing inorganic materials from lignite, a type of coal, is chemical desulfurization. In this study, lignite samples from two different reserves in TÜRKİYE were treated with H2O2 and H2SO4 reagents at varying temperatures, reagent concentrations, and durations to examine sulfur removal. According to the results obtained, the sulfur removal rates for Tunçbilek (TB) and Muğla-Yatağan (MY) lignites were found to be 31.81% and 48.12% respectively at 30% H2O2 concentration, and 32.12% and 57.14% respectively at 30% H2O2 and 0.1 N H2SO4 concentrations. As the concentration of the chemical reagent increased, sulfur removal also increased. In a 20% H2O2 solution under process conditions of 30-90 minutes, pyritic sulfur in TB lignite decreased from 0.73% to 0.21%, and in MY lignite, it decreased from 0.43% to 0.20%. In the desulfurization process conducted at 50°C with H2O2 reagent, the sulfatic sulfur content in TB and MY lignites was obtained as 0.21% and 0.07% respectively. The method used in this study proved effective in removing sulfur from low-rank lignites. It is considered a potent method to mitigate the environmental harmful effects of sulfur.

3.6 (17:40-18:00) A Study on Efficient Energy Utilization in Grinding

Barış AKKAYA, Dr. Zonguldak Bülent Ecevit University, TURKIYE

İhsan TOROĞLU, Prof. Dr. Zonguldak Bülent Ecevit University, TURKIYE

Mehmet BİLEN, Assoc. Prof. Dr. Zonguldak Bülent Ecevit University, TURKIYE

In this study, a method specifically developed for the comparison of the useful energy used in direct size reduction in grinding according to different grinding variables is introduced. According to this method, a method-specific benchmark parameter (Ecx), which depends on the amount of new material passing below different sizes of the material and the specific energy, is calculated and based on this, a comparison of the effective energy spent directly in grinding for different sieve sizes and grinding conditions is made. It is envisaged that this comparison can be effective in determining the grindability of the material independently of the grinding capacity and mill design, and in reacting quickly and appropriately to the differences in the material. A stirred mill was used as the mill, bottom ash as the material, different time (1-2,5-5 d) as grinding variables and 900 rpm as mixing speed. The size analysis of the product obtained according to the grinding times was performed.

SESSION 4 (16:00 – 18:00)
COAL MINING, PREPARATION, AND HANDLING – 1

Mr. Francis Lau, Prof. Dr. Feridun Boylu

4.1 (16:00-16:20) Astec Osborn Coal Processing Equipment and Case Study of Kangal Power Plant's Crushing and Screening System

Oguzhan TOPRAK, Regional Sales Manager, Astec Industries, Chattanooga TN, USA

Osborn company began in 1919 as Samuel Osborn a subsidiary of Sheffield England steel company founded to market special steels for industry and mining and South Africa. In September 2000 Osborn became a member of US industrial group, Astec Industries Inc. Today Astec Osborn is one of the South Africa's foremost manufactures of equipment over a wide range of products including coal crushing and screening systems.

Serving the South African coal market for more than 80 years, Osborn's Coal Crushers have proven to be extremely reliable and have gained popularity as far afield as Australia, TÜRKİYE and neighboring African countries, such as Zambia, Zimbabwe, Botswana and Mozambique.

The preparation of ROM coal commences the moment it is received from the mine. The Rotary Coal Breaker crushes and breaks the coal and removes most of the rock contamination.
The sized coal from the Rotary Breaker can then be fed into a Rolling Ring Crusher which produces a finer product.
For more specific and smaller sizing of the coal, the Double Roll Crusher is generally the preferred machine, particularly for processing the sizes required by power stations and for the export market where tight specifications are required.

Osborn has commissioned a huge coal crushing and processing plant in TÜRKİYE in 2008, located in Sivas/Kangal area. the plant is preparing 1500ton/hour coal for the power plant. the presentation will be about the coal processing equipment of Astec Osborn and Kangal Power plant's coal plant.

4.2 (16:20-16:40) Future Mining Technology - Advanced Monitoring and Control in Coal Mining with Smart Helmets

Cem CAN, Mining Engineer, Turkish Coal Enterprise, Ankara, TÜRKİYE

Mining, especially in coal mines, is an industry that carries significant accident risks with serious consequences for workers and the environment. In coal mines, situations such as gas poisoning, gas explosion or collapse can be encountered that negatively affect the ecosystem and human life. For this reason, coal mining, where many dangerous activities take place, can have serious material and spiritual impacts. On the other hand, accidents in coal mines can be prevented by methods such as monitoring the temperature and harmful gases that cause these effects. The main objective of this study is to develop a system to monitor harmful gases such as CO2, CO, methane and to control temperature and humidity in coal mines. This system is planned to be integrated into the hard hats worn by the workers. This technology is planned to include a series of sensors, data acquisition and communication systems. With the help of the sensors integrated into the helmet, environmental variables (temperature, humidity, gas concentration, etc.) will be continuously monitored. When gases and fire above the limit value are detected by the sensors connected to the microcontroller, the device will give an audible warning and the data will be transmitted to another receiver via the receiver. The data received by the other receiver will be transmitted to higher authorities and emergency services using the GSM module. This is of great importance in preventing a possible accident or providing detailed information about the location of the accident. This paper aims to investigate the potential of smart helmet technology by addressing the limitations of traditional helmets used in coal mines. In addition, the information obtained through smart helmet technology can be analyzed and can help in the development of occupational health and safety policies.

Keywords: Gas sensors, coal mining, smart helmet, occupational safety, GSM, microcontrollers

4.3 (16:40-17:00) An Assessment of Direct Gas Content Measurement Techniques on Asphaltite Samples

Anıl Soylu, Istanbul Technical University, TÜRKİYE
Samet Bozdoğan, Istanbul Technical University, TÜRKİYE
Abdullah Fişne, Istanbul Technical University

Asphaltites are energy raw materials existing in various locations in the World. Although being less common than coal and bituminous shale, it represents the third branch of hydrocarbons. They are petroleum originated. They resemble to coal and currently used

like coal in Southeastern TÜRKİYE. They are mostly produced in open pit mines while there are several underground mining practices. Similar to coal, asphaltite production brings risk of gas explosion, dust explosion and spontaneous combustion etc. In this study, gas content of asphaltite samples and its measurement methods are focused. Firstly, asphaltites are introduced with their physical, chemical and geological properties. Then, direct gas content measurement techniques are assessed and compared based on laboratory experiments. For the experiments, sample collection from Üçkardeşler vein in Şırnak was done on drill site with desorption canisters. Volumetric measurement of desorbed gas was carried out with a u-tube arrangement. Temperature and barometric pressure were measured in each reading as well. In addition to desorption data production, pulverized asphaltite samples were obtained after desorption experiments was over. Proximate analysis was applied on pulverized samples in order to obtain a chemical background. The results of experimental procedure are shared, various techniques are used on desorption and discussed to estimate gas content values. USBM, Smith and Williams, curve fit and fast desorption techniques are investigated. USBM method is determined as best technique. Average gas content is calculated as 1.68 m^3/t.

Key words: sulfur in coal, macerals, graphitization, coal-based graphite

4.4 (17:00-17:20) Bitumen and Bituminous Gravel Reserves in Albania

Ekita Toska, Msc, National Agency of Natyral Resourses, Tirana, ALBANIA

Genc Demi, Prof.Ass.Dr. Faculty of Geology and Mines, Rr. Elbasanit, Tirana, ALBANIA

Kimet Fetahu, Prof.Ass.Dr. Faculty of Geology and Mines, Rr. Elbasanit, Tirana, ALBANIA

Bituminous gravel is a derivative of bituminous materials which is used as a very good fuel for factories that produce construction materials such as cement, bricks, as well as for plants that produce energy through combustion. Bituminous gravel and its concentrates have a very high calorific value. Bituminous gravel is a natural fuel, it is found together with natural bitumen and its fields of use are very wide. It is black, friable, combustible like coal and melts at a higher temperature than bitumen. Bituminous gravel, (pyrobitumen, bituminous coal), have a free carbon content of 70-92% and a calorific value of 3500-7500 kcal/kg.

Keywords: Bitumen, bituminous gravel, calorific power, reserves, schemes, technology of processing and enrichment

4.5 (17:20-17:40) Innovations in Mine Safety Technology for Coal Mines

Cem CAN, Mining Engineer, Turkish Coal Enterprise, Ankara, TÜRKİYE

Mining is a sector with a considerable risk of accidents, especially in coal mines, which is grave consequences for employees and the environment. Developed countries have made noteworthy progress to develop modern technologies for increase mining safety in coal mines, as well as having a strong safety culture. This paper, will discuss these innovations and potential impact in reducing coal mining accidents and deaths.
The current research discuss various new technologies, including digital solutions such as artificial intelligence, Internet of Things (IoT), Internet of Behaviors (IoB) and big data analytics. Virtual Reality (VR) technology can improve the work environment adaptation occupational safety. The use of VR technology can allow workers toacquire and practice the right behavior in a controlled, safe environment. Furthermore, Proximity Detection Systems (PDS) can detect people, vehicles and structures around a vehicle and sounds an alarm, or by integrating systems such as artificial intelligence (AI), AI can take control and take measures such as stopping the vehicle during an impending collision. New safety devices such as smart helmets also consist various sensors. It prevents unauthorized and helmetless persons from entering the mine, detects any hazards, monitor vital information and send the data to the control station to alert the miners.
The potential positive aspects of these developments are analyzed, as are the challenges and drawbacks associated with their use. The cost of implementing new systems can be a major obstacle for many mining companies. Also, there may be concerns about the reliability and cybersecurity of digital solutions.
Overall, the research provide information on the latest innovations in mine safety technology for coal mines, highlighting their potential benefits and the challenges associated with their adoption. By fostering collaboration and discussion among mining industry stakeholders, this presentation aims to contribute to the development ofsafer and sustainable mining practices and a culture of safety.

Keywords: coal mining technologies, occupational health and safety, smart mining

4.6 (17:40-18:00) Projecting High Faced Mechanized Longwall Panels at Çayirhan Underground Mines

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Murat KUMRU, Umut Ramis ÜNAL, Doğan BAYER
Çayırhan Lignite Plant

Longwall mining is known as a highly profitable method for underground production. In longwall mining, high production and efficiency are closely related to panel design. In panel design; bore hole data, geological-hydrogeological reports and vein structure of the coal are very important. In this study, planning and designing processes of panels in K site of KIAS Çayırhan Underground Coal Mine are examined.

POSTER SESSIONS

Wednesday, October 4 (18:00 – 19:30)

GT: GASIFICATION TECHNOLOGIES

GT-P1 Underground Coal Gasification for a Low-Carbon Future: San Juan, La Guajira, Colombia

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Colombia is one of the world's leading coal producers and has high quality coal deposits in the La Guajira and La Cesar regions. The San Juan field is located in the La Guajira region in northern Colombia.

The coal-bearing sequence of the Tertiary Cerrejon Formation overlies the Cretaceous basement rocks in the underground mining area. The Middle-Late Paleocene aged Cerrejon Formation has numerous coal seams and their thickness varies between 6 meters and a few centimeters.

Cerrejon Formation is divided into three groups (lower, middle, upper) according to coal thickness and distribution, and its possible total reserve is 671.7 million tons. The vitrinite reflectance values (Rm%) of the coals, which we can classify as high volatile bituminous coal, vary between 0.5 and 0.7. The result of coal petrography analyses San Juan coals composed of vitrinite (48.3-79.7 %), exinite (1.0-6.6 %), fusinite (0.3-5.6 %), semifusinite (5.5-25.9 %) and mineral matter (0.6-13.3 %).

The studies and data obtained so far in the field show that the coal bed contains a significant amount of gas. Within the scope of the project, first of all, site selection for geological modeling and test wells will be made with the available data. Next, injection and production wells will be planned and a pilot module with in situ combustion and management will be developed to determine the efficiency of the gasification process in the identified coal seams.

Using the coal seam as a gasification reactor to convert coal into syngas underground, this method is an important opportunity to reduce the environmental footprint of mining in energy production. Since this phenomenon is highly compatible with the Mining and Environment policies of the Colombian Government, the implementation of this project for a low-carbon future will be an important milestone in the country.

Keywords: Environment, energy, gasification, Colombia, coal, petrography.

GT-P2 Effect of Particle Morphology of Coal Gasification Fine Slag on Collector Adsorption and Flotation

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Coal gasification fine slag (CGFS) is a solid waste, flotation decarbonization is beneficial to its resource utilization. Particle structure plays an important role in

flotation. In this paper, shape, roughness, and pore structure of CGFS particles were characterized by scanning electron microscopy (SEM), fractal calculation and N_2 adsorption and the effect of particle morphology on collector adsorption were also analyzed. The results showed that the smoother structure, the larger pore volume/width that contributed to collector adsorption. CGFS could be classified into three fractions: <0.074 mm, 0.074-0.25 mm, and >0.25 mm based on morphology. The collector adsorption equilibrium times on the three components were 120s, 160s, and 80s. Fine particles (<0.074mm) were smoothness, the collector filled in particle interstices quickly and allowed well flotation result, and combustible recovery was 41.86%. The intermediate particles (0.074-0.25 mm) had a rough surface and rich internal pores and the collector was absorbed, which led to poor flotation result and combustible recovery was 26.56%. Coarse particles (>0.25 mm) were mainly detached ash particles, and it was difficult to absorb diesel, so the flotation result was worst. Therefore, it is recommended to carry out pre-treatment by particle size and then develop diversification decarbonization processes of CGFS.

Keywords: Coal gasification fine slag, Morphology structure, Collector adsorption, Adsorption kinetics, Particle flotation characteristics.

GT-P3 Effect of Modes of Occurrence on Release Behavior of Mercury During Pyrolysis of Low-Rank Coal

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The release of mercury (Hg) and its compounds from low-rank coal into the environment can cause long-term environmental pollution problem. In this study, the modes of occurrence and migration behavior of Hg in low-rank from Xinjiang Naomaohu coal (NMH) and Inner Mongolia high sulfur coal (GL) were studied through sequential chemical extraction, pyrolysis and thermochemical equilibrium simulation. And the effects of modes of occurrence, final temperature, heating rate and residence time on the release of Hg were also studied. The results indicate that the mode distribution of Hg in NMH and GL was organic-bound mode (70.37% and 91.18%), aluminosilicate-bound mode (28.12% and 1.25%), disulfide-bound mode (1.41% and 6.3%) and carbonate-bound mode (0.10% and 1.27%). The modes of occurrence of Hg seriously affected its release behavior. Organic-bound mode was easily volatilized at low temperature, while carbonate-bound, aluminosilicate-bound and sulfide-bound modes would be volatilized at medium to high temperature. The heating rate had no effect on the release of Hg, while extending the residence time favored the release of Hg. The thermochemical calculation of FactSage 8.2 showed that the main gaseous products of Hg were Hg, HgO, HgCl, HgCl2 and HgS. Cl had an im-pact on the release of Hg and the differences in the release behavior in two coals were mainly determined by the final temperature, m-ode distribution, Cl content and coal rank. There were differences between simulation and experimental results, and further studies were still needed.

GT-P4 Computational Fluid Dynamics Study on Coal Combustion and Gasification

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The utilization of coal for energy production remains a significant concern due to its environmental and economic implications. In addressing these challenges, Computational Fluid Dynamics (CFD) has emerged as a powerful tool to analyze and optimize coal combustion and gasification processes. This study presents a comprehensive overview of recent advancements in CFD-based investigations pertaining to coal combustion and gasification. The primary focus lies in the assessment of combustion efficiency, emission control, and gasification kinetics. The application of CFD techniques enables the detailed analysis of complex multiphase flow phenomena, heat and mass transfer, and chemical reactions within coal combustion and gasification systems. Through the integration of fundamental combustion and gasification theories with numerical simulations, researchers have gained valuable insights into the intricate interactions occurring within these processes. The simulations aid in characterizing temperature distribution, species concentration profiles, and reaction rates, offering a deeper understanding of combustion kinetics and pollutant formation. Moreover, CFD-driven studies contribute to the design and optimization of advanced combustion and gasification technologies. Computational models provide a platform to explore various operational parameters and their effects on process performance, offering a cost-effective approach to evaluate different scenarios prior to full-scale implementation. Additionally, insights gained from CFD simulations facilitate the development of novel strategies for emissions reduction and cleaner energy conversion. In conclusion, this paper underscores the pivotal role of Computational Fluid Dynamics in enhancing our comprehension of coal combustion and gasification dynamics. The synergy between theoretical principles and numerical simulations fosters innovative strategies for efficient and environmentally sustainable energy production. As CFD methodologies continue to evolve, they hold the potential to revolutionize coal utilization processes and drive the transition toward cleaner energy solutions.

CM: CARBON MANAGEMENT

CM-P1 a Laboratory Study on Improving Coal Seam Permeability with Naoh to Enhance Co_2 Sequestration

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The purpose of this study was to evaluate the effect of sodium hydroxide on increasing coal permeability to increase CO_2 adsorption capacity. The coal used in this study has low moisture content and high ash yield. The coal samples were dried and prepared into untreated coal samples that were then treated with sodium hydroxide at different concentrations (0.1 M, 0.5 M, and 1M) over a period of six hours. A volumetric apparatus was used to measure the amount of CO_2 adsorption on both untreated and treated coal samples in order to determine the effect of operating pressure on the amount of CO_2 adsorption. The coal sample is high rank coal, drying did not result in any significant changes, but after treatment with NaOH for 6 hours, the coal samples showed evidence of breakage, along with increasing NaOH concentrations. According to SEM results, untreated coal has minerals that fill up the pores, whereas treated coal has opened pores, created fractures, and a fracture network. In CO_2 adsorption experiments, the sample treated with NaOH exhibited an increase in CO_2 adsorption capacity with increasing concentration and pressure. Accordingly, the results of the study indicate that NaOH increases coal permeability and enhances CO_2 adsorption.

Keywords: CO_2 adsorption, NaOH treatment, permeability enhancement.

CM-P2 Using AI for Predicting Tea of The Co_2 Capture Process in Precombustion Applications

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Matlab (v.2020a) was used to develop an Artificial Neural Network (ANN) with the aim to rapidly predict the CAPEX, OPEX, and LCOC of the CO_2 capture process obtained using Aspen Plus V.11 for 35 different physical solvents in a pre-combustion 543 MW IGCC power plant. These solvents included (11 Ionic Liquids (ILs), 7 oxygenated hydrocarbons, 5, cyclic hydrocarbons, 5 hydrocarbons, 3 polymers, 2 subcooled solvents, and 2 nitrogenized hydrocarbons). The CO_2 capture process was carried out in a fixed-bed absorber, packed with a structured packing (Mellapak 250Y) or random packing (IMTP50). The CO_2 capture efficiency was set at 90 mol% from sulfur-free fuel gas streams. A total of (801) Aspen Plus runs were carried out.
The developed ANN required the knowledge of the solvent and packing properties, the pre-combustion power plant capacity, the solvent water retention, and the plant operating conditions. It consisted of one-input layer with 11 nodes, two-hidden layers with 10 nodes, and one-output layer with 3 nodes. The ANN was first trained with 320 randomly selected points (40% of the total points) and it was able to predict CAPEX, OPEX, and LCOC with high accuracy the process. The ANN was then tested using 481 points,

representing the remaining 60% of the total data points and it was able to predict the CAPEX, OPEX, and LCOC values with R^2 of 0.9934, 0.9992, and 0.9991, respectively. Thus, this ANN can perform TEA of numerous potential new solvents for CO_2 capture in seconds compared to hours with Aspen-Plus, which is a significant timesaving, provided that the plant capacity, solvent properties, and operating conditions are within its boundaries used in the development of the ANN as given below. It should also be emphasized that this ANN should strictly be used for interpolations because it will fail in any extrapolations not covered by it domain of applicability.

Table 1: Domain of applicability of the developed ANN

Parameter	Minimum	Maximum
Power plant capacity (MW)	54.3	543
Solvent temperature (K)	223.15	323.15
Solvent density (kg/m^3)	691.77	1,581.53
Solvent viscosity (Pa.s)	3.19×10^{-4}	1.37
Solvent Vapor pressure (Pa)	1.01325×10^{-5}	18,899.26
CO_2 Henry's Law constant (mol/m^3.bar)	37.49	3,790.67
H_2 Henry's Law constant (mol/m^3.bar)	0.07897	37.5115
Solvent cost ($/L)	0.18	41.50
Solvent water retention (binary)	0	1
Specific surface area of packing (m^2/m^3)	102	256
CAPEX ($)	10,171,495	216,736,909
OPEX ($/year)	2,622,825	1,370,783,510
LCOC ($/ton CO_2)	7.14	355.15

CM-P3 TEA of the CO_2 Capture Process in SMR-CCS Applications

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The production of "blue hydrogen" is mostly through Steam Methane Reforming-Carbon Capture and Sequestration (SMR-CCS). A novel process using SMR-CCS was designed in Aspen Plus V12.1 for CO_2 capture from fuel gas streams of an SMR-CCS process using a hydrophobic physical solvent (Diethyl Sebacate) in a counter-current fixed-bed absorber packed with a structured packing (Mellapak 250Y). The specific area of this packing (a) is 256 m^{-1}. The shifted fuel gas mass flow rate in the SMR-CCS process was 240.97 ton/h at (204 ºC and 24.5 bar) and it contained 60.01 mol% H_2, 4.11 mol% CH_4, 0.40 mol% CO, 15.17 mol% CO_2, 20.00 mol% H_2O, and 0.31 mol% N_2. The constrains imposed on the process were: (1) no flooding in the absorber and the packing height (H) to the absorber diameter (D) ratio (H/D) is greater or equal 6, (2) the CO_2 capture efficiency is greater or equal 97 mol%, and (3) the CO_2 stream intended for sequestration has a water content of less or equal 600 ppm, and a fuel gas (CH_4, H_2, and CO) content of less than 0.5 mol%. The solvent flow rate and CO_2 absorber dimensions were varied in order to meet the process constraints. The process hydraulics (pressure drop, liquid holdup, and flooding) and mass transfer characteristics (liquid-side (k_L) and gas-side (k_G) mass transfer coefficients, and the normalized specific packing wetted area (a_w/a)) were obtained. Also, a detailed techno-economic analysis (TEA) of the CO_2 capture process in terms of the capital expenditure (CAPEX), operating expenditure (OPEX) and levelized cost of CO_2 captured (LCOC) was performed.

The process began with knocking off the water vapor from the shifted fuel gas stream using a water separator at 38 ºC and 24.5 bar. To increase the CO_2 partial pressure in the shifted fuel gas stream, a compressor was used to boost the total pressure of the water-free fuel gas from 24.5 bar to different discharge pressures (49 bar, 61 bar, 73.5 bar, 97 bar, 98 bar, 99 bar, 110 bar, and 122.5 bar). Hence, the effects of the gas compression ratio on the process hydraulics, mass transfer characteristics and TEA (CAPEX, OPEX, and LCOC) were investigated.

The Aspen Plus V12.1 calculations using the rate-based model indicated that all process constraints mentioned above were met and at each compressor discharge pressure the, following data were obtained: (1) gas-phase and liquid-please temperature profiles, (2) gaseous CO_2 mole fraction profile, and (3) process hydraulics and mass transfer characteristics profiles. Each profile represents the changes in the respective parameter along the absorber packing height.

The calculation results showed that the lowest LCOC of 59.04 USD-2023 per ton of CO_2 captured was obtained at a compressor discharge pressure of 97 bar. The corresponding CAPEX and OPEX values at this pressure were 63.97 million USD-2023 and OPEX of 55.10 million USD-2023 per year, respectively. At this pressure, the total pressure drop was 12 mbar and the average liquid-phase holdup was 27.8%. Also, the average k_L, k_G, and a_w/a were 2.15E-4 s^{-1}, 1.86E-2 s^{-1}, and 63.4%, respectively. This indicates that the process is mainly controlled by the liquid-side mass transfer coefficient (k_L) since the liquid-side resistance to mass transfer ($1/k_L$) is greater than that of the gas-side resistance ($1/k_G$).

CAM: COAL ASH MANAGEMENT

CAM-P1 Nu-Rock "ENGINEERED ROCK" Process Converts All Ash from Coal Fired Power Stations into a Usable Product and Abates Carbon Dioxide Emissions and Uses 12% of the Embodied Energy of a Concrete Product or Clay Fired Product

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Nu-Rock has just won the best Green Building product in Australia awarded by the Housing Industry association with more 25,000 builders across Australia. Previously Nu-Rock won the award as the best Site remediation technology in the world from Care CRC which is awarded every 3 years and beat Chevron who were the runners up to the award. Also the last award we received was form the mining industry wining the Colorado Mining Cleantech Challenge for the best technology for dealing with mine tailings. Nu-Rock is offering Coal fired power stations, Steel mills, Smelters, Mines and Alumina plants a total clean up solution for 25% of any other companies cost of remediation or Liability transfer of the site. In Australia it has been out lawed to transfer an environmental liability from a company to another which did not cause the environmental liability. This is because the second company in turn disappears leaving the legacy problem to the State Government and people after running off with all the profit from there venture.

Nu-Rock is offering a solution to ash dams where, Nu-Rock will use the ash dam completely and leave a green field site at the end of life of the power station. Nu-Rock will also create Carbon Abatement credits at the same time which it retains. The way this works is that the Power Station pays a portion of the plant cost so Nu-Rock can build a processing module on their site. The standard module is a 300,000 ton per annum (250,000 tonne) a year ash processed per annum and the cost is $15 million USD. Nu-Rock requires the utility to invest $8 million USD to receive a shareholding in the Site specific Special unincorporated Joint Venture, that will to the utility will be $8 million USD per annum when the module is at full capacity selling its entire product made from the ash as a rebate for the ash for their investment.

If the power station is producing 300,000 tons of ash a year and 300,000 tons (250,000 tonnes per annum) of ash being added to the landfill Ash Dam. In this example the power station has an ash dam with 4.5 million tonnes in the ground, Nu-Rock would set up two modules on the power station so that at the end of life of the power station say for example this was 10 years. All of the fresh ash and portions of the ash dam would be used each year so, by the end of life of the power station the ash dam would have been consumed completely and the site a green field.

CAM-P2 Investigation of Coal Grindability (HGI) and Ash Fusibility (AFT)

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In this study, a total 29 coal samples were collected and analyzed in terms of their grindability (HGI). In order to carry out this analyzes, collected coal samples were initially crushed and samples were prepared in terms of proximate analyzes. After performing proximate analyzes of the samples, each samples were analyzed to determine grindability in terms of HGI tests. In addition to HGI test carried out, samples were burned at laboratory conditions and ash samples (a total of 29 samples) for each corresponding parent coals were obtained. In terms of ash fusibility tests, ash samples were prepared and their AFT tests were carried out. Based on the obtained results of HGI (grindability tests) and AFT (ash fusibility tests), interrelations were statistically investigated.

CS: COAL SCIENCE

CS-P1 Evaluation of Coal Tailings (Coal Slimes) Obtaining from Lignite Washery

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Factors such as the fact that coal, which has a homogeneous distribution in the world and has a production prevalence, has a higher lifetime than other fossil fuels, makes coal an indispensable energy source. In addition to all these, features such as price stability, ease of transportation, convenience of storage facilities, safety and reliability in terms of ease of use, cheapness and continuity of supply to the user are other important reasons for preference.
The most important issue is the efficient use of coal reserves, which have an important place among energy resources in TÜRKİYE as in the whole world, in economic and environmental terms. This necessitates coal washery, which ensure the enrichment of low quality coals. Approximately 95% of TÜRKİYE's coal reserves consist of lignite coal and 65% of this is low quality lignite with a calorific value of 2000 kcal/kg. For this reason, coal preparation processes come into play in order to obtain higher quality energy raw materials from these reserves. As it is known, the coal enrichment process is generally done by wet methods, heavy media separators, jigs, spiral, Kelsey jigs, etc. Gravity separators are widely used. Although the most important issue in these processes is the units in which fine sized coal is enriched, especially the slurry coals obtained after the enrichment process under 1 or 0.5mm size pose significant problems. It is an environmental and economic necessity to reuse this waste material, which constitutes 20-25% of the total feed, due to the highwater content and high amount of coal it contains. In the facilities that have the most important lignite reserves in TÜRKİYE and were established for the purpose of enriching the coal in Kütahya and Soma regions, especially coal slimes under 0.5 mm in size have been stored in these regions since the past, and large residual ponds have been created. It is a current issue to store the residues in these waste ponds by adapting them to environmental regulations and to bring the coal in its composition back into the economy. For this reason, within the scope of this study, samples taken from 3 ponds in the Tunçbilek basin and coal slime samples obtained from a facility in Soma were used. Characterization studies of these slimes were carried out and enrichment studies were carried out by classification according to size. As a result of the studies carried out, coal with a calorific value of around 3000 kcal/kg can be produced from Soma coal slimes, while coals with a high calorific value such as 5000-5500 kcal/kg can be obtained from Tunçbilek slime ponds.

Keywords: Coal, Slimes, Tailings, Coal Washing, Energy, Fine coal.

CS-P2 Distribution Characteristics of Heavy Metals and Sulfur in Magnetized Coal Char During Pyrolysis

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The distribution of sulfur and heavy metals in char of Gansu lignite and Shanxi subbituminous coal was studied by means of pyrolysis and magnetic separation at different pyrolysis temperatures. The contents of sulfur and heavy metal elements in char were analyzed and determined by ICP-OES and ICP-MS, and the mineral composition and apparent morphology of char were characterized by XRD and SEM-EDS. The results show that the highest desulfurization rates of Gansu lignite and Shanxi Subbituminous coal can reach 52.37% and 17.54% respectively under optimal conditions. This is related to the phase transition behavior of pyrite during pyrolysis. The desulphurization rate of Shanxi subbituminous char is lower than that of Gansu lignite char mainly because the occurrence and inclusion of associated minerals and the organic matter influence the transformation of pyrite during pyrolysis. Ni and Cr have a strong affinity with Fe–S minerals, which are enriched into magnetic char with sulfur. At 800 ℃, Cr content in magnetic char of Gansu coal and Shanxi coal is 8698.25 μg/g and 32327.47 μg/g higher than that in non-magnetic char, respectively. The pyrolytic magnetization of low-rank coal and the distribution of sulfur and heavy metals in its char products provide data support and a new idea for the removal of sulfur and heavy metals from coal.
Keywords: low-rank coal pyrolysis; char; magnetization; sulfur; heavy metals.

CS-P3 Classification of Mabesekwa and Masama Coals and Determination of Their Chemical Formulae

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There has been a lot of research on classification of coal. The United States Geological Survey (USGS) suggested four major coal types (or coal ranks) being lignite, sub-bituminous, bituminous and anthracite through the physical and chemical changes that occur over time causing metamorphism, accompanied by structural deformation which alter the fixed carbon content in the coal (USGS, 2017). The European Commission finalized a report in 2012 which agrees with coal ranks suggested by USGS but further added hard coal, coking coal and steam coal to their classifications (European Commission, 2012). There is a general principle that high rank coals have low volatile matter and verse versa. International Organization for Standardization (ISO) and American Society for Testing and Materials (ASTM) are international standards to consider when ranking or classifying coal. ASTM suggests that coal specification covers classification of coals by rank which is the degree of metamorphism and natural alteration and therefore follows a series from lignite which is low rank coal to anthracite being high rank coal (ASTM D388 - 19a, 2019). According to Chen (2002), coal classifications can be done based on either scientific or commercial/technical purposes. Peat is a precursor to coal being a soft, partly decayed organic plant and mineral matter (USGS, 2017). Botswana coal classification, gasification and thermal behavior requires further research. Ultimate analysis was performed under standard laboratory conditions with Bureau Veritas Testing Centre in South Africa. Average CHNSO was reported as 37.2%, 2.08%, 0.83%, 0.24%,59.65%; and 49.1%, 3.47%, 1.02%, 2.0%, 9.35% for Mabesekwa and Masama coals, respectively. Botswana coal classifies as sub – bituminous grade C according to the ASTM D388-19a standard. Botswana coal empirical formula is predicted as C84H49O28N2S.

Keywords: Classification, Coal rank, Botswana coal, Chemical formula

CMN: COAL MINING, PREPARATION, AND HANDLING

CMN-P1 Psychosocial Studies in the Workplaces of Turkish Coal Enterprises

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The aim of this study is to analyze the effect of psychosocial risk factors on the occurrence of occupational accidents in the mining industry. By using the results of the analysis, it is aimed to contribute to the protection of the psychosocial health of the employees and to the creation of a safe working environment. In line with these purposes, two separate projects were carried out in 2018 and 2023 in underground and surface mines belonging to Turkish Coal Enterprises (TKİ).
The project carried out in 2018 consists of a total of nine parts and focuses on determining the psychosocial levels of the employees. As a result of the study, the psychosocial risk management training method, material and calendar were determined by collaborating with the training experts of the Labor and Social Security Education and Research Center. It is aimed to increase psychosocial awareness by providing trainings to employees between 2019 and 2021.
In the project carried out within the scope of the "Improvement of Occupational Health and Safety Grant Program" with the financial support of the Republic of TÜRKİYE and the European Union in 2023, the "Psychosocial Security at Work" project was implemented. Applications made by Istanbul Bilgi University in TKİ workplaces were analyzed. With this project, it is aimed to plan the actions to reduce the sources of danger and risks after evaluating them in order to manage psychosocial risks.
In this study, in order to reveal the effects of psychosocial risk factors on employees at TKİ workplaces, the results of the implementation in 2023 and the results of the implementation in 2018 were compared. According to the results of both applications, similar elements measured. As a result of these changes, the effectiveness of the trainings after 2018 and the action plans planned after 2023 were discussed.

Keywords: Psychosocial risk, safety culture, work accident, mining workplace.

CMN-P2 Characterization Study of Overburden Materials in Coal Mining Activities

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In accordance with the current national environmental legislation, characterization studies of the overburden /waste soil in the mining areas where coal mining activities are carried out should be executed. In this direction, protocols have been signed between TKI and Dumlupınar University in various periods in order to carry out characterization

studies of the stripping/overburden soil formed in the mining sites of TKI and to demonstrate that this material is in the inert waste class. The purpose of these protocols is to carry out analysis and laboratory tests to determine the acid production potential of the overburden soil, which is formed as a result of underground and open pit activities carried out by the subsidiary directories directly or in the form of service procurement, and to evaluate the results obtained and finally to develop solution proposals and reporting. According to the current Mining Waste Regulation; in order for the mine waste to be defined as inert mine waste, the sulfur (S-2) amount of the mine waste should be at most 0.1%. If the sulfur (S-2) amount of the mine waste is between 0.1% and 1%, we look at the neutralization potential (NP) of the mine waste and in order for the mine waste to be inert this time, acidification potential (AP) must be determined by statical tests, and the NP/AP ratio should be greater than 3. If the S-2 is in any way more than 1 %, mine waste can not be determined as inert waste.
As a result of the studies carried out, it has been revealed that the overburden soil of Tuncbilek and Soma regions is classified as inert, that is, harmless mine waste, in other words, it has been determined that the risk of acid mine drainage from the waste samples taken from the GLI and ELI waste areas is below the limit values determined in the environmental regulations. In this study, the studies carried out to determine the potential of acid mine drainage in the stripping/overburden soil are included and the data obtained are shared.

CMN-P3 Main Albanian Coal Deposits

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Main Coal mines and deposits of Albania are described in the paper. It is shown location, actual reserves, quality, methods of mining, the enrichment schema and technological figures after washing of them. The coals can be washed after mining increasing their calorific value in concentrates.

CMN-P4 Investigating the Evolutionary Trajectory of Cognitive Workload in Hazardous Decision-Making Tasks among Coal Mine Operators Following the Deprivation of Artificial Intelligence Support

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Harnessing artificial intelligence (AI) applications to optimize mineral extraction, mitigate environmental and societal costs, and promote equitable development in the mining industry is vital. However, it is equally crucial to consider potential risks, especially in cases of AI technology failure within coal mine production systems, where ensuring a seamless and safe transition for staff to take over AI-supported tasks becomes imperative. To explore the evolution of cognitive workload among coal mine operators in hazardous decision-making tasks following the loss of AI assistance, this study engaged twelve participants in evaluating underground coal mine risk levels based on key environmental parameters. Two conditions were compared: AI-assisted, where abnormal data points were highlighted, and unaided, where only raw data were provided. Participants' mental workload was assessed through visual search behaviors (number of lookbacks, gaze time, and eye skips) and decision-making metrics (reaction time and correctness rate). The results reveal a significant surge in cognitive workload after the sudden loss of AI assistance, with a 52.53% increase in lookbacks, a 32.43% rise in gaze duration, and a 33.52% increase in eye skips. Decision-making efficiency decreased as the average decision time shortened by 11.38%, although no significant change in decision accuracy was noted. In conclusion, this study underscores that the abrupt AI assistance loss in coal mine safety decision-making temporarily elevates operator cognitive load, potentially affecting system efficiency and safety, while its broader implications warrant further investigation.

CMN-P5 Emergency Preparations in Mines, Activities of Turkish Coal Enterprise Within the Scope of Emergency Preparations and Examples of Exercises

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An emergency is an event that requires an emergency response, struggle, first aid or evacuation, such as fire, explosion, and spread of hazardous chemicals, natural disaster, which may occur in all or part of the workplace. Emergency preparedness refers to the execution of the plan including information and practical actions, including work and operations to be performed in case of an emergency in the workplace. The main objectives of this study are to provide preventive activities for the accidents that may occur in the mines operating in our country, to ensure the management with a healthy organization during an accident and to determine the improvement areas to be made after the accident. Emergency preparedness activities, which mainly consist of "preparation / planning" and "harm reduction" phases, provide both managers and practitioners with the support they need in reducing the risk of social vulnerability as well as increasing the effectiveness of the intervention in unexpected emergencies. and Energy Within the context of emergency preparedness activities Natural Resources Ministry Emergency and Crisis Management Center was established to TÜRKİYE Disaster Response sectoral meetings with the participation of relevant institutions and organizations with the mining sector in the Plan line was carried out. In this study, legal procedures related to emergency prevention and response in line with Emergency Preparations, main elements of emergency preparations, emergency preparations in world mining, examples from developed countries, emergency preparedness in our country and the studies of Turkish Coal Enterprises within the scope of emergency preparations and the effectiveness of these studies. The National Mining Exercises, which he planned and prepared in order to see.

CMN-P6 Inclusion of Slurry Coals into Fuel Category and the Standardization Process

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Considering the objectives of optimum use of resources, TKI carries out R&D projects in cooperation with various universities in order to recover fine-grained slurry coals formed in coal enrichment (washing) facilities and to minimize their environmental impacts. These projects include the characterization of slurry coals and their evaluation as thermal power plant fuel. As a result of the studies carried out to date, positive results have been obtained and it has been revealed that slurry coals can be added to thermal power plant feeds as a fuel type. Subsequently, in the light of the data obtained from these studies, an application was made to the Turkish Standards Institute (TSE), a national public authority that carries out standardization and conformity assessment in various fields, in order to register that slurry coals have fuel properties. TKI / Slurry Coal TSE-K 636 Certification Criteria was officially published by TSE on 31 Jan. 2022 as a result of experimental studies and theoretical evaluations carried out in cooperation with TSE and TKI. As a result, it was determined that the test results on TKI slurry coals complied with the criteria and TSE-K Certificates were obtained for the slurry coals in the same year. In this study; The TSE-K process is explained in detail and it is revealed that slurry coals, which have an economic value as well as an environmental problem, can be considered in the fuel category and this issue has also been documented by public authorities.

VA: VALUE-ADDED PRODUCTS FROM COAL

VA-P1 POZZOLANIC ACTIVITY OF FLY ASH AND BOTTOM ASH BY FRATTINI TEST AND ELECTRICAL CONDUCTIVITY TEST

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Pozzolanic activity is an important property of supplementary cementitious materials (SCMs), which plays a fundamental role in determining their suitability for the usage in cements and concretes. This activity is most often determined by reaction between the aluminosilicate component of pozzolan and Ca(OH)2 under normal conditions. In this work, the pozzolanic activity of fly ash (FA) and bottom ash (BA) from a lignite power plant in the Czech Republic was studied from the perspective of the Frattini test and the electrical conductivity test. At the same time, the effect of grinding on pozzolanic

activity was studied. It was found that all FA and BA samples showed pozzolanic activity by Frattini test. The least consumed Ca2+ ions, and therefore the lowest pozzolanic activity, were attested in unmodified FA and BA samples, which at the same time also had the smallest specific surface area value. A continuous electrical conductivity test for a period of 24 hours confirmed a similar course of the eclectic conductivity decline curves in the observed time for both types of SCMs.

This project was co-financed with the state support of the Technology Agency of the Czech Republic within the scope of TREND Program FW01010195.

VA-P2 Effect of CaO Content on the Elimination of Alkaline-Silica Reaction of Mortars with the Addition of FBC Ash

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The alkali-silica reaction (ASR), often called concrete cancer, is a chemical reaction occurring between the reactive siliceous aggregate particles and hydroxyl ions of the pore solution in hardened concrete. It has been proven that materials with pozzolanic properties such as fly ash, silica fume, metakaolin, slag, etc. have an effect on the elimination of ASR. The aim of this work was to observe the effect of CaO content present in FBC ash on the elimination of ASR. Five mortars with 30% replacement of FBC ash for cement were prepared and then tested by the expansion test according to ASTM 1260, ČSN 72 1179 and strength measurements. The FBC ash contained from 18 to 30 wt.% CaO. According to ASTM 1260, it was found that the ability to eliminate ASR decreases with increasing CaO content. Simultaneously it was found that all the mixtures containing FBC ash had an effect on ASR elimination according to ASTM 1260 compared to the reference sample without FBC ash. On the contrary according to ČSN 72 1179 and strength measurements the effect of CaO content on ASR elimination was not proven.

This work was co-financed with the state support of the Technology Agency of the Czech Republic within in the TREND Program: TAČR FW01010195 (Advanced and innovative processing technologies for strategic utilization and storing of coal combustion products (CCPs); 2020 – 2023)

Keywords: ASR, FBC ash, ASTM 1260, ČSN 72 1179, mechanical properties.

VA-P3 Concrete with a High Admixture Content of Modified Fly Ash

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The work deals with the treatment of low-calcium fly ash and bottom ash from a coal-fired power plant in the Czech Republic. These coal combustion products (CCPs) were modified by milling to meet the requirements of EN 450-1. At the same time, their physical and chemical properties were studied. The treated CCPs were used to prepare mortars and concretes according to the requirements of EN 206+ A2, with a fly ash to cement ratio of 0.33 and a water to binder ratio up to 0.45. The rheological behavior of the prepared mortars and concretes was also described. Subsequently, the mechanical properties of hardened bodies were studied depending on the CCPs treatment method after 2 and 28 days. It was found that after 2 days of hydration the compressive strengths of hardened bodies containing treated CCPs were lower compared to reference samples without CCPs (activity index 75-98%). On the contrary, after 28 days of hydration, it was found that the compressive strengths of the bodies with CCPs were higher compared to the reference samples and the activity index reaches values of 101-124%.

This work was co-financed with the state support of the Technology Agency of the Czech Republic within in the TREND Program: TAČR FW01010195 (Advanced and innovative processing technologies for strategic utilization and storing of coal combustion products (CCPs); 2020 – 2023) and the Grant Agency of the Czech Technical University in Prague (SGS22/136/OHK1/3T/11).

Keywords: Fly ash, bottom ash, milling, cement, mechanical properties.

VA-P4 Possibilities of Partial Replacement of Cement with Sulfocalcic Binder Based on FBC Ash

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The reduction of CO2 emissions brings new challenges to the construction industry, which are, among other things, related to the preparation of alternative hydraulic binders with a lower carbon footprint. The article deals with the use of a sulfocalcic binder (SFX binder) based on FBC ash as an admixture in concrete. A total of six mixtures containing from 10 to 100 wt.% of SFX binder were prepared. In addition, a reference mixture containing Portland cement was prepared. Selected properties on fresh slurries such as consistency and setting times were studied. The hardened mixtures were subjected to volume stability test and compressive and bending strength tests. Moreover, the phase composition of hardened samples was determined by XRD analysis. Very good properties of binders containing FBC ash compared to Portland cement were found. The initial setting time ranged from 93 to 250 minutes and the final setting time ranged from 168 to 336 minutes. The compressive strength of hardened slurries containing FBC ash ranged from 107 MPa to 127 MPa after 28 days. Although the phase analysis revealed that the main crystalline phase is ettringite, no volume changes were recorded in the hardened bodies.

This work was co-financed with the state support of the Technology Agency of the Czech Republic within in the TREND Program: TAČR FW01010195 (Advanced and innovative processing technologies for strategic utilization and storing of coal combustion products (CCPs); 2020 – 2023) and the Grant Agency of the Czech Technical University in Prague (SGS22/136/OHK1/3T/11).
Keywords: sustainability, cement, FBC ash, sulfocalcic binder, XRD, mechanical properties

VA-P5 Study of the Alkali-Silica Reaction of Mortars with the Addition of Modified FBC Ash

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Alkali-silica reaction (ASR) is a long-term chemical reaction occurring at the interface between aggregate grains and the binder phase, leading to structural failure and degradation of mortars and concretes. Fly ash is one of the pozzolanic active material and is able to eliminate ASR in concrete. The effect of FBC ash on ASR is not well documented in the literature. The aim of this work was to observe the effect of the addition of FBC fly ash and FBC bottom ash and simultaneously the effect of particle size of these FBC ashes on ASR development. The accelerated expansion test according to ASTM 1260 was used to study ASR, which was further supplemented by studying the mechanical properties after exposing the prisms to 1 M NaOH solution for 28 days. The experiments were carried out on test prisms containing 30 wt.% FBC ash in 3 different grinding fineness and with the addition of a 2-4 mm glass fraction. It was found that according to ASTM 1260, the CaO content of the FBC ash samples had a greater

effect on ASR elimination compared to its fineness. The addition of FBC bottom ash achieved comparable results to slag addition on ASR elimination, while the results on FBC fly ash were comparable to fly ash from conventional combustion.

This work was co-financed with the state support of the Technology Agency of the Czech Republic within the TREND Program: TAČR FW01010195 (Advanced and innovative processing technologies for strategic utilization and storing of coal combustion products (CCPs); 2020 – 2023)

Keywords: Alkali-silica reaction, FBC ash, ASTM 1260, concrete, mechanical properties

PP: POWER PLANTS

PP-P1 Effects of Water Content in Coal and Feed Gas on Self-Heating

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Increasing the utilization of low-rank coals, such as sub-bituminous coal, has become important in Japan to suppress fuel costs and ensure energy security. Sub-bituminous coal generally exhibits higher self-heating characteristics than bituminous coal, making spontaneous ignition in coal piles a serious problem. To prevent spontaneous ignition and effectively monitor the temperature in coal piles, it is necessary to evaluate the factors of coal self-heating. Previously, various internal factors (water content and volatile matter, etc.) and external factors (temperature and humidity, etc.) have been reported as factors associated with coal self-heating. Among them, the water content of coal and the water content of feed gas are considered to significantly affect the coal self-heating from room temperatures. Several methods have been proposed to evaluate the mechanisms of coal self-heating. The R70 test, one of the adiabatic methods, involves supplying oxygen to a sample placed in a vessel in chamber and accurately controlling the chamber temperature to reflect the sample temperature. This method is considered suitable for evaluating actual coal pile conditions from room temperature. In this study, this method was used to evaluate the effects of the water content of the sample and the water content of feed gas on the self-heating of three coal samples. In addition, the relationship between the rate of temperature increases in coal and the rate of generation of gas components (CO and CO2), which are commonly used as monitoring gas components in coal piles, was evaluated to further understand the influence of water on the gas generation.

GF: CLEAN COAL AND GAS TO FUEL

GF-P1 Batch Reactor Modeling and Simulation by MATLAB for Clean Coal Technologies: First and Second Order Kinetic Modelling Approaches

Mikail Olam, Figen Gündüz, Inonu University, TÜRKİYE; Cemil Koyunoğlu, Yalova University, TÜRKİYE; Hüseyin Karaca, Prof. Inonu University, TÜRKİYE

This study presents a comprehensive numerical calculation method for investigating the co-liquefaction of coal and biomass in a batch reactor. The primary objective is to determine the concentrations of different components under varying types of coal and biomass, facilitating the selection of optimal batching options based on reactor capacity. The kinetic model is developed by amalgamating literature data, preliminary experiments, and fundamental principles of both first-order and second-order reaction kinetics. The co-liquefaction process is represented as a series of coupled first-order and second-order reactions involving two reactants: coal and biomass. The core of the model consists of coupled differential equations that describe the rate of change of coal and biomass concentrations over time. The rate of change is directly proportional to the product of their concentrations, scaled by reaction rate constants `k1`, `k2`, `k3`, `k4`, `k5`, and `k6`, representing different reaction steps. To address these non-linear differential equations, the MATLAB `ode45` function, employing the Runge-Kutta method suitable for non-linear systems, is utilized. The reaction rate constants `k` are estimated through experimental data, where the experimental concentration-time profiles are fitted to the model's predictions. Model validation is accomplished by comparing its predictions against experimental conditions not used in parameter estimation. Statistical metrics such as the correlation coefficient and root mean square error (RMSE) are used to assess the goodness of fit. Additionally, a sensitivity analysis is conducted to examine the impact of various parameters including the reaction rate constants `k` on the model's predictions. This involves varying the initial concentrations of coal and biomass as well as other pertinent parameters relevant to the co-liquefaction process. To enhance accessibility, a MATLAB-based Graphical User Interface (GUI) is developed, enabling researchers and industry professionals to input experimental conditions, conduct simulations, and visualize real-time results. It should be noted that the values of reaction rate constants `k1`, `k2`, `k3`, `k4`, `k5`, and `k6` are assumed for illustrative purposes and should be adjusted based on experimental data for specific reactions. The simulations offer insights into the concentration profiles of the reactants and products over time. Overall, this study significantly contributes to the understanding of the co-liquefaction process of coal and biomass, paving the way for the design of an efficient plant infrastructure based on the components that yield the highest total conversion due to first-order and second-order reaction kinetics.

GF-P2 Coal-Algae Liquefaction: a Sustainable Pathway to Renewable Biofuels

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Liquefaction of coal and algae together has emerged as a groundbreaking technology for converting combined biomass into liquid biofuels, presenting a sustainable alternative to conventional petroleum-based fuels. Both coal and algae offer unique advantages. While coal is a rich source of carbon and energy, algae have rapid growth rates, the ability to be cultivated in diverse environments such as wastewater and seawater, and a high lipid content suitable for biofuel production. The combined liquefaction process involves hydrothermal treatment, where the mixed biomass of coal and algae is broken down into a range of liquid products like bio-oil, biocrude, or biodiesel through various conversion technologies like hydrothermal liquefaction, pyrolysis, or solvent extraction. Our study delves into the potential of combined coal and algae liquefaction as an environmentally friendly and economically viable solution for producing renewable fuels and chemicals. By harnessing algae's capacity to grow on non-arable land and its efficient utilization of carbon dioxide through photosynthesis, combined with the energy density of coal, the resulting biofuels offer low land use and contribute to carbon dioxide sequestration. Additionally, the process does not compete with food production, thus mitigating food security concerns. We conducted experiments comparing the liquefaction efficiency of various coal and algae mixtures, introducing novel catalysts such as boron and its derivatives, previously untested in this context. The hydrothermal method led to promising results, with Colemanite and Tincal demonstrating total conversion rates above 75%. Furthermore, the presence of pentane in the gas product confirmed the occurrence of hydrogenation reactions, indicating an optimized liquefaction approach based on hydrogen content. This paper reviews the current state of combined coal and algae liquefaction technology, emphasizing its benefits in terms of energy output, environmental sustainability, and potential applications in diverse industries, including combustion engines and boilers. We also address the challenges that must be addressed to facilitate the commercial viability and large-scale implementation of this combined liquefaction technology. The emergence of coal and algae co-liquefaction as a novel pathway to renewable biofuels holds significant promise in the transition towards a more sustainable and greener energy future. This technology has the potential to revolutionize the biofuel industry by providing an abundant, eco-friendly, and economically viable alternative to fossil fuels, contributing to a cleaner and more sustainable global energy landscape.

SE: SUSTAINABILITY & ENVIRONMENT

SE-P1 At the Business Directorates Affiliate of TKI Socio-Economic Impact Analysis of Coal Mining Activities

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The energy policy of our country in general term; It has been determined as the provision of the country's energy need in a timely, sufficient, reliable, economic conditions and taking into account the environmental effects, in a way to support and direct social development moves in order to realize economic growth. In this context, carrying out coal production activities in an efficient, effective, environmentally, friendly manner and meeting the needs of the society is among the main priorities of TKI. In line with this understanding, social impact analysis studies were carried out within the subsidiary directorates of TKİ in order to reveal a social benefit-oriented corporate culture, to fulfill the mission of creating social benefit more effectively, and to present convincing evidence of the benefits provided to society and the environment. With these studies, it is aimed to evaluate the direct or indirect impact of the mining activities carried out on the stakeholders and to present this impact in a transparent manner based on valid indicators and data. Focus group meetings and survey studies were carried out with expert psychologists and sociologists on the stakeholders (workers, worker families, local people, tradesmen) determined within the scope of the study, and reporting studies were completed. In this study; By revealing the results of the socio- economic impact analysis, important clues to improve the work and life quality of the miners working in the mine sites, their families and all people affected by this process and also meaningful points that will form the basis of strategies and policies to increase productivity and quality in enterprises are touched on.

SE-P2 Within the Scope of TKI/GLI Coal Mining Activities Underground and Well Water Wastewater Treatment Plant

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In mining activities, wastewater is generated in ore preparation/enrichment facilities and during underground activities. It is forbidden to discharge wastewater into the receiving environment without meeting the discharge standards determined within the framework of the Regulation on Control of Water Pollution. In this context, wastewater should be purified and discharged. A wastewater treatment plant was built in cooperation with TÜBİTAK-MAM, a public authority in charge of scientific research within the mine site of TKİ, located in Tunçbilek region, in order to treat underground and well waters. It is planned to discharge the treated water formed in the pre-treatment system of the treatment plant to the nearest stream in a way that will meet the discharge standards allowed in the current environmental regulations, and the treated water from the recycling units will be used as domestic water and process water of the LAVVAR plant. The treatment plant with a capacity of 6,500 m³/day and physical and advanced treatment, namely reverse osmosis units, was commissioned in 2019. With the commissioning of a wastewater treatment plant, an example of which is rarely seen in a mining establishment in our country, both the process water of the coal washing plant and the utility water needs of the mine workers are met, and the potential of the wastewater generated as a result of underground activities to harm the ecosystem is reduced.

SE-P3 TKİ Çanakkale/ÇAN Regional Villages Beekeeping Activities and the Social Responsibility Project of Supporting Organic Lavender Honey Production

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With the aim of demonstrating our social benefit-oriented corporate culture, a social project was planned to be realized together with the local people in TKİ Çan region, and with the aforementioned project, it was planned to increase the awareness of the local people and to improve the public perception of mining activities in a positive way. Within the scope of the said project; in the first step, the local villages of Çan district were visited and the social responsibility project surveys were prepared to measure the perspective of the local people on social responsibility projects and to clarify what kind of projects should be supported in order to increase the welfare level were applied to the residents of the villages around the ÇLİ lavender garden affected by the mining activities and the expectations of the society were revealed. Within the framework of the "Due Diligence, Preliminary Research and Roadmap Report" prepared on the subject; it was decided to implement the project in a way to include 5 villages, and it was planned to distribute a total of 288 honey bee hives and beekeeping equipment sets (masked beekeeping clothing, gloves, bellows, etc.) to 36 village residents (8 hives per person). In this study, The stages of the aforementioned social responsibility project are given in detail.

SESSION 5 (11:00 – 12:20)
GASIFICATION TECHNOLOGIES – 2
Prof. Johan Van Dyk, Prof. Dr. Hasan Can Okutan

5.1 (11:00-11:20) Thermodynamic Modelling of Inorganic Components in Coal, Municipal Solid Waste and Biomass for Clean Energy Production in Gasification

JC van Dyk (presenter)[1], T Eastland[2], S Petersen[3]

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[3] GTT-Technologies, Aachen, Germany

The inorganic behaviour of carbon sources (coal, biomass, waste, etc.) and specifically ash flow temperatures, slag formation and viscosity, are some of the parameters currently widely used controlling gasifier stability, as well as to predict the melting behaviour of the ash in conversion processes. In-depth knowledge of viscosity, density and surface tension in multicomponent oxide melts is of fundamental importance to understand the physical and thermochemical processes in many industrial applications. The AFT of a coal source gives an indication of the extent to which ash agglomeration and ash clinkering are likely to occur within the gasifier. It has been demonstrated that ash flow temperature can be correlated with FactSage™ calculations, which will give a faster, more accurate and real-time control mechanism for operating control.
FactSage™ is currently being applied as a unique inorganic simulation tool in predicting and optimization of gasification processes, and specifically U-Gas™ and R-Gas® technologies of GTI Energy, but also other gasification technologies, for slag viscosity predictions and slag profile quantification.
The purpose of this paper is to illustrate the importance of inorganic chemistry, understanding and control for gasification by means of applying high-quality thermochemical data and state of the art inorganic databases, i.e., the FactSage™ tool. This is a very important and current topic in a drive towards gasification optimization towards a green and waste feedstock approach in clean energy production.

5.2 (11:20-11:40) Real-Time Feedstock Analysis for Gasification Control

JC van Dyk (presenter)[1], T Eastland[2], Zach El Zahab[3], C Romero[4] and R de Saro[5]

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The use of biofuels and waste coal has significant environmental benefits, and it can contribute to promoting a low-carbon economy via hydrogen production. However, there are issues with gasifying biofuels and waste coal. The first one is the widely varying organic makeup and moisture content of the feedstock which makes optimization and proper control of the gasifier very challenging. The second is the impact on the slag properties of the inert part of the fuel, affecting reactor operation, stability and reliability.

To solve these issues and therefore take full advantage of these feedstocks, the project team is developing machine learning (ML) enhanced diagnostics to enable gasifiers to process waste coal and biofuels optimally and economically; thus, avoiding them from being landfilled and taking advantage of their value and favorable environmental properties. Laser induced breakdown spectroscopy (LIBS) along with the use of advanced ML signal processing, can accurately measure important properties of the feedstock such as proximate and ultimate analyses, including moisture and ash content, elemental concentrations, heating value, and ash slagging temperatures.

It is standard LIBS practice to use calibration curves to relate the measured spectral emissions to target element's concentration. However, linear calibration curves have drawbacks. For example, spectral overlap, in which the target element's emission is obscured by an adjacent emission; and self-absorption or signal saturation, which leads to non-linear calibration curves that diminish their usefulness.

Solid fuel elemental analysis with LIBS is complex due to the variability in feedstock quality and inhomogeneity in its composition. A degree of improvement has been achieved in LIBS spectral analysis by the use of multivariate methods and non-linear algorithms. An extension to multivariate analysis is provided by machine learning and

artificial intelligence (AI). This technique has been reported in a broad range of applications with particular traits that include feature engineering, pattern recognition, deep learning, classification, and correlation of multivariate problems. These AI methods provide features that are adequate to provide a robust correlation method to connect LIBS spectral intensity inputs, and analyte elemental concentration and higher order parameters in a large training database, and subsequent predicting capabilities.

FactSage™ will then be applied coupling the ML output in a real-time gasifier control EQUILIB for faster and effective adjustment of the gasifier operation. This is a unique inorganic simulation tool in predicting and optimization of gasification processes, and specifically U-Gas™ and R-Gas® technologies of GTI Energy, but also other gasification technologies, for slag viscosity predictions and slag profile quantification.

5.3 (11:40-12:00) Geochemical Assessment of Coal Relics from Underground Coal Gasification

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Underground coal gasification results in a cavity which can cause the overburden to collapse due to lack of support. The growth of the cavity can be a complex process but invariably involves spalling and intermediate-scale fracturing coupled with collapse activities. All of these actions results in a chaotic rubble-filled cavity characterized by pyrometamorphosed mineral assemblages. This study assesses the coal relics and high temperature mineralogical changes from an underground coal gasification plant(UCG) in South Africa. The samples were obtained through core drills intercepting the gasifier. Assessment of the char and surrounding rocks detected high temperature silica polymorphs of tridymite and cristobalite. Amorphous material (glass) was also detected in the overburden which indicates fast cooling in the gasification chamber. The results of this study shows the heterogeneous nature of gasification in a UCG chamber where different sections experience changing temperatures resulting in a varied temperature profile across the geo-reactor.

5.4 (12:00-12:20) Effect of Microwave Irradiation on the Gas Production Performance of Underground Coal Gasification

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The gas product quality in underground coal gasification (UCG) is not satisfying due to the low reactivity of coal seam caused by poor heat and mass transfer. Microwave heating has the advantages of low energy consumption, selective heating, and high feasibility for underground coal seam, which is a possible way to improve the UCG performance. In this work, UCG experiments were performed in an ex-situ experimental system with moving injection, which includes a gas supply unit, a moving device, a tube reactor, a thermal imaging unit, and a gas analyzer. The coal block is subjected to microwave irradiation for a certain time before being put into the UCG furnace. The thermal imaging unit is mainly composed of a thermal imager, which takes pictures of the coal block in the reactor every 15 min and converts the radiation signal into temperature. The gas analyzer can realize online monitoring of O_2, H_2, CO, CO_2, CH_4, and C_nH_m, and display the curve change of each gas with time on the computer through the data acquisition software. According to the calorific value of gas products at different microwave pretreatment time (t_m), when t_m =1 min the performance is the best. For all cases, the calorific value increases dramatically to the maximum value and then decreases with time. The maximum calorific value decreases when the microwave time increases. It is difficult to get stable gas production in UCG, while a proper choice of microwave time is able to improve the performance. According to the results of different gas species, CO and H_2 are the main combustible gas products, especially showing a large proportion before 0.5 h. At the late stage of the reaction, CO_2 is the most species since unburnt coal is not enough and oxygen is in excess. During microwave irradiation, the mass of the coal block is recorded. The mass loss increases from 0 to 5.9% when the microwave time increases from 0 to 4.5 min. The mechanism of microwave effect on UCG performance is discussed in detail. When the microwave time is short, the moisture in coal is decreased and the pore structure is more developed, leading to more combustible gas yield in UCG. When the microwave time is long, the coal starts to lose volatile and other combustible content, thus the performance of UCG gets worse. This work proves that microwave modification of coal is able to improve the gas product quality in UCG, while the choice of microwave time is important.

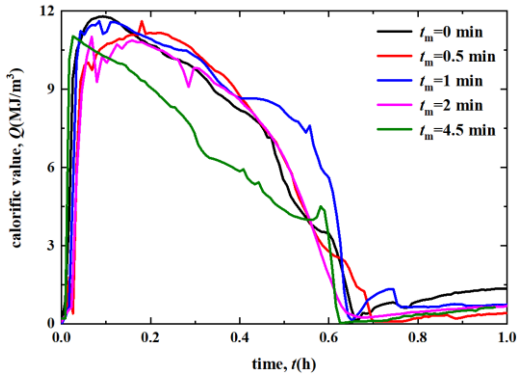

Fig. 1 effect of microwave time on gas calorific value

SESSION 6 (11:00 – 12:20)
VALUE-ADDED PRODUCTS FROM COAL - 2
Dr. Ahmed Aboudheir, Prof. Dr. Gülay Bulut

6.1 (11:00-11:20) Valorization of Ttk Armutçuk Region Coal by Transforming It into High Value-Added Products

Faik ALP, TTK Armutçuk Müessesesi Müdürü, TURKIYE

Zonguldak Coal Basin is located in the North West region of TÜRKİYE. Although most of the coals in the Basin are high volatile bituminous coal with good coking properties (FSI value 7-9), there are coals with no coking properties (FSI value 0-1) in the Amasra Region in the eastern part of the Basin and bituminous coals with poor coking properties (FSI value 2-4 and Lustrous Carbon value 8-12) in the Armutçuk Region in the north-western part of the Basin.

Today, TTK Armutçuk TIM's coal is washed with Baum Jet at the 210 ton/hour capacity Armutçuk Lavuar facility established by McNally Company in 1960, and 100-18 mm size range lump coal is marketed as domestic fuel, 18-10 mm and 10-0.5 mm size range clean coal is marketed as industrial coal and 0.5 mm size is marketed as power plant coal. Ash values above the project value and decreases in plant performance are observed from time to time in the ash of 18-0.5 mm clean coal, which is obtained as a result of washing in Armutçuk Laver, which has completed its operational life, and marketed as industrial coal.

In this study, information is given about the washing of the raw coals produced in TTK Armutçuk TIM in a new lavvuar to be built in order to obtain high value-added products and the physical, chemical and technological properties of the clean coals obtained. In addition, technical information is given on the grinding of these products and their use as raw materials in the production of injection coal to be used as a substitute for metallurgical coal in blast furnaces, additive to casting mold sand for precision castings and activated carbon. On the other hand, a technical analysis of the current situation in the world and in TÜRKİYE is also made.

6.2 (11:20-11:40) Influence of Platinum Nanoparticle Size on Hydrogenation and C-N Bond Cleavage Performance in Hydro-Denitrogenation

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The presence of nitrogen-containing compounds in coal-based liquids can have a negative impact on the environment and subsequent process catalysts. Their removal is usually by hydro-denitrogenation. The hydro-denitrogenation reaction requires two primitive steps, hydrogenation and C-N bond cleavage, while catalyst size has different effects on both. The role of catalyst size in hydrogenation and bond cleavage has not been elucidated. For this purpose, the hydrogenation and C-N bond cleavage of 1,2,3,4-tetrahydroquinoline, 5,6,7,8-tetrahydroquinoline and decahydroquinoline over Pt catalysts of different particle sizes were investigated to clarify the size dependence of the hydrogenation of benzene rings and nitrogen heterocycles and C-N bond cleavage. For the reactivity study, it was found that the hydrogenation rate of the benzene ring of 1,2,3,4-tetrahydroquinoline was much higher than the hydrogenation rate of the nitrogen heterocycle of 5,6,7,8-tetrahydroquinoline. DFT theory showed that the adsorption

energy of 5,6,7,8-tetrahydroquinoline was lower than that of 1,2,3,4-tetrahydroquinoline, and the interaction with the catalyst surface was weaker and reactivity lower. The radical steps of the hydrogenation of both were studied and it was found that the hydrogenation of octahydroquinoline to decahydroquinoline was a fast control step in the hydrogenation. The hydrogenation reactions on catalysts of different sizes were studied and it was found that the hydrogenation of the benzene ring and nitrogen heterocycle in this system is not a structure sensitive reaction. In contrast, the C-N bond cleavage of decahydroquinoline is a structure sensitive reaction. The surface atomic TOF values were calculated by polynomial relationships between the particle size and the number of atoms in the corner, step and terrace sites on the surface, and the results showed that the TOF at the step site did not vary with the number of step sites at particle sizes larger than 1.7 nm, so the active site for C-N bond cleavage was the step site. At small particle size, excessive adsorption is the main factor inhibiting bond cleavage activity. In summary, in the hydro-denitrogenation process, the hydrogenation reaction is structure insensitive and its reaction is related to the dispersion of the catalyst, i.e. the number of Pt atoms on the surface, while the C-N bond cleavage is structure sensitive and the active site is the surface step atom.

6.3 (11:40-12:00) High-Selective Separation of Polycyclic Aromatic Hydrocarbons from Coal Tar

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Polycyclic aromatic hydrocarbons are representative products in coal tar, which are usually difficult to derive from the petrochemical industry. Therefore, the primary structure of coal tar has a great application value. Anthracene, account for more than 1 wt% of coal tar, is an important compound due to its fluorescence and high luminous efficiencies, the critical parameters in making luminous materials. Anthraquinone, the oxidized product of anthracene, is utilized in dyes, papermaking, and medicine. Thus, anthracene and its downstream products have many applications. Efficient enhancement of intermolecular interactions between solvents and target compounds during the separation process is the key to anthracene separation, which could effectively improve the utilization value and the production efficiency of industries. As pointed out in "Designing for a green chemistry future" by Zimmerman et al., a significant focus should be given to applying intermolecular interaction in future research, highlighting a greater significance of intermolecular interaction. Therefore, our work summarized the influencing factors of different types of intermolecular interactions, and then obtained the types and ranges of dominant interaction energies under different separation systems using energy as the entry point. Comparative analysis of the current reported developments of various solvents and different approaches to enhance intermolecular interactions during the separation process has been classified. This energy-based analysis would provide a new strategy to design the suitable and efficient solvents for separating anthracene products from coal tar, which is as follows: Guided by the structural differences of the substances to be separated; identified by the type of intermolecular interaction energy; then designed and selected the suitable solvents; finally completed the process of separation and purification. The separation of anthracene products has been investigated by us based on the proposed strategy. The electrostatic interactions were used as incubation points to guide the selection of naphthalene-based solvents to ultimately achieve the goal of separating and purifying anthracene. According to our proposed separation process, the separation process is effective with higher purity at lower temperature viscosity and economic cost. This work not only provides a new perspective on the selection of solvents but also promotes the application of intermolecular interaction in the separation and purification technology of analogous polycyclic aromatic hydrocarbons.

Keywords: coal tar; solvents selection; polycyclic aromatic hydrocarbons; anthracene products

6.4 (12:00-12:20) Molecular Design and Application Investigation for the Preparation of Solar Thermal Fuels from Coal Tar

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Coal tar is an essential product of the coking industry and contains a large amount of valuable basic chemical materials. The current utilization of coal tar is mainly through hydrogenation to fuel oil, asphalt deep processing and chemical preparation. Although certain research advances have been achieved, there are still problems such as low utilization rate of components and few high-value products. It is therefore imperative to promote the coupling of coal tar with sustainable energy and to explore new avenues for the clean and efficient utilization of coal tar. Solar thermal fuels are a class of molecules with photo-controlled reversible switching characteristics, which can harvest and store photon energy as chemical energy within the conformations and release the stored energy controllably in the form of heat upon external triggering. The utilization process of solar thermal fuels is free of greenhouse gas and pollutant emissions. Therefore, the coupling of coal tar with sustainable solar energy to prepare coal-based solar thermal fuels offers new avenues for clean, high-value and diversified utilization of coal tar. Aiming to fully utilize the structural advantages of coal tar, a series of coal-based solar thermal fuels (anthracene derivative, azobenzene, azo-indole and azo-carbazole) with light-chemical-thermal energy cycle conversion characteristics were fabricated using anthracene, phenol, indole and carbazole contained in the coal tar. The storage energy densities of anthracene derivatives, azobenzene, azo-indole and azo-carbazole after ultraviolet light irradiation can reach up to 84.2 kJ mol^{-1}, 56.7 kJ mol^{-1}, 75.5 kJ mol^{-1} and 137.8 kJ mol^{-1}, respectively. The stored energy can be maintained for days to months in room temperature environment. Blue light-triggered heat release from coal-based solar thermal fuels can increase the temperature by 5.2-12.1 ℃, showing tremendous insulation and heating application potential. These key parameters of coal-based solar thermal fuels are able to be further enhanced by imparting photo-controlled reversible solid-to-liquid phase change properties. This molecular design strategy not only provides a unique approach to the frontier scientific problem of clean and efficient utilization of coal tar, but also enriches the existing the utilization manners of solar energy.

Keywords: coal tar; coal-based chemicals; solar thermal fuels; molecular energy storage; solar thermal conversion

SESSION 7 (11:00 – 12:20)
CLEAN COAL DEMONSTRATION AND COMMERCIAL PROJECTS

Mr. Don Stevenson, Prof. Dr. Murat Olgaç Kangal

7.1 (11:00-11:20) Clean Coal Gasification and Hydrogen Production: Sustainable Energy Solutions

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This study presents a comprehensive study on the potential of clean coal gasification and hydrogen production as sustainable energy solutions. The paper investigates the environmental impact and efficiency of these processes through parametric case studies. Clean coal gasification, a technology aimed at converting coal into syngas with reduced emissions, is analyzed for its applicability in power generation and fuel synthesis. The process involves the conversion of coal into a gas mixture rich in hydrogen and carbon monoxide, reducing greenhouse gas emissions and minimizing the environmental footprint of coal utilization. The paper delves into the feasibility of deploying clean coal gasification technology to address energy demands while mitigating environmental concerns. Additionally, the paper explores hydrogen production from coal using various methods such as coal gasification, pyrolysis, and liquefaction. These processes enable the generation of hydrogen, a versatile and clean energy carrier, from coal feedstock. The environmental implications of hydrogen production from coal are assessed, taking into account carbon capture potential and utilization of hydrogen as a sustainable fuel source. Parametric case studies are employed to evaluate the environmental impacts and efficiencies of both clean coal gasification and hydrogen production from coal. The findings shed light on the potential benefits of adopting clean coal technologies for power generation and fuel synthesis, as well as the promising role of coal in hydrogen production as part of the sustainable energy transition. Overall, this paper contributes to the growing body of knowledge on sustainable energy solutions, highlighting the importance of clean coal gasification and hydrogen production from coal as viable pathways towards a greener and more sustainable future.

7.2 (11:20-11:40) A Sample Feasibility Calculation for a Coal Liquefaction Plant

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This paper provides comprehensive information on coal liquefaction plants, enabling the conversion of coal into liquid fuel for efficient use, but it raises environmental concerns due to harmful gas emissions. It explores various technologies and measures to mitigate environmental impacts, along with an overview of global projects and ongoing research. The feasibility study for a co-liquefaction plant is presented, analyzing technical, economic, and environmental aspects, including the use of biomass and fossil fuels as feedstocks. Lignite liquefaction to produce 4 million tons of synthetic fuel annually is outlined, emphasizing the need for continued research and cost optimization to enhance economic and environmental benefits. Furthermore, the paper highlights the importance of incorporating innovative approaches to improve the efficiency of the coal liquefaction process. Advanced maintenance technologies and exploring alternative feedstock sources could contribute to reducing operating costs and minimizing environmental impacts. While both coal and lignite technologies offer potential for sustainable energy production, careful consideration of impacts, costs, and ongoing research is crucial for realizing their full benefits and contributing to a greener energy landscape. Supportive policies and subsidies for renewable energy projects can further advance the adoption of these innovative co-liquefaction technologies. Ultimately, collaborative efforts from academia, industry, and policymakers are essential to ensure a successful transition towards cleaner and more sustainable energy solutions.

7.3 (11:40-12:00) Integrating Bentonite-Enhanced Algae Cultivation for Biobased Fuel Production from High Furnace Flue Gas: a Numerical Case Analysis

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This paper presents a numerical case analysis that investigates the potential implications of using bentonite in algae cultivation for the production of biobased fuel from high furnace flue gas. The study aims to showcase the successful implementation of the project with the integration of bentonite during the algae cultivation process. The data used for the analysis includes the CO2 emissions from high furnace flue gas, which amount to 50,000 tons per year, and NOx emissions, which total 20,000 kg per year. The algae cultivation area is considered to be 5,000 m², with an algae growth rate of 0.1 kg/m²/day. The algae oil yield is estimated to be 30%, while the biobased fuel yield from algae oil is projected to reach 90%. Additionally, the biobased fuel price is set at 1,500 USD per ton. The duration of the project is assumed to be one year, with a bentonite usage of 2 kg/m². The numerical calculations are conducted in three steps. Step 1 involves algae cultivation and CO2 absorption, where it is found that approximately 49 kg of CO2 can be absorbed daily through the utilization of 1,000 kg of bentonite in the algae cultivation area. Step 2 focuses on the harvesting of algae, resulting in a daily production of 500 kg of algae biomass from the 5,000 m² area. Step 3 addresses biobased fuel production, yielding 150 kg of algae oil daily, which will be used for the biobased fuel production process. Based on the calculations, the overall biobased fuel production is projected to reach 54,750 kg (54.75 tons) during the one-year project duration. This production would generate a total revenue of 82,125 USD (54.75 tons x 1,500 USD/ton). To determine profitability, various costs, including human resources, materials, equipment, technology, and infrastructure, need to be considered. The analysis reveals positive environmental and social impacts of the project. The use of bentonite enhances CO2 absorption, leading to more effective recycling of high furnace flue gas. This contributes to environmental protection by reducing pollution and promoting sustainable energy production, thus enhancing energy security. Additionally, algae cultivation areas support aquatic ecosystems, fostering biodiversity and providing potential for wastewater treatment. In conclusion, the numerical case analysis demonstrates the technical and economic viability of biobased fuel production from high furnace flue gas using algae, while the incorporation of bentonite enhances CO2 absorption. However, the success of the project requires further research and development, along with supportive policies. Emphasizing the project's substantial contribution to sustainable energy goals and environmental preservation is essential.

7.4 (12:00-12:20) Deep Coupling Technology of Coal Chemical Production with Renewable Energy

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The CO2 emission of coal chemical production is facing more and more stringent restrictions due to China's promise to reach carbon neutral in 2060, the introduction of green hydrogen into the chemical production process is one of the ways to reduce CO2 emission. The challenge is large fluctuation of renewable power supply and high cost of the green hydrogen. To solve this problem, we introduce the new way of deep coupling the coal chemical production and renewable energy supply, make a integrated green H2 production, flow battery power storage, heat storage/release, and coal chemical production system. The 10MW demonstration project is under development and design and will be built by China Energy Group in ShaanXi Yulin of China. Furthermore, the integration of air separation unit with renewable power supply is proposed to further improve the overall energy efficiency and make the chemical plant function as the energy buffer and storage for renewable power system. This will take advantages of both system and will be the direction of technology development for new coal chemical production.

SESSION 8 (11:00 - 12:20)
COAL MINING, PREPARATION, AND HANDLING - 2

Mr. Francis Lau, Asso. Prof. Dr. Abdullah Fişne

8.1 (11:00-11:20) Hazard Map Application by Using GSI in Polyak Eynez Underground Lignite Mine

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Safe ambient conditions are very important for safe and sustainable work environment in underground coal mines. Stable roadways provide efficient use of manpower and safe ambient conditions from the start of the first operations to the end of production on the galleries. For stable underground openings, rock formations are analyzed carefully and according to these analysis, proper support systems are formed. Rock formation examinations should be carried out throughout the mine life and these results must be recorded regularly. In this way, along the gallery advance, it is observed that which rock formation is passed, which support system is used and whether correct support system is used according to rock formation or not. Considering the results of these observations, there may be an understanding about which/where dangerous situations will occur and with this, necessary precautions are taken on time. In this study, preparation and evaluation of hazard map by using geological strength index are examined in Polyak Eynez Underground Lignite Mine.

8.2 (11:20-11:40) Implementing Three-Product Heavy Medium Cyclones in Turkish Lignite Processing: Operational Insights and Outcomes

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DEFAS has obtained the Eynez II Coal Project license and planned produce 70.000.000 tons of coal over a mine life of 18 years using fully mechanized longwall mining with caving method (LTCC). As a part of the whole project, 700 tph capacity Coal Washing Plant (the "CWP") was established to wash Run of Mine (ROM) coal to obtain desired coal products. Coal washing technology has remained almost the same over the years including desliming, heavy medium separation with drum separators and dense medium cyclones, screening, spiral concentrators for fine coal and dewatering. On the other hand, the progression of coal washing technology has led to the emergence of three-product heavy medium cyclones, representing a significant leap in coal beneficiation. Originating from the need for more precise separation methods, these cyclones offer distinct advantages. Historically, traditional coal washing methods faced limitations in achieving efficient separation and consistent product quality and also operational issues related to the number of equipment employed. The development of three-product cyclones addressed these challenges by introducing higher separation efficiencies and simple flowsheet with less equipment. These cyclones excel in classifying coal particles into distinct density fractions, enhancing the quality of the end products. One of the standout advantages is their adaptability to automation, streamlining operations and minimizing human intervention. Additionally, three-product cyclones excel in handling fine coal particles, contributing to higher yields and reduced waste generation. Recognizing the inherent advantages of three-product heavy medium cyclones and their alignment with the specific needs of the Soma region's coal, DEFAŞ made a strategic decision to embrace this innovative technology.
This paper offers a detailed look into an innovative coal washing project in Soma, TÜRKİYE. It covers the entire process, from making the decision to use advanced three-product heavy medium cyclones to installing them and evaluating their impact.

8.3 (11:40-12:00) A New Approach in Staffing Norm Practices in Mining – TKI Case Study

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One of the most basic working areas of human resources units of organizations should be norm staff studies. Human resources are not only an important cost factor for organizations, but also have a separate efficiency-based cost factor because they use or operate other resources such as machinery, materials and capital during production. For this reason, it is only possible to carry out physical or mental activities related to tasks/works in a unit in accordance with the principles of productivity, only by employing a sufficient number of people (norm staff) with the qualifications, abilities and skills appropriate to their requirements. Job analysis studies, including norm staff studies shed light on the questions of where we were, where we came from, where we are going.
In this paper, the method rather than the outputs of the project, which was carried out for a period of approximately two years at one of the most important state-owned enterprises of TÜRKİYE operating in the mining sector, is discussed. Because, with the "Job Analysis and Process Improvement Project" studies carried out in Turkish Coal Enterprises (TKI), a methodical approach different from the known practices has been brought to the norm staff work. This method, of course, can be used in all businesses that produce goods and services. However, workflows in the mining industry are often both irregular or non-repetitive, and their durations are quite long. Therefore, the method applied in the Job Analysis and Process Improvement Project is of particular importance for the mining industry.
As it is known, cadres in an organization are basically divided into two, depending on the workload and the task. The cadres attached to the task are mostly the cadres of the owners of the place of duty in the structural organization, that is, the administrative cadres. Therefore, if there is a place of duty in the organizational chart, there must be a managerial staff who undertakes the responsibility of fulfilling the duties in this place of duty. The temporal workloads of employees, whether officers or workers, are determined by time measurement techniques. Actual times of activities carried out by workers with more physical effort are measured with a chronometer and standardized as predicted times after evaluation. The times and frequencies of the activities, which are mostly non-repetitive or irregularly repeated and carried out by the officers, are determined by asking questions and recorded in the work/time schedules.
In the project carried out by the TKİ Institution, the work/time schedules were sent to the employees as empty and they were not asked to be filled, as in the current practices. The methodological difference of this project from similar studies is that, first, task analysis studies were carried out with the project groups formed in all units from the smallest unit such as chief engineering and chief officer to the heads of departments, and each main task was divided into its smallest part, which is considered indivisible, and tasks with a clear content were revealed. Then, after the net tasks of the units, from the smallest to the largest, were recorded on the work/time sheets, only the units were asked to estimate the frequency and duration of these net tasks. Then, by evaluating the filled-in data, the norm positions were calculated.
On the other hand, within the scope of this project, job analysis studies were carried out to reconsider and review the job descriptions which cover all task/work definitions related to the titles of officers and workers, and then job descriptions were updated using the job analyzes.
Additionally, work sampling studies were carried out in order to determine the workloads related to daily wage and service recruitment workers.

In summary, the following can be said about all these studies:
A total of 1,347 job analyzes were made at the Headquarters and three other enterprises and the forms were filled. Based on these job analyzes and making use of other sources, a total of 490 job descriptions, which of 421 task and 69 work definitions, and approximately 1,500 pages of task/work definitions of three pages each, were written for the Head Office and three other enterprises.
During the work sampling studies carried out to determine the workloads for the workers working in the field, a total of 1,388 people were observed in the three enterprises, and the number of observations was reached to 100,339. The average number of observations per person is 72.
As a result of the task analysis studies, 6,753 net tasks, including the Head Office and the enterprises, were determined. Task trees related to each functional unit were created by using a certain systematic approach.
Work/Time chart forms were prepared based on task trees. By evaluating the completed and incoming forms, the temporal workloads of the relevant departments or branches were calculated. Based on the temporal workloads, the norm staff numbers of all units, from the smallest to the largest, were determined and compared with the current staff numbers, plus or minus differences were revealed.
In the light of the information that emerged as a result of the interviews with many people in the Head Office and all units of the Enterprises, organizational chart drafts were created as a suggestion regarding the structural organization of the Institution and presented to the management together with all other findings, including areas for improvement.

8.4 (12:00-12:20) Assessment of Kosovo Coal in the Context of the Western Balkan States

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Rina Basholli, MSc, University of Sheffield, WiCyS, Detroit, MI

Coal is the biggest mineral wealth of Kosovo. Coal has a large territorial extent and colossal reserves estimated at billions of tons that affect the social-economic life of the country. The effective use and management of these coal reserves is one of the main challenges of today and the medium- and long-term future. The collection, systematization and processing of data and studies in the field of coal in Kosovo, as well as the provision of forecasts and economic and scientific strategies are a necessity of today's time.
The evaluation of the energy potential of the coals of the Kosovo basin extracted as a natural raw material to be used with or without technological processing, constitutes a great dilemma which must be looked at seriously and eventually studied.
Conclusion: Kosovo's coal base is Balkan energy potential and more broadly, their enrichment is immediate.

Keywords: Coal in Kosovo and the Western Balkans, reserves, calorific power, extraction and processing technology.

SESSION 9 (16:00-18:00)
CARBON & COAL ASH MANAGEMENT
Asst. Prof. Husain Ashkanani, Asso. Prof. Dr. Mustafa Özer

9.1 (16:00-16:20) Balancing Act for the Developing Countries Between the Use of Coal and The Paris Agreement

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The ratification of the Paris Agreement by almost all states around the world has imposed new challenges for many countries globally, however particularly developing countries will face many hurdles in the selection of choices for their energy policies and their management over the coming decades. As fossil fuels have historically been the engine of economic development around the world, their presence in energy portfolios over renewable energies, however, will inevitably reduce substantially due to climate change concerns. Therefore, investing in any fossil fuel project to generate energy is an increasing risk for investors due to concerns about fossil fuels being associated with greenhouse gas emissions and, consequently, climate change. Meeting the greenhouse gas emission targets imposed by the Paris Agreement on individual countries will prove that this is an extremely challenging activity since it will require a balancing act between the energy requirements of the societies/economic growth and mitigating the greenhouse gasses. Some of the major developing economies, namely BRICS (Brazil, Russia, India, China, and South Africa), MINT (Mexico, Indonesia, Nigeria, and Türkiye), and/or the Next Eleven (comprising the MINT countries, as well as Bangladesh, Egypt, Iran, Pakistan, the Philippines, South Korea, and Vietnam) will also face similar challenges as their economies are still in the transitional phase. Practitioners in the energy field also face similar challenges due to the technical choices available and corresponding project economics and meeting the greenhouse gas emission targets. This current paper highlights some of the challenges faced by policymakers, investors, and practitioners in this new era of sustainable energy generation since fossil fuels, particularly coal will still be one of the formidable portfolio choices amongst others due to reliability, availability, and ease of energy conversion. This is also reflected in the overall statistics where coal is still the number one commodity traded all over the world. However, any coal project contesting to be one of the energy choices in the future needs to be well-prepared to address public concerns.

9.2 (16:20-16:40) An Improved CO2 Separation System Based on Compression Theory for Oxy-Fuel Combustion of Coal

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Carbon Capture and Storage (CCS) Technologies involves three distinct processes of: (1) capturing CO2 from large point sources such as industrial or power plant flue gases, (2) compressing and transporting in pipelines or by trucks and (3) its underground storage by injecting into deep geological formations. CCS is highly essential to achieve net zero carbon emissions by 2050. CCS helps transition from low carbon economy to net zero carbon emission in production by accelerating the decarbonization of all sectors. In this transition, hydrogen becomes an important element of the new energy era. For its low carbon production, it should go hand-in-hand with CCS technologies. CCS is a proven technology close to commercialization. It can be grouped based on the stage of carbon capture: Pre-combustion CO2 capture, Post-combustion CO2 capture and Oxy-fuel. Oxyfuel combustion holds the advantages of carbon dioxide capture and storage from existing plants. CO2 capture becomes less complex and less expensive since the flue gas consists mainly of CO2 and H2O. However, the flame temperature and combustion intensity increase under oxyfuel combustion conditions leading high NOx formation. Due to the strict requirements for CO2 transport and storage, NOx removal might be prerequisite to avoid its potential adverse effects. NOx removal from oxyfuel combustion gases is also more applicable. CO2 rich flue gas stream can be recycled to control the flame temperature to limit NOx emissions. This recycle stream also improves the heat transfer for a better combustion efficiency.

CO2 may either be compressed to its supercritical liquid state pressure using a gas compressor or liquefied at a much lower pressures and then pumped to the desired pressure. The underlying premise of the compression-liquefaction approach is that it requires significantly less power to raise the pressure and liquid compressors are less expensive than gas compressors. The aim of this study is to develop a novel compression-liquefaction based CO2 capture process at a semi-pilot scale from the flue gas representing the oxy-fuel combustion conditions. The experimental set up is composed of five main units: simulated flue gas preparation and feeding system, water vapor condensation and separation, CO2 compression and storage, PLC system for process control and gas chromatography for monitoring the efficacy of the process. In the experiments, CO2 liquefaction has been carried out at the temperatures of between -15 and 0 oC and under pressures of 30 to 60 bars. To simulate the hybrid liquefaction-compression process, ChemSep and CHEMCAD simulation programs have been applied in order to execute the mass and energy balance calculations after the validation of the simulation results by the experimental data. Promising results on the hybrid cryogenic-compression CO2 capture process have shown that an effective CO2 removal performance can be achieved at much more mild conditions.

9.3 (16:40-17:00) Opportunities for CO2 Utilization in Coal-to-Methanol Processes: Optimal Design and Performance Evaluation

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Methanol is an extremely important chemical product and alternative fuel, which is predominantly produced by a coal-to-methanol process in China. However, the high carbon dioxide (CO2) emissions and low resource utilization of traditional coal to methanol have significantly reduced the competitiveness of coal in the methanol industry. The strategy of co-gasification of coal and biomass not only can effectively reduce carbon emissions and improve resource utilization, but also can regulate the syngas fraction by adjusting the biomass blending amount. To effectively utilize CO2 and syngas, a novel process that deeply couples coal/biomass co-gasification to methanol with CO2 hydrogenation to methanol is proposed to optimize the system performances of the conventional coal-to-methanol process. Furthermore, methanol synthesis using CO2 also provides an effective solution for carbon reduction. The process is powered by solar energy or zero-carbon renewable energy to power the coal/biomass co-gasification reaction, separating the energy and elemental properties of the material and reducing carbon emissions from the source. The gasification unit is coupled with adsorption-enhanced water-gas conversion to hydrogen technology to regulate the syngas fraction to meet the H2/CO ratio required for the methanol synthesis reaction and to enrich high concentrations of CO2 using reaction separation integration. The enriched CO2 is directly hydrogenated for resource utilization to produce methanol to replace the original process of geological sequestration of CO2. This process can reduce carbon emissions as well as increase methanol production by coupling photothermal coal/biomass gasification, adsorption-enhanced water-gas conversion to hydrogen technology and CO2 hydrogenation to methanol technology. The key parameters are analyzed and optimized on the basis of the established model of the novel process. The simulation results indicate that the process exhibits better overall performance higher feedstock utilization. Taking the co-gasification of bituminous coal and straw as an example, the process has 47.9% higher carbon efficiency, 68% higher methanol yield and 56% lower carbon emission compared with the conventional coal to methanol process.

Keywords: CO2 utilization; coal-to-methanol; coal/biomass co-gasification; water-gas shift reaction

9.4 (17:00-17:20) Sorption Capacity Evaluation of Carbon Dioxide from Flue Gas Mixture using South African Coal Seams

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South Africa heavily relies on coal combustion for power generation, resulting in significant CO2 emissions. The nation is resolute in its commitment to curbing greenhouse gas emissions, particularly CO2, from coal power plants. Utilizing unmineable coal for CO2 storage has emerged as a promising strategy, holding the potential to boost methane recovery while mitigating migration risks. This study investigates the sorption efficiency of industrial flue gas, in comparison to pure CO2 while considering the influence of both pressure and temperatures. The aim is to evaluate gas adsorption in two South African coal types of varying ranks, AN and TD. Experiments employed the volumetric adsorption method, measuring excess adsorption isotherms of pure CO2 and a synthetic flue gas mixture (N2, CO2, O2, and SO2) to quantify adsorption capacity for the coal samples. The experiments were carried out at temperatures ranging from 35°C to 65°C and pressures of up to 100 bar. The findings

indicate that temperature has a negative influence on the adsorption capacity of both coal types. The temperature effect was more pronounced in the presence of other gas impurities than with pure CO2 sorption. In the presence of other gas impurities, AN coal sample had 93% drop in CO2 adsorption at a temperature of 35 °C while TD had 90% drop at the same temperature. AN coal sample (high rank) with higher vitrinite content adsorbed more CO2 across all temperatures, even in the presence of other gas impurities. TD coal sample (low rank) had high volatile, moisture and ash content which hindered adsorption. Despite reduced CO2 adsorption due to other gas impurities, both coal types demonstrated preferential CO2 sorption from flue gas components, with SO2 exhibiting the lowest adsorption. The sorption of the flue gas components in the coal samples were fitted using Frendlich, Langmuir and Temkin adsorption isotherm models. Temkin model offered a better fit to the experimental data, with the Temkin parameter indicating a physisorption process. The evaluated isosteric heat of adsorption ranged between 10 – 59 kJ/mol for both coal types, further confirming the physisorption process. AN displayed a slightly higher isosteric heat of adsorption compared to TD.

Keywords: CO2, flue gas, coal, adsorption isotherms, isosteric heat of adsorption.

9.5 (17:20-17:40) Utilization of Treated Oil Shale Bottom Ash as a Partial Replacement for Concrete Components

Dr. Yaniv Knop, Assistant Professor at Ariel University, Israel

Oil shales are rocks that contain organic matter and are used as a low-grade fuel for energy production. In addition, the oil shale combustion process produces large quantities of ash as combustion waste.
These residues contain a high concentration of calcium anhydrite (CaSO4) and calcium carbonate (CaCO3), which can be utilized to neutralize acidic wastes (e.g., wastes from the phosphate industry) .
Over the past few years, there has been a growing interest in developing cement and concrete mixtures, partially replacing cement and the natural aggregates in the concrete with recycled material such as oil shale bottom ash. However, using untreated oil shale bottom ash as partial substitutes for aggregates, natural sand, and cement in concrete mixtures has significantly decreased the performance of the concrete mixes.
The research aims to develop green concrete mixtures by partially replacing pure cement and reducing the natural aggregates and sand in the concrete mix with oil shale bottom ash while improving the concrete's performance. It was found that with chemical treatment of the ash by blending it with acidic solutions, the concrete properties (the compressive strength and the workability of the concrete mixtures developed) prepared with partial addition of the treated ash were improved.
This work studied the chemical and physical properties of the oil shale ash before and after the chemical treatment of the oil shale bottom ash and the performances of concrete mixtures that blended cement with oil shale ash in various types of industrial concrete mixtures.The main results and developments will be presented

9.6 (17:40-18:00) Oil Shale Bottom Ash as a Neutralization/Fixation Reagent of Acidic Wastes and the Utilization of Treated Ash as A Partial Substitute to Cement and Aggregates in Industrial Concrete

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Oil shale is one of the low-grade fossil fuels, but it is very abundant in nature and amounts to very large quantities in many countries. Thus, is used as an energy source in few countries like Estonia. Israel does have appreciable amounts of the material, but it is used commercially in one site at ROTEM ANFERT plant in a 30MW drop tube furnace boiler for steam production. Oil shale combustion generates large amounts of ash (Bottom Ash- OSBA ~ 90% and the rest, Fly Ash- OSFA) during combustion. All the OSBA produced in ROTEM is disposed of as a waste, with only a small fraction being utilized.
The OSBA contains significant levels of calcium in the form of anhydrite (CaSO4) and calcite (CaCO3), thus it can be used for neutralizing acidic waste and fixation of trace elements.
The OSBA can't be used as a partial substitute to cement and aggregates in industrial concrete, but the OSBA treated with the acidic waste is excellent to be used as partial replacement and it improved the properties of the concrete.
The results of the study suggest that OSBA has the potential to be used as a neutralization reagent for acidic wastes and the treated OSBA as a valuable commodity to be utilized in production of industrial concrete, while also providing a viable solution for managing industrial waste.

SESSION 10 (16:00-17:20)
VALUE-ADDED PRODUCTS FROM COAL & COMBUSTION TECHNOLOGIES - 1

Prof. Johan Van Dyk, Prof. Dr. Abdulkerim Yörükoğlu

10.1 (16:00-16:20) Research and Development of Advanced CTL And Product Upgrading Integrated Technology

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Fischer-Tropsch Synthesis (FTS) constitutes catalytic technology that converts synthesis gas to synthetic liquid fuels and chemicals. Whilst synthesis gas can be obtained from any carbonaceous feedstock, current industrial FTS operations are almost exclusively based on natural gas. Due to the energy structure of China where cheap coal is abundant, coal-to-liquids (CTL) technology involving coal gasification, FTS and syncrude upgrading is increasingly being considered as a viable option to convert coal to clean transportation fuels. This report gives an in-depth introduction to the advanced CTL and product upgrading integrated technology of National Institute of Clean-and-Low-Carbon Energy (NICE), CHN Energy.
Following challenges encountered in the upscaling of our FTS catalyst technology, we developed a new generation FTS catalyst named CNFT-1 that presents high stability in industrial application in two large-scale plants, i.e., one operated at Ningxia Coal Industry (4 million ton/a, mt/a) and one at Lu'an CTL (1.8 mt/a), with a time yield of ~1.0 t-oil/(t-cat·h) and a catalyst consumption of 1.5 kg per ton oil. Essential to optimum catalyst activation, we developed a fluidized bed catalyst activation technology for Fe-based FT catalysts with a capacity of 20 t per batch. The performance of catalysts activated by this gas-solid fluidized bed technology is comparable to that of slurry bed activation. By developing and validating a computational fluid dynamics-population balance model (CFD-PBM) of a slurry bed reactor for FTS operation, we could predict and realize a 25% capacity increase for a practical plant. The diesel components produced by direct and indirect coal liquefaction in a million-t industrial plant were verified in a 10,000 t blending test. The diesel products met the most recent China VI emission regulations for heavy-duty vehicles were obtained. For waste treatment, membrane separation technology was employed to deacidify the Fischer-Tropsch synthetic water and to extract and separate alcohols from the synthetic water in the pilot plant. The resulting water effluent was treated into boiler water by an acid-resistant biochemical method, so as to realize the water resources reuse. The resulting integration of these technologies results in advanced CTL technology to produce clean gasoline and diesel products complying with the most recent emissions standards.

10.2 (16:20-16:40) Deep Learning-Based Model for Real-Time Prediction And Control Optimization of NOx And NH3 Concentrations At SCR Outlet

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Minimization of NOx emission is one of key requirements for design and operation of coal-fired power plants. Together with low-NOx combustion technologies as primary measure, selective catalytic reduction (SCR) systems are commonly installed downstream in the boiler to remove NOx generated from combustion. This requires injecting ammonia as reducing agent into the flue gas, which eliminates NOx on the catalyst surface. For efficient NOx reduction, the ammonia injection needs to be controlled in correspondence to the amount of NOx in the flue gas. Excessive ammonia injection results in unreacted ammonia, known as ammonia slip, which may lead to fouling in the downstream process by the formation of ammonium bisulfate. Considering that the amount of NOx in the flue gas is subject to significant variations depending on the fuel properties, operation load, and other operation conditions, optimizing the control of ammonia supply with the help of artificial intelligence (AI) can minimize the NOx emission and ammonia slip.
In this study, a deep learning model was developed to pre-emptively predict real-time NOx and ammonia concentrations at the SCR exit. Approximately 5 months of data at 1-minute intervals was collected from a 500 MWe tangential coal-fired boiler, which included the key operation variables of the boiler as well as the SCR system. For model training and evaluation, 80%, 5%, and 15% of the data were used as the training, validation, and test sets, respectively. Four models were compared for real-time

prediction: multi-layer perceptron (MLP), long short-term memory (LSTM), gate recurrent unit (GRU), and an ensemble GRU model that combines MLP and GRU. The predicted NOx and ammonia concentrations at the SCR outlet showed very similar results between the models with a very high accuracy (root mean square error of approximately 0.2). The ensemble GRU model, which demonstrated the highest predictive performance among the evaluated models, was implemented into a new methodology to optimize the ammonia supply in real-time. In this methodology, virtual scenarios were generated by varying the flow rate of ammonia from its actual value at a specific point, enabling selection of an optimal flow rate that can meet the target concentrations of NOx and NH3 at the SCR outlet. It is anticipated that the proposed method for determining the optimal NH3 injection based on the deep learning model can provide supplementary operational guidance for the SCR system.

10.3 (16:40-17:00) Study on the Transformation Behavior of N During Co-Combustion of Coal And Ammonia

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Ammonia(NH3), as a carbon-free fuel, can replace partial traditional fossil fuels by co-combustion with coal, resulting in large-scale carbon reduction and environmental protection.NH3 can not only be oxidized to NOX, but also can be used as a reducing agent to reduce NOX. It is not clear how the presence of NH3 affects the migration and transformation of N during co-combustion of coal and NH3. Therefore, it is particularly important to investigate the migration and transformation behaviors of N in fuels, especially the heterogeneous reaction of NH3 and coal, for the promotion of ammonia-coal co-firing technology.

In this work, Self-designed TG coupled with MS was employed to obtain the N-containing gas release characteristics during co-combustion of coal and NH3 under different temperature and oxygen content. At the same time, semi-char samples under different combustion conditions were also collected and characterized by Raman, XPS, etc. Coupled with the analysis of gas-solid two-phase products, in order to study the effect of temperature and oxygen concentration on N transformation behavior during co-combustion of coal and NH3, providing theoretical support and technical guidance for the industrial application of ammonia-coal co-combustion technology

10.4 (17:00-17:20) Study on the Digital Twin System Of 660mw Ultra Supercritical Circulating Bed Boiler

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Under the carbon peaking and carbon neutrality strategy, China's demand for diversified, clean and low-carbon energy utilization is increasingly urgent. The national low-carbon development and energy security are facing major challenges. The national energy consumption is dominated by coal. Clean and efficient utilization of coal plays a decisive role in the national energy revolution and is a national major strategic demand. Circulating fluidized bed (CFB) combustion technology is an advanced energy utilization technology developed rapidly in the last 30 years. It has the advantages of wide fuel adaptability, good environmental performance and wide range of load regulation. CFB technology will play an important role in the clean and efficient utilization of coal for carbon neutrality. At present, the 660MW ultra-supercritical circulating fluidized bed (USCFB) boiler is being constructed in Weihe Power Plant in Guizhou Province and Binchang in Shaanxi Province, China. It is the largest circulating fluidized bed boiler in the world, marking a new milestone in the development of circulating fluidized bed boilers. Weihe Power Plant adopts the high efficiency USCFB boiler technology to improve energy efficiency and remove flue gas pollutants synchronously, which is a circulating fluidized bed national demonstration unit with the world's largest single unit capacity, the highest parameters and the world's leading overall performance of the unit, and effectively solve the problem of efficient and clean utilization of high sulfur anthracite. Digital twin technology has great application potential in thermal power plant. It can provide comprehensive physical and functional descriptions for unit systems and equipment, provide a verification platform for advanced and intelligent control strategies, improve production efficiency and safety of thermal power plant, reduce production costs, and optimize maintenance and overhaul processes. This article takes Weihe Power Plant as the object to study the digital twin technology of USCFB boilers. The study on the digital twin system of 660MW USCFB boilers is divided into three stages: offline preparation stage, online tracking stage, and intelligent learning stage.

SESSION 11 (16:00 – 18:00)
COAL SCIENCE – 2
Prof. Atsushi Ishihara, Prof.Dr. Fatma ARSLAN

11.1 (16:00-16:20) Catalytic Effects of Extraneous Mineral Matter on Product Distribution During Pyrolysis of Blends of Highveld Fine Coal Rejects, Its Beneficiated Fractions and Reactive Oxides of Major Coal Minerals

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The influence of the mode of occurrence of coal mineral matter on the distribution and properties of pyrolytic products is not well discerned. As a result, a composite material of reactive oxides and hydroxide minerals derived from extraneous coal minerals has been on the pyrolysis behavior of fine coal rejects was evaluated by the yields of tar, char, and activation energy analysis. The effects of extraneous mineral matter were examined and discussed in terms of the activation energy trends, distribution of pyrolytic products, and composition of the tars. Adding composite reactive oxides of extraneous minerals increased the average activation energy due to initial decomposition and reduction of Ca(OH)2 and Fe2O3, respectively. The highest carbon conversion was obtained for the mineral-rich sink fraction (Sl1.9) sample due to the presence of cleat minerals and Ca/Mg/Fe-bearing minerals. Increasing the content of these minerals has lowered the ash fusion temperatures of aluminosilicates to form amorphous Ca/Mg/Fe-silicates which suppressed pyrolytic reactions. Also, deoxygenation reactions were impeded by the high presence of oxygen carriers associated with composite EM. This paper further highlights the propensity of cleat minerals to promote carbon conversion under pyrolysis conditions. This study provides insight into the effect of the mode of occurrence of mineral matter during the pyrolysis of fine coal rejects

11.2 (16:20-16:40) Cracking Reactivity of Zsm-5 Zeolite Prepared in the Presence of Vietnamese Coal Ash Components

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Ash components from coal can be used to make inorganic materials such as zeolites. The chemical composition in the ash of Quang Ninh (QN) among Vietnamese coals could be used for the preparation of zeolites. In this study, we prepared ZSM-5 zeolite catalysts with different SiO2/Al2O3 ratios using reagents that match the ash components of QN coal. As a result of analyzing the prepared catalyst, it was found that crystals of zeolite grew under the condition of 150oC and 48h when the SiO2/Al2O3 ratio is 52 and higher than 52. The difference in reactivity between zeolites with and without coal ash components was investigated through catalytic cracking of low-density polyethylene (LDPE) using a Curie point pyrolizer (CPP) method, which has some advantages that it can be analyzed with a small amount of sample, it has high reproducibility, and the decomposition temperature is wide.
ZSM-5 zeolite catalysts with coal ash components were prepared using colloidal silica (SiO2) as silica source, sodium aluminate (NaAlO2) as alumina source, sodium hydroxide (NaOH) as base, H2O as solvent, and tetrapropylammonium hydroxide (TPAOH) as a structure-directing agent. As Quang Ninh (QN) coal ash components, calcium carbonate ($CaCO_3$) as CaO source, iron oxide (Fe_2O_3) as Fe_2O_3 source, potassium carbonate (K_2CO_3) as K_2O source, magnesium oxide (MgO) as MgO source, ammonium dihydrogen phosphate ($NH_4H_2PO_4$) as the P2O5 source, titanium oxide (TiO_2) as the TiO_2 source, and sodium sulfate (Na_2SO_4) as the Na_2O source were added. Crystallization was carried out at 150°C for 48 hours in a closed stainless steel dry container. After filtering and washing the resulting solid (QNCA-C-ZSM-5), it was

calcined at 550°C for 6 hours. In order to exchange Na+ cations to H+ (QNCA-H-ZSM-5), the calcined catalyst of QNCA-C-ZSM-5 was treated with ammonium nitrate (NH4NO3) solution, and QNCA-H-ZSM-5 was calcined again under the same conditions.
Catalyst Name. For example, in the case of the catalyst QNCA-C-ZSM-5-CR150(48h)_52, the notation of the catalyst is as follows: QNCA means Quang Ninh Coal Ash, C represents conventional Na+ cation, ZSM-5 means the type of zeolite, CR150 means the crystallization temperature of 150oC, 48h means crystallization time in parenthesis, and a number after an underline represents the silica-alumina ratio. Characterization. Catalysts were characterized by XRD, XRF and nitrogen adsorption/desorption measurements. Reaction experiment. CPP method was used. 0.2 mg of LDPE and 1.0 mg of catalyst were packed into a pyro-foil for 500oC. Carrier gas was 0.6 MPa of He, reaction time was 5 seconds, and reaction temperature was 500°C. The products were directly analyzed by GC-FID.
In XRD measurements typical signals for ZSM-5 crystal were observed for ZSM-5 catalysts with SiO2/Al2O3 ratios of 52 and higher than 52 even in the presence of coal ash components. Conventional H-ZSM-5-CR150(48h)_52 catalyst prepared in the absence of coal ash components exhibited smaller signals than QNCA-H-ZSM-5-CR150(48h)_52, indicating that crystals of ZSM-5 have not grown yet sufficiently. However, QNCA-H-ZSM-5-CR150(48h)_78 exhibited almost same signals as H-ZSM-5-CR150(48h)_78. The relative intensity of ZSM-5 crystals increased with increasing the SiO2/Al2O3 ratio and that of the sample with 156 reached the maximum. N2 adsorption /desorption measurements demonstrated that the presence of coal ash components slightly affected the pore structure and increased external surface area and mesopore volume.
In catalytic cracking of LDPE, C5-C11 gasoline products increased and C1 to C4 gas products decreased with increasing SiO2/Al2O3 ratio. In general, the activity increases with decreasing the SiO2/Al2O3 ratio because the acid sites increase with increasing the SiO2/Al2O3 ratio. In the present study, the reverse results were obtained probably because the crystallinity of ZSM-5 would be very important for the activity in this case rather than the SiO2/Al2O3 ratio. It was also found that the activity was affected by the presence of alkali and alkaline-earth metals in coal ash components.

11.3 (16:40-17:00) Using Thermal Analysis TGA/DSC to Determine Coal Properties and the Combustion Behavior of Coals

Haim Cohen, Professor at Ariel University, Israel

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Prior to combustion in utilities, a detailed analysis of the coal properties is needed. This is carried out by slow and time costly well-established methods. Also, the combustion behavior of the coals is important in order to operate the boilers appropriately and this depends very much on the volatile content on the used coal.
Lignites (brown coal) or Bituminous and sub-bituminous coals (Steam Coal) are the coals which are used as fuels in power stations.
Combined TGA (thermogravimetric analysis)/DSC (differential thermal calorimetry) instrumentation has been used determine the basic coal properties (volatile matter, moisture content, ash content and calorific value) of lignite and bituminous coals and to evaluate the combustion profile of the coals.
The results indicate that the combined TGA/DSC method can be used as analytical method to determine coal properties and also to evaluate the combustion properties of the coals

11.4 (17:00-17:20) Combined Thermogravimetric Analysis (TGA)/Differential Scanning Calorimetry (DSC) as a Tool for Determination of the Chemical Processes Accompanying the Spontaneous Heating of Coals

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Coal is the largest energy resource in the world for power production and the steel industry and will stay as the main source in the near future.
The main coal types used are Lignites (brown coal) or Bituminous coals (Steam Coal). Lignites can't be stored and have to be used immediately post mining. Bituminous coals can be stored and transported prior to utilization. Upon storage, self-heating accompanied by emission of toxic and fire hazardous gases might occur and in extreme cases self-ignition of fires will erupt stemming from LTO (low temperature, RT-150°C, oxidation) of the coal. In this study, thermal analysis (combined TGA/DSC) accompanied by Gas Chromatography and on-line Mass Spectrometry have been used to determine the risks of toxic and hazardous gasses emissions occurring during the spontaneous heating from Lignites and Bituminous coals which are the result of the Low Temperature Oxidation of the coal

11.5 (17:20-17:40) Mechanistic Study of Coking Behaviour and Coke Structure Formation Under Stamp-Charged Conditions

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Stamp-charged coke-making is an effective technique to improve the quality of metallurgical coke produced from weakly coking coals or blends of premium and low-quality coals. Stamping is known to be more effective on weaker coals. However, the exact mechanism of thermoplasticity development, the interaction between coal grains, and coke structure formation under stamp-charged conditions is not fully understood. This study investigates the impact of charge density on 3 Australian single coals with varying rank and petrographic properties. A custom-designed permeability/dilatation test rig and a 4kg coke oven test facility were used to evaluate the impact of charge density on in-situ coking behavior. Additionally, the microstructural transition from coal to coke was analysed through the fast sampling of the plastic layer followed by Synchrotron micro-CT imaging and 3D image analysis.
The results showed that stamping positively influences coke strength, while the extent of improvement is coal type dependent, where cokes made from the lower rank and higher inertinite coals benefit more from stamping. Higher charge densities drastically improved the dilatation of high inertinite coals and widened the low-permeable region. The onset temperature of dilatation decreased at elevated charge densities. Stamping also increased the internal gas pressure (IGP) of high inertinite coals, while the thermoplasticity of high vitrinite, high fluidity coals was not impacted. Similarly, synchrotron micro-CT results showed an overall decrease in coke porosity at higher charge densities for weak caking coals. The study of the interface between inertinite- and vitrinite-derived maceral components indicated improved contact and bonding.
These results suggest that stamp charging affects particle adhesion and mass transfer in the plastic layer, including (1) increased dilatation and enhanced plasticity of coal; (2) decreased coke porosity; and (3) enhanced bonding of inert particles to the coke matrix. The findings of this study have improved the fundamental understanding of the mechanisms by which elevated bulk densities improve coke quality and can form a basis to improve blend design for stamp-charged coke-making operations

11.6 (17:40-18:00) Evaluation of Dense Medium Cyclone Performance

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Coal provides more than 25% of the world's primary energy needs. 40% of the world's electricity is dependent on thermal coal and about 70% of iron and steel production is dependent on metallurgical coal. In addition, coal is used in different industrial areas as an important component in the production of various end products. It is an inevitable necessity to wash the coal and bring it to the appropriate properties for the field of use. For this purpose, a wide variety of methods and devices have been developed and continue to be developed. Today, the flow chart of coal preparation plants has become standard to include two or more parallel circuits in which coarse, medium, thin and very fine sized coals are washed in different devices. Coarse and medium sized coals are washed with heavy medium baths and cyclones, fine size coals are enriched with spirals. In 3 different Coal Washing Plants within Uysal Mining, the performance of the Dense Medium Cyclone was tried to be determined. For this purpose, representative samples were taken from the determined points of the system at one-hour intervals for three days, taking into account the sampling principles. Particle size analyzes were made to the samples taken and the ash and calorie values of each fraction obtained from here were measured. Using these measurements, material balance was created and Dense Medium performance was evaluated. In the study, the particle size of the dense medium cyclone feed was -20+0.5mm fraction and in the analyzes, it was observed that the separation performance was high in the -20+2mm fraction and the separation performance decreased in the -2+0.5 fraction. Research has been carried out to increase the separation efficiency of -2+0.5mm fraction.

SESSION 12 (16:00 – 17:20)
COAL BED METHANE AND SHALE GAS & COAL MINING - 3

Mr. Don Stevenson, Mr. Dursun Akyürek

12.1. (16:00-16:20) Analysis of Gas Content Determination Methods for Coal Beds in TÜRKİYE

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Methane is constituted more than 95% of the gases forms as either biogenically or thermogenically-derived gas in coal beds and is stored as adsorbed gas and free-gas in the pores of the coal. The accurate determination of the coalbed gas content has a great importance for the estimation of the methane emissions that will occur in the underground coal mines, and accordingly for the planning of the mine-ventilation, as well as for the reservoir studies on the economic recovery of coalbed methane (CBM). Gas content determination techniques can generally be grouped into two categories as direct and indirect. In direct methods, coal samples taken from the coal seam are placed in sealed canisters and the volume of gas released from the sample is actually measured. Although different direct methods have been developed, such as quick-crushing and extended desorption methods, all direct gas content measurement methods are based on the same principles. The most commonly used methods subdivide the total gas content of a coal sample into three parts: lost, desorbed, and residual gas. Each of these parts is generally measured or estimated by a different procedure, and then combined to yield the total gas content of the sample. In the direct method developed by the US Bureau of Mines (USBM), which is widely used among the direct methods, core samples with a length of 50 cm are periodically collected and promptly placed in sealed canisters during drilling operation. The amount of gas released during sample collection process represents the lost gas component, which is not directly measured but can be estimated from desorption graphs. After the samples placed in canisters, the amount of gas released from core samples refers desorbed gas component, can be directly measured with a manometric gas volume measurement apparatuses. Finally, a small amount of gas still remains in the samples after the desorption is completed, known as the residual gas component. To measure residual gas component, samples are crushed to particle size below -200 mesh using a sealed mill. In indirect methods, the gas storage capacity of the sample can be determined by using various empirical equations or adsorption isotherms obtained in the laboratory. The USBM direct method was applied to coal samples taken from different coalbeds such as Yatagan and Milas coalfields in TÜRKİYE. The gas content values of the Yatagan and Milas coalfields is found to range between 0.20 - 0.39 m3/t and 0.05 - 0.16 m3/t, respectively. Based on the findings, it can be concluded that, by implementing well-designed and sufficient ventilation systems, underground coal mines in these coalfields can be operated safely. However, the gas capacity of the fields is not suitable for methane drainage systems aimed at producing clean energy. In this paper, the results obtained from tests were analyzed, application procedures of the USBM direct method were explained in detail and gas content determination methods were compared for different coalbeds from TÜRKİYE.

12.2. (16:20-16:40) Methane Drainage Application in Polyak Eynez Lignite Mine

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This article covers topics the methane drainage applications in Polyak Eynez Underground Lignite Mine and preparations for electricity production using the methane that is emitted by coal. Although coal seam contains low gas; the fact that tectonics movement, permeability of faults and its activities, coal seam thickness (10-30m), being the deepest underground lignite mine in TÜRKİYE (850-1350m), water drainage from upper aquifers (500-600m3/h) and the pores here being filled with methane gas etc. For these reasons, high amounts of methane gas flow into the openings during production and development operations and this sometimes makes "methane drainage" necessary to support mine ventilation. In order to carry out the production and development operations safely, the main objectives of this study are to plan to extract the methane gas drained from the main gas network to the surface and convert it into electrical and heat energy

12.3. (16:40-17:00) Investigation of the Effectiveness of Methane Drainage in a Multi-Seam Coal Mine with the Use of Long-Reach Directional Drilling - a Case Study from USCB, Poland

Wiesław Szott, Małgorzata Słota-Valim, Krzysztof Milek, Piotr Łetkowski, Piotr Rucinski, Oil and Gas Institute – National Research Institute, POLAND

The main problem of most of the coal mines in the Upper Silesia Coal Basin (Poland) is related to their high methane content. Most of the remaining hard coal mines have high methane hazards, which must be addressed for operational safety reasons (Krause, 2005; Krause and Skiba, 2014). The high methane content of the GZW mines and problems related to hard coal mining technology directly threaten work and human safety, which has been observed more and more often in the last 20 years. The methane hazard in hard coal mines determines the increase in coal mining costs related to the financial outlays incurred to prevent and combat this hazard. High costs are generated by the need to carry out methane drainage (Jureczka, 2017). On the other hand, methane captured by methane drainage systems can be a carrier of clean energy, covering the costs associated with methane drainage and even bringing additional profits (Karacan et al., 2011; Flores et al., 2019; Zhang et al., 2022). Recently, attempts have been made to capture methane from the surface by drilling holes and fracturing coal seams (Jureczka, 2017; Jureczka and Hadro, 2022). In our study, we evaluate the efficiency of new drainage technology with the application of the long-reach directional drilling boreholes network drilled above the exploited coal seam in one of the multi-seam hard coal mines in USCB, Poland (Leśniak et al., 2022). To address the aim of the study, numerical modelling was used, combining geomechanics with reservoir fluid flow models constructed in the framework of 3D structural models including both the architecture and the properties of the rocks occurring in the study area. To employ the method of effective coupling between geomechanical and flow simulations and concerning the influence of geomechanical state variations upon the transport properties of rocks within the model region, flow and geomechanical simulations were performed for several selected time steps. The results of geomechanical simulations provided deformation and stress distributions which were quantified and converted to find permeability modifications with the use of Kozeny-Carman (Bear, 1972) and Shi and Durucan (Shi & Durucan, 2005) models. The simulation model of the 501-coal seam and its surroundings was calibrated achieving a satisfactory match with the historical data related to the coal production from the C lot of the seam including schedule and measurement data. The calibrated model of the 501 coal seam and its surroundings was used to simulate a hypothetical scenario that did not apply directional boreholes for methane drainage to compare it with the real case implementing those boreholes. The fundamental results of that simulation in terms of (i) total gas production by the ventilation system, (ii) total methane production by the ventilation system, (iii) total gas production by the standard drainage borehole system, and (iv) total methane production by the standard drainage borehole system, and the results for the volume of methane left in the C lot of the 501 coal seam led to the conclusion that the application of the long-reach directional boreholes significantly (by ca. 52%) decreases the methane content in the ventilation gas and notably (by ca. 48%) reduces the methane content in the coal matrix of the excavated coal seam thus proves the effectiveness of methane drainage by the long-reach directional boreholes. Conducted sensitivity analysis of geological and structure parameters and their influence for their relative modifications by □10% upon the above 4 significant methane drainage effectiveness criteria allow to draw conclusions referring to the estimates of the methane available to the drainage process and, consequently, drainage requirements. The analysis of the technological parameters of the methane drainage strategy brought up the conclusion that the closer the trajectories to the 501 seam, the larger the methane total production and the higher the recovery of the methane originally adsorbed in the C lot of the 501 seams.

12.4. (17:00-17:20) Maliqi Peats, their Reserves and Energy Potential

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The formation of coal and peat in the Pogradec-Korce basin is related to the Quaternary. They are located near the surface and are characterized by a significant content of ash, volatile matter and organic and inorganic sulfur. For this purpose, a full and deep knowledge of the petrographic aspects is aimed of the carbon mass, the chemical and mineralogical knowledge of the carbon-holding basin as well as the technological possibility of their re-evaluation.
The introduction into the energy scheme of power plants that burn both coal and peat with calorific power between 1900-3500 kcal/kg, makes it possible to activate about 350-400 million tons of verified geological reserves of the Korce-Pogradec basin.

Keywords: Coal, peat, calorific power, ash, geological reserves, petrography and mineralogy.

SESSION 13 (11:00-12:00)
CLEAN COAL AND GAS TO FUELS - 1
Dr. Zhuowu Men, Ms. Mücella Ersoy

13.1 (11:00-11:20) Experience of SNG Production from Thar Coal In Pakistan

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Engr. Abid Aziz, Pak Motors (Pvt) Ltd, Pakistan

Work has started on the production of SNG (Synthetic/Substitute Natural Gas) in Pakistan. Gasification studies are being conducted in Lahore and South Africa. So far, the results have been encouraging. Substantial reduction of moisture was seen for ROM (Run of the Mine) Coal samples received from Thar. In a period of ten days, the moisture dropped from 45% to 9% which is a substantial reduction. A similar air drying of as mined coal is carried out at Kemper County Energy facility of Mississippi Power at IGCC plant (Integrated Gas Combined Cycle) that produces 582 MW power. After mining the Coal is Air dried under an open Lignite Dome structure before being charged to the 'Gasifier'.

In Lahore, Steam/Oxygen gasification was carried out for Coal under 50mm particle size in a small laboratory gasifier. The gas Calorie Value was around 950 Btu per cubic feet (Natural Gas currently in use = 920 Average) with out of reach imported LNG (Liquid Natural Gas) prices, production of SNG using the large indigenous Coal deposits (175 billion tons) seems a viable option for an energy-starved country like Pakistan. Affordable fuel is the best way forward

13.2 (11:20-11:40) A Pilot Study of Fischer Tropsch Synthesis in a Multitubular Fixed-Bed Reactor and Fuel Characteristics and Performance Tests of Fischer Tropsch Fuels

Özlem Ataç, Özgür Can Korkmaz, Salih Obut, Selda Durmaz Sezgingil, Gamze Behmenyar, Abdullah Zahid Turan, Eftal Muhammet Peker, Yeliz Çetin, Mehtap Çolakoğlu, Ahmet Saygılı, Özlem Doğan, TÜBİTAK Marmara Research Center, Clean EnergyTechnologies Research Group; TKİ, General Directorate of Turkish Coal Enterprises, TÜRKİYE.

In this study, a pilot scale Fischer Tropsch (FT) Synthesis study was conducted to produce hydrocarbons and the properties of obtained syncrude oil were investigated. The syngas was used was produced in a gasification unit using a low rank Turkish lignite followed by gas cleaning and CO2 removal units respectively. FT study was carried out in a multitubular fixed-bed reactor with iron-based catalyst. The fresh syngas feed was 100 Nm3/h and total feed to the reactor was 280 Nm3/h with recycle. The reactor was operated with a mean temperature of 230 °C, 20 barg pressure and a space velocity 1.75 Nm3/h/kg-cat for 151 hours. Obtained liquid and wax hydrocarbons were collected in separate traps. Liquid and wax products were analyzed to determine the hydrocarbon range. Liquid phase hydrocarbons was fractionated in a pilot scale crude oil distillation plant. Gasoline, kerosene and diesel fractions were collected and no further upgrading study was conducted. Gasoline and diesel products was analyzed according to TS EN 228 gasoline and TS EN 590 diesel fuel standards, respectively. Diesel range product was tested in a single cylinder diesel engine and performance of the FT diesel crude product and a petroleum diesel fuel were compared. It was observed that even no fuel upgrading was carried out, FT diesel was compatible or even more advantages compared to petroleum diesel for all the parameters tested.

13.3 (11:40-12:00) Optimization of Ideal Mixing Rate and Catalyst Concentration for Ensuring Homogeneity of Coal and Biomass Liquefied Products in a Reactor

Cemil Koyunoğlu, Yalova University, TÜRKİYE;
Hüseyin Karaca, Prof. Inonu University, TÜRKİYE.

In the quest for sustainable and renewable energy sources, coal and biomass co-liquefaction has emerged as a promising technology. However, to harness the full potential of this process, achieving homogeneity in the liquefied product within the reactor is crucial. This study aims to explore the optimization of ideal mixing rate and catalyst concentration to ensure uniformity and maximize product yields during coal and biomass co-liquefaction. The investigation was carried out through a series of experimental and computational simulations utilizing a batch reactor setup. Various combinations of coal and biomass were used as feedstock, and the impact of different mixing rates and catalyst concentrations on the reaction kinetics was studied. The liquefaction process was modeled as a complex set of reactions, considering the involvement of coal and biomass reactants and catalysts. To characterize the mixing performance, the mixing rate was varied systematically, and its effect on the homogeneity of the liquefied product was evaluated. The concentration profiles of key components within the reactor were monitored over time, and the influence of mixing rate on product yields was analyzed. The goal was to identify the optimal mixing rate that resulted in the most uniform distribution of reactants and products. Furthermore, the study investigated the role of the catalyst concentration on the reaction kinetics and product formation. Different catalyst concentrations were evaluated to determine their impact on the overall reaction rate and the selectivity of desired products. The correlation between catalyst concentration, product yield, and the reaction time was investigated to establish an ideal catalyst loading for enhanced liquefaction efficiency. Results from the experimental and simulation data were analyzed, and the findings provided valuable insights into the importance of mixing rate and catalyst concentration for ensuring homogeneity in coal and biomass liquefaction. The study contributes to the understanding of the complex reaction mechanisms involved in the co-liquefaction process and lays the groundwork for designing efficient and sustainable co-liquefaction reactors.

SESSION 14 (11:00-12:20)
COMBUSTION TECHNOLOGIES - 2
Prof. Chung-Hwan (Steve) Jeon, Prof. Dr. Hasan Can Okutan

14.1 (11:00-11:20) Oxy-Fuel Combustion Technology and Techno Economic Analysis of Carbon Dioxide Capture

Barış Oktay, Hasan Can Okutan, ITU Synthetic Fuels and Chemicals Technology Center, TÜRKİYE; Hande Çukurlu, TUBITAK Marmara Research Center, TÜRKİYE; Alper Sarıoğlan, Assoc.Prof.Dr., ITU Synthetic Fuels and Chemicals Technology Center, TÜRKİYE.

Oxyfuel combustion is one of the three main routes used to reduce carbon dioxide emissions emitted into the atmosphere by applying cost-effective and technically viable carbon capture. It has advantages such as high CO2 purity and lower gas volumes for capture. The oxygen diluted with a portion of the flue gas rather than with nitrogen helps to control the flame temperature leading less NOx formation as well. In this study, oxyfuel combustion technology has been techno-economically assessed against the competing conventional combustion technologies: Pulverized and fluidized bed combustion technologies. The basis of the comparison is for the conditions of both atmospheric and pressurized oxy-combustion. In the assessment, five different scenarios have been formed to examine all in the presence of supercritical boiler : (1) Pulverized combustion with air at atmospheric pressure, (2) Pulverized combustion with O2 & CO2 at atmospheric pressure, (3) Circulating fluidized bed combustion with air at atmospheric pressure, (4) Circulating fluidized bed combustion with O2 & CO2 at atmospheric pressure, (5) Circulating fluidized bed combustion with O2 & CO2 under pressure. The power plant capacities of pulverized and circulating fluidized bed combustion technology have been selected as 150 MWe, net and 400 MWe, net, respectively. Turkish lignite from Orhaneli-Bursa has been chosen as the basis of design. Having all scenarios examined, it has been observed that the facility's capital requirements were directly proportional to the gross energy output of the plant as expected. Moreover, gross power to be met in the power plant due to the internal power demands by units such as air separation and cryogenic carbon dioxide capture, is significantly higher compared to the facilities with the equivalent net output. It was predicted that the increase in this gross power led to the higher capital requirements of the process.

14.2 (11:20-11:40) Silopi Thermal Power Plant Asphaltite Coal Fired Fluidized Bed Boiler and Second Phase Slagging Problem as High Limestone Usage

Özgür ER, Deputy General Manager, Silopi Thermal Power Plant, Şırnak, TÜRKİYE

The production capacity of Silopi TPP is 3x135 MW. It is designed to burn Asphaltite coal from Harbul and Silip mining zones. Silopi TPP is the unique "Asphaltite" Coal Fired Circulating Fluidized Bed Boiler Power Plant in the world.
Asphaltite is a main bitumen that can be formed by the separation of the petroleum and it can be placed into the pore of the rocks. During tectonic movements, the petroleum is separated from the reservoir and it penetrates to the cracks and after long time oxidation, asphaltite can be formed.
Mining Plant total reserve: 44.448.466 tons
Current reserve (2023): 36.273.549 tons
Asphaltite Analyses:
Calorific Value: 5.500 kCal/kg
Sulphur: %7
Commercial Production Starting Time:
Unit 1-2-3: 02/05/2009 08/05/2015 22/12/2015
Production Capacity: 2.916.000.000 kWh/year
Fuel Consumption: 1.255.608 tons/year
Limestone Consumption: 432.000 tons/year
Main Steam Temperature / Pressure / Flow Rate: 535 ºC 135 bars 440 t/h
Reheated Steam Temperature / Pressure: 535 ºC 25 bars
Boiler Efficiency: %92
Main Contractor: CMEC, China

The type of the boiler is circulating fluidized bed. The coal is burned at the heated sand and ash bed with the help of the primary air.
Circulating fluidized bed can provide perfect air and fuel mixture, so higher burning efficiency and high sulfur elimination conditions.
Calcium carbonate (CaCO3) is injected into the boiler first phase for sulphur dioxide (SO2) elimination at the plant. Therefore it is an environment friendly power plant.
However, as high sulphur content, too much limestone powder must be used into the boiler and it causes slagging at the second phase of the boiler. So, it is necessary to clean the pipes heating surfaces mechanically every 4 months.

14.3 (11:40-12:00) A Study on the Characteristics of Coal and Ammonia Co-Combustion Using a Lab-Scale Fluidized Bed Reactor

Jae-Sung Kim, Min-Woo Kim, Mu-Hyeock Yeon, Seung-Mo Kim, Byoung-Hwa Lee, Chung-Hwan Jeon, Pusan National University, SOUTH KOREA.

This research is being conducted to explore the co-firing characteristics of ammonia, a carbon-free fuel, with coal and solid fuels, aiming to address the climate crisis caused by carbon emissions. The Circulating Fluidized Bed (CFB) boiler, known for its clean technology, offers the advantage of utilizing various fuels. Countries like South Korea and Japan are actively engaged in technological development, including the substitution of ammonia for a portion of coal in thermal power plants, to reduce CO2 emissions through direct fuel conversion and maximize the utilization of existing facilities, which includes the development of CFB boilers. However, ammonia presents certain challenges, such as a narrow flammability range and a slow combustion rate, requiring sufficient residence time for complete combustion. It also contains nitrogen, which may increase the emissions of nitrogen oxides (NOx) and exhibits low radiative strength. These characteristics pose potential issues not only with combustion and heat transfer within the boiler but also with exhaust emissions (NOx, ammonia slip, etc.). Consequently, conducting a preliminary examination of the feasibility of ammonia application in CFB boilers is essential. To assess the potential applicability of ammonia, an experimental setup for fluidized bed ammonia combustion was designed and constructed to investigate the co-firing characteristics of ammonia with coal. This research aims to gain insights into the behavior of ammonia and coal co-combustion. When applying selective catalytic reduction (SA) in coal combustion experiments, the generation of NH3 decreased, but the emission levels were too low to establish a clear trend. NH3 co-combustion tests with SA showed reduced emissions of nitrogen oxides (N2O and NO).Ammonia emissions decreased with the application of SA, and this reduction was observed regardless of ammonia injection. However, when ammonia was injected separately, nitrogen oxide emissions increased. In the 20% NH3 co-combustion test, a small amount of ammonia slip occurred, slightly increasing detected ammonia levels. However, the overall emission amounts were significantly low and showed no significant difference compared to coal combustion tests. In the 20% NH3 co-combustion test, moisture generated from ammonia combustion increased, while CO2 emissions decreased. Under PA conditions, CO2 decreased by approximately 18%, and under SA conditions, it decreased by approximately 12%.

14.4 (12:00-12:20) Comprehensive Review on Combustion and NOx Emission for NH3 Co-firing Technology,

Byoung-Hwa Lee, Jae-Sung Kim, Si-Hyun Cho, Chung-Hwan Jeon, Pusan National University, SOUTH KOREA.

Recently, ammonia has attracted more attention in terms of global carbon neutrality. In order to achieve zero carbon emissions in power generation, it is most important to replace existing fuels. As a carbon-free fuel, ammonia has several advantages over hydrogen. However, the low burning velocity and high fuel NOx emission of ammonia fuel are challenges in practical use. Therefore, in this paper, ammonia fuel was first analyzed and reviewed in terms of thermal properties and fundamental combustion characteristics. This paper also evaluates and discusses the mechanisms of NOx emissions that can be rapidly elevated by NH3. Based on the reaction mechanism, the characteristics of major NOx production and reduction under various conditions were identified and several methods for NOx control were presented. In particular, it contributes to finding optimal conditions by analyzing the ammonia co-firing characteristics of existing coal-fired boilers. This study systematically summarizes the basic combustion behavior of ammonia fuel and uses it as a theoretical reference for ammonia combustion and exhaust emissions to suggest practical applications in power generation fields where ammonia conversion is important. Ammonia has a lower calorific value compared to typical hydrocarbon fuels and a lower gravimetric density than hydrogen on a mass basis. However, on a volume basis, ammonia has a higher volumetric energy density than liquid hydrogen. Ammonia is less flammable and reactive than methane due to its narrower flammability range, lower adiabatic flame temperature, higher ignition temperature, and lower laminar combustion rate. Ammonia flames produce yellow or orange colors due to NH2 and overheated H2O vapor emission, while methane flames produce blue flames due to CH* emission. In flame propagation experiments, ammonia flames exhibited longer flame lengths compared to methane flames under similar conditions. The optimal condition for ammonia combustion to minimize NO emissions was found at an equivalence ratio of 1.1, where both NH3 and NO showed minimal emissions. Ammonia combustion also produced N2O and NO2 at specific equivalence ratios. In coal combustion with injectable NH3, the location of NH3 injection in the furnace affected the NOx formation. Injecting NH3 in the flame region resulted in the lowest NO concentration due to active reducing reactions. As the co-firing ratio of NH3 with coal increased, the peak NO concentration shifted from the flame region to the post-flame region, indicating different NOx reactions with increasing NH3 amounts. Overall, ammonia offers unique advantages and challenges as a fuel, and its combustion characteristics differ from traditional hydrocarbon fuels like methane. There are many new challenges to utilizing ammonia in combustion systems. Ammonia has problems in that its burning velocity is lower, its combustibility limit is narrow, and its generation of NOx is high compared to other hydrocarbon fuels, so research and development in these fields is more necessary. In particular, in the power generation field, more in-depth research is needed in terms of combustibility and environmental characteristics in a situation where ammonia is injected into the existing coal-fired boiler and a strategy to reduce NOx is needed. This study proposes an in-depth study on the co-firing ratio and injection position when injecting ammonia into existing coal-fired boilers, and suggests that a strategic approach to air-staging and fuel-staging is needed.

SESSION 15 (11:00 – 12:20)
RARE EARTH ELEMENT – 1
Dr. Satya Chauhan, Prof. Dr. Ekrem Yüce

15.1 (11:00-11:20) Building Environmental Justice and Equity into the Development of Critical Mineral Industries

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The global transition toward low-carbon energy not only means an increase in demand for clean electricity and renewable resources, but also an increase in demand for the critical minerals (CMs) and rare earth elements (REEs) that these technologies rely upon. Indeed, low-carbon energy technologies, such as those used for wind turbines and electric vehicle motors, require significantly more lithium, nickel, cobalt, manganese, graphite, and other CMs than fossil-based energy technologies. The growing demand for new forms of low carbon energy will necessitate a proportional scale-up of CM and REE extraction and processing. Presently, the majority of extraction and processing activities for CMs and REEs are concentrated in very few countries, primarily in China and the Global South. CM and REE supply chain activities conducted in or controlled by these countries are commonly associated with widespread and well documented human rights abuses and environmental degradation. As a result of concerns related to supply chain security, worker welfare, and the overall need for additional sources of CMs and REEs, governments worldwide have begun to explore policy pathways for the development of new supply chains.
The development of new supply chains for CMs and REEs represents a multifold opportunity to accelerate the global deployment of low-carbon energy fleets, reduce global carbon emissions, build political resilience—and also to enhance policy objectives of environmental justice and equity in the clean energy transition. Fulfilling these policy objectives requires energy producers to navigate a maze of global supply chain policies designed to shape and accelerate the growth of new markets. In the United States, for instance, President Biden recently implemented fiscal and trade policies that incentivize both domestic and global reliance on U.S.-produced CMs
and REEs, leveraging key relationships in Asia and Europe to ensure the accelerated buildout of the U.S. supply chain. The Biden Administration's framework also emphasizes that new supply chains for CMs, REEs, and other low-carbon energy pathways must generate benefits for marginalized and disadvantaged communities, build energy equity, and contribute to the Biden Administration's vision of environmental justice.
CM and REE supply chains include several stages, including mining, processing, transport, utilization, and disposal, each of which involves different environmental justice considerations and potential injustices. This study explores how technical innovation, paired with responsible community engagement and empowerment, can help inform the development of energy equity and environmental justice at all stages of new supply chains. The study highlights these opportunities on a broad scale. We also lend a specific focus to research at the University of Wyoming School of Energy Resources that aims to guide the development of CM and REE industries in communities with high economic dependence on coal and other fossil fuel industries, identifying pathways to grow a U.S. domestic supply chain by producing CMs from coal, coal by-products, and coal waste streams. These production pathways represent a potential new supply for

CMs across the U.S. and elsewhere, thereby enhancing national security and accelerating the widespread deployment of low-carbon energy technologies, while also generating alternative applications for remaining coal reserves and aiding in a just transition for rural energy-producing communities.

15.2 (11:20-11:40) Consortium for Assessment of Northern Appalachia Resource Yield (CANARY) of CORE-CM for Advanced Materials

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The objectives of this study are to 1) assess and catalog Northern Appalachian (NA) basin Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) resources and waste streams, 2) develop strategies to recover CORE-CM from these streams, 3) assess the infrastructure, industries, and businesses in the NA basin to determine CORE-CM supply chain gaps, 4) review technology gaps related to CORE-CM production, 5) formulate plans to establish Technology Innovation Centers, and 6) develop stakeholder outreach and engagement in educational activities. It will expand Penn State's Power and Mineral Industrial Stakeholders group (PMISG) and include advanced carbon product manufacturers in the region to cover all aspects of CORE-CM.

Under this project, CANARY team collected and examined the published data on historic mining and processing sites from the region, data currently held by the project team members (e.g., Penn State Coal Database) and by an expanded PMISG. Published data, and analyses of additional samples collected under this study are being analyzed for CORE CM from acid mine drainage, refuse piles, fly ash ponds/storage sites, mine waste dumps and AMD sludges. Penn State Coal Data Bank maintains a suite of 39 well-preserved Department of Energy coal Samples (DECS) coal samples. Samples from Northern Appalachian region were analyzed by Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) to generate missing data for the elements Li through U. Preliminary results showed that an anthracite sample was found to contain over 1000 ppm Li and greater than 800 ppm TREE+Y+Sc. A geospatial portal is being developed to share the collected data using Data Commons.

Available technologies to extract from these secondary resources, infrastructure, and business aspects in the Northern Appalachian Region are being evaluated to identify the gaps for the domestic production of these critical elements. This presentation discusses the results obtained and the gaps in the development of these resources.

15.3 (11:40-12:00) Critical Minerals and Rare Earth Elements in Powder River Basin Coal and Associated Sediments, Wyoming, USA

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The demand for Rare Earth Elements (REE) and other critical minerals (CM) required for consumer products, defense-related applications, and low-carbon energy technology is increasing rapidly. Unconventional sources of REE/CM, such as coal and associated sediments, could prove very important in building resilient and ethical energy supply chains. Utilization of existing infrastructure and the highly trained energy workforce in traditionally coal-producing regions in emerging REE/CM industries could provide an economic boost to coal communities. The Powder River Basin (PRB) of Wyoming and Montana, USA, is a prime candidate to investigate the feasibility of extracting REE/CM from coal and associated sediments. The PRB hosts thick (>50 ft) coal seams that are mined at the surface and more than 40% of the coal produced in the US comes from the PRB.

Geochemical data from multiple locations in PRB coal systems show REE enrichments at the top and bottom margins and at internal partings in coal seams. This trend is exhibited in two cores drilled at Peabody's North Antelope Rochelle mine in the east central PRB, the largest coal mine in the world. The two cores include the Wyodak Anderson coal zone as well as the over- and underlying shale units. The Wyodak Anderson coal zone is part of the Paleocene Tongue River Member of the Fort Union Formation in which most of the coal resources in the PRB reside. To understand REE/CM enrichment, a total of 188 samples were analyzed for their major and trace element chemistry from both cores, sampled at one foot or smaller intervals. The two cores show distinct REE enrichments in the uppermost and lowermost 3 to 12 feet of the Wyodak Anderson coal zone, as well as enrichments in bounding carbonaceous shale units. Total REE+Y (REY) concentrations as high as 2510 ppm (all concentrations reported on an ash basis), or 15 times average upper continental crust values (Taylor and McLennan, 1995), were identified in the coal. Partings within the coal zone also show relative REE enrichment, with concentrations up to 485 ppm REY. The remaining interior portions of the coal zone contain lower concentrations of REE, resulting in an average REY for all samples from both cores of 288 ppm. The proportion of high-value critical REE (Nd, Eu, Tb, Dy, Er, Y) compared to REY averages 36%, which is higher than the critical REE proportion in average upper continental crust of 33%. This finding highlights the relative enrichment of middle REE compared to light REE, in contrast to many conventional REE deposits.

Other critical trace elements that show enrichments above average upper continental crust include Ga, Nb, and V. Within this sample suite, Ga concentrations range from 2.8 to 213 ppm, with an average of 29 ppm; Nb from 2.9 to 166 ppm with an average of 26 ppm; and V from 27 to 1695 ppm with an average of 188 ppm. None of these trace elements exhibit the same distinct pattern of enrichment as REE in the upper and lower bounding layers and internal partings of the coal zone. Major element chemistry indicates CaO concentrations averaging ~25% in the coal samples from both cores, which has important implications for the extractability of REE from coal. Calcium-rich PRB coal has been shown to be more amenable to REE extraction than lower calcium coals by some methods (Stuckman et al., 2019; Taggart et al., 2016), highlighting the importance of REE extractability in addition to REE concentration in assessing the value of potential feedstocks.

The original coal resource in the PRB is estimated at 1.16 trillion short tons (Luppens et al., 2015). Thus, the PRB represents an important potential unconventional source for REE and other CM. Ongoing research to fully characterize the REE/CM resource, identify enrichment mechanisms, and further develop and scale extraction technologies is necessary to understand the full potential of this resource.

15.4 (12:00-12:20) A Novel Process for Improved Recovery of Scandium from Allanite Concentrates

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Dan McFarland Park, Staff Scientist, 2 Lawrence Livermore National Laboratory, USA

Allanite is an epidote group mineral known to be rich in REE and Sc. Penn State in a project with Lawrence Livermore National Laboratory (LLNL) developed an effective leaching process to recover Sc at a leaching efficiency >70% in a solution with an REE concentration of over 3000 ppm from an allanite concentrate and Fe removal of >99%. The low iron solution would be used to separate Sc using some biological methods by LLNL. Fe was to be removed because it interferes with the biological separation process. This paper focuses on developing the leaching process. Allanite sourced from the surface rocks from Arizona was preconcentrated using magnetic separation followed by flotation. This concentrate was processed using a NaOH pretreatment followed by a two-step H2SO4 baking and water-leaching process. The Baking was performed at 250°C for 2h followed by leaching at 75°C for 2h in DI water. 98% of the Sc was recovered; up to 40% improvement over a contemporary single-step acid bake-water leach process.

SESSION 16 (14:00-15:00)
CLEAN COAL AND GAS TO FUELS – 2 & POWER PLANTS

Dr. Zhuowu Men, Asso. Prof. Dr. Fırat Burat

16.1 (14:00-14:20) Application of a Novel Gasification Technology with Carbon Capture and Utilization for the Production of Clean Fuels

Gary Williams, CEO, TCG Projects (Pty) Ltd, Pretoria, SOUTH AFRICA

Anthony Williams, Technical, TCG Projects (Pty) Ltd, Cape Town, SOUTH AFRICA

TCG Projects has patented gasification technology that consists firstly of an oxygen-starved pyrolysis chamber with an internal jacket heater and a gas recycle system. Hot pyrolysis gas is taken out, heated and then put into a high temperature blower for internal recycle to achieve appropriate heat flux in the pyrolysis chamber. To achieve zero carbon emissions, hydrogen is separated from the syngas, produced by the gasifier system, and used as the combustion fuel for the recycle gas heating. The solid feed material entering the pyrolysis chamber is fed counter-directionally to the recycle gas to take advantage of the Log Mean Temperature Difference of the solids and the gas. Pyrolysis produces carbon char and ash which then moves into a separate, externally heated gasification reactor, which gasifies the solid carbon. Next, ionized water is injected into a steam reformer and through the water shift reaction, syngas is produced. The hot syngas is water quenched and scrubbed in a proprietary, ionized water treatment system. The exiting syngas passes through a filter (set of cyclones in a pressure vessel) where ash removal occurs. This results in a clean, dry syngas, with no liquid discharge, from the process. Carbon dioxide is then separated from the syngas in an amine scrubber. The carbon dioxide free syngas then passes through a PSA to separate out the hydrogen, with the lean tailgas being available as a fuel for on-site use. The carbon dioxide and hydrogen are suitable for use as feedstock for various chemical production processes, including methanol, methanation to produce synthetic natural gas (SNG), and production of ammonia, which can be further converted to urea

16.2 (14:20-14:40) Gasification of Coal and Biomass to Generate Net-Negative Carbon Electric Power and Hydrogen

S. Can Gülen, Bechtel Fellow, Bechtel Infrastructure & Power, Inc., Reston, VA USA
Babul Patel, NexantECA, Inc.
Dennis Leppin, P.E., GTI Energy
Horst Hack, EPRI, Inc.
Roman Estrada, Nebraska Public Power District

This paper describes the development of a coal plant concept to co-produce electric power and hydrogen with net-negative CO2 emissions under the aegis of the 21st Century Power Plants initiative of the U.S. Department of Energy (DOE), whose goal is to advance innovative power plant concepts that are capable of flexible, net-zero carbon emission operations while producing cost-effective "blue" hydrogen to support economy-wide decarbonization goals. The proposed standalone plant will be in Nebraska, USA. The specified design feedstock is a hybrid blend of Powder River Basin (PRB) subbituminous coal from Wyoming and local Nebraska biomass (corn stover), 50 wt.% (dry basis). Other potential feedstocks, including woody biomass (eastern red cedar) and waste plastic (auto shredder residue) were evaluated or reviewed as alternates. The proposed process block comprises a high-pressure, oxygen-blown fluidized bed gasifier (GTI Energy U-GAS process) coupled with water-gas shift, the Selexol process for acid gas (H2S and CO2) removal, and pressure-swing adsorption (PSA) to yield 8,500 kg/h of high-purity hydrogen. The off gas from the PSA unit is used in the power block (gas turbine combined cycle) to generate electric power to support the gasification process, hydrogen production, and 50 MWe net electric power to the grid. All major plant equipment including the gasifier, gas cleanup system, and power generation are commercially available and proven in other applications and considered at TRL 8-9. Overall thermal efficiency of the plant is 50% (HHV) with net atmospheric CO2 removal at a rate of 32 t/h. Design activities necessary to provide input to a FEED study (Phase II of the project), including the development of the Environmental Information Volume (EIV) for the host site, and an investment case, based on a pro-forma pre-FEED level cost estimate, have been completed and are described in detail in this paper.

16.3 (14:40-15:00) Ash Fouling Free Regenerative Air Preheater for Solid Fuel Combustion

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The regenerative air preheater is one of the most widely used pieces of heat-recovery equipment in solid-based energy conversion to achieve high thermal efficiency. Practically, its heat transfer efficiency decreases due to gradual ash fouling (e.g., combustion residue) over time. For coal-fired power plants operated at low loads with selective catalytic reduction (SCR) in service all season long, the fouling tends to penetrate much further from the cold end into the intermediate layer of heating elements. This is very difficult to clean out with a conventional soot blower technique. This is because the ammonia bisulfate (ABS), produced from unreacted ammonia and SO3 in the flue gas, enhanced by SCR, solidifies and attaches to the heating elements at temperatures below ~370 °F, which occurs at the intermediate and cold end heating element layer during these operating conditions. The University of Kentucky (UKy) proposed a cost-effective and simple way to achieve fouling-free operation with an in-situ auto-cleaning (temperature-swing) technique that requires only minor modification to an existing regenerative air preheater. The UKy approach is to periodically restrict air flow through a designated semicircular section at the air inlet. No such restriction is included on the flue gas side, so that those heating elements within the designated section continue to be heated by flue gas without being cooled from air. This enables the metal surface temperature of the heating elements to be maintained above 400 °F, allows the ABS to decompose, and prevents the built-up of ash. A 250 kWth pilot scale unit was designed, installed and is being operated at a 460 MWe coal-fired power generation unit. The pilot unit represents one section of the UKy air preheater. Air and flue gas are forced to flow through the heating element counter currently and alternately, to simulate the operation of the revolving regenerative air preheater. The unit has been operated for over 3400 hours, more than 2200 hours with the in-situ auto-cleaning sequence in service. Under conventional operating conditions when the gas outlet temperature falls below 250 °F, the test unit experienced heavy ash built-up. When the in-situ auto-cleaning sequence was in service, the metal surface temperature at the cold end was periodically increased to >520 °F, and the gas outlet temperature was continuously maintained above 250 °F. During this period, the pressure drop across the heating elements remained low, at 1 to 1.5 in wc, suggesting ash built-up was prevented. The in-situ auto-cleaning sequence only requires low frequency self-cleaning action, minimizing the cost of heat transfer efficiency. The overall boiler efficiency can be improved by maintaining a low pressure drop and cost is saved by eliminating power outages for air preheater cleaning.

SESSION 17 (14:00 – 15:00)
SUSTAINABILITY & ENVIRONMENT & CLEAN HYDROGEN

Prof. Sarma Pisupati, Mr. Dündar Ergunalp

17.1. (15:00-15:20) Evaluation of Diesel-Electric Conversion of Excavators; a Case Study of Can Lignite Enterprise, TKI

Mücella Ersoy, Deputy Operation Manager, Turkish Coal Enterprıses (TKI), Address: Çan Lignite Enterprise (CLI), Çan/Çanakkale, TÜRKİYE

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The climate and energy crisis, which is one of the most important problems of today's world, has made it necessary for almost all countries to turn to clean energy use and energy efficiency. This study focuses on the diesel-electricity conversion of excavators, which is one of the most important machines of mining activities, for both clean energy use and energy efficiency purposes.

When the literature on excavators is evaluated, it was seen that the literature mainly focuses on the recovery of the energy used by the excavators and the energy efficiency in diesel-electric conversion is put into the background. In this study, the energy efficiency and loading performance of excavators after diesel-electric conversion were investigated through field studies carried out at Can Lignite Enterprise (CLI).

At the beginning of the study; CLİ, one of TKİ's important coal enterprises, was introduced briefly. The production activities of the CLI are carried out by the excavator-truck method at Can Open Pit Mine. Annual lignite production capacity of the Enterprise is 3-5 million tons. The lignite produced by CLI is mainly consumed by two thermal power plants having capacities 2x160 MW and 330 MW respectively.

In 2020, one of the 2 diesel-powered Hitachi EX 1200 5D excavators was converted into electricity within the scope of energy efficiency and clean energy use. After conversion, energy consumption of diesel and electric excavators under similar operating conditions were investigated. The detailed research results of one year (2022) showed that the energy consumption of the electric excavator is 66.8% less than the energy consumption of the diesel excavator under similar conditions. When the energy, engine oil and oil filter advantages of the electric excavator are evaluated together with the sales prices of parts such as diesel engine, radiator and battery after conversion, the return on investment was calculated as 641 hours. In addition, when the loading data of the excavator before (2018-2019) and after the conversion were compared, it was determined that the loading performance of the excavator increased by 22.6% after the conversion.

12.2. (17:00-17:20) Numerical Analysis of Ammonia Cracker Using Porous Catalyst for Hydrogen Production

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Professor/Director, School of Mechanical Engineering/Pusan Clean Energy Research Institute, Pusan National University, Busandaehak-ro 63 beon-gil, Geumjeong-gu,

There are many technical problems in the hydrogen energy supply industry. The representative technical problem in the hydrogen society is the difficulty of securing the economy of hydrogen storage and long-distance transportation. To overcome this, hydrogen carriers that can convert hydrogen to other forms of compounds to increase the storage capacity per unit volume and reduce the economic cost are being actively researched. In particular, ammonia is attracting attention as a very suitable substance because it has many practical advantages among hydrogen carriers. Therefore, a technology to decompose ammonia into high-purity hydrogen is necessary to construct a large-capacity hydrogen infrastructure. There are various techniques for decomposing ammonia into hydrogen, and among them, research on thermochemical decomposition, which is the most efficient method for decomposing ammonia, is being actively researched. In this research, numerical analysis was performed inside the ammonia pyrolysis reactor. which is a device that efficiently decomposes ammonia by a thermochemical method. Momentum, energy, mass conservation equations, realizable k– ε turbulence model, discrete ordinate radiation model and Eddy-dissipation model were used for the numerical analysis models. The flow and heat transfer inside the combustor were analyzed through numerical analysis, and the cause of the non-uniform temperature distribution inside the reactor was identified. In addition, flow and heat transfer characteristics according to the presence or absence of a Ru catalyst inside the reactor were confirmed. Through this research, various advantages of internal heat transfer and use of Ru catalyst were confirmed. and it can influence efficient hydrogen production and design of large ammonia pyrolysis reactor in the future.

12.3. (17:20-17:40) Production of Ultra-Clean Hydrogen from Deep Coal Seams

Michael S. Blinderman,
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The proprietary Enhanced Hydrogen Recovery (EHR™) technology for production of “the greenest blue hydrogen” and a plethora of other ultra-low-carbon products integrates elements of in-situ gasification with a novel carbon capture, use and sequestration approach. Deep unminable coal seams serve both as a source of hydrogen-rich syngas and a potent sink for any surplus carbon.

The conceptual designs, energy efficiency, and carbon efficiency of EHR™ process are considered using modeling of commercial-scale plants producing clean hydrogen, methanol, ammonia, and single-cell proteins. Financial modeling suggests that the costs of these products are lower than the incumbents with much larger carbon footprints.

The EHR™ technology is implemented in a clean hydrogen commercial plant being built by Cvictus Inc. in Alberta, Canada. The process occurs in a 12m thick sub-bituminous coal seam at the depth of 1500m. Fully integrated plant with initial hydrogen capacity of 7 tonnes per day is scheduled for commissioning in the second half of 2024.

The proof-of-concept test of the EHR™ process was conducted on site of the future hydrogen plant from October 2021 through March 2022. A total of four wells were engaged in the test, including one for CO2 injection and three for monitoring, one of which could also serve for production. As part of the test, over 1500 metric tonnes of supercritical CO2 were injected into the Mannville coal seam with a flow rate of up to 17.6 tonnes per hour. The monitoring system included multiple sensors of formation fluid pressure, temperature, and composition. Two types of seismic sources and a fiber optics receiver were used in the efforts to follow the spread of the CO2 plume. The results of processing the CO2 injection test data confirm the viability of EHR™ technology and suggest that deep coal seams should play a very prominent role in the sequestration of industrial carbon streams.

SESSION 18 (14:00-15:20)
RARE EARTH ELEMENT - 2
Dr. Satya Chauhan, Prof. Dr. Murat Olgaç Kangal

18.1. (14:00-14:20) Investigation of the Relationships Between Coal Based Samples’ Grindabilty and Their Ree Contents

Mehmet BİLEN, Assoc. Prof. Dr. Zonguldak Bülent Ecevit University, TURKIYE

Deniz TALAN, Asst. Prof. Dr. West Virginia University, USA

Rare earth elements (REEs) play an important role both in defense industry applications and in the production of advanced technology products. Recent studies emphasize that coal and coal by-products could be a potential source of raw materials for these elements. REEs are present in coal in ion adsorbed and/or ion-substituted and organic-bound forms in autogenic or clastic mineral forms. Coal grindability can be considered a parameter based on the abovementioned structure of coal and its chemical composition. Since many parameters affect the grindability index value of coal, literature studies indicate significant relationships between the chemical composition of coal and its grindability. While the chemical composition of coal is mostly addressed in terms of grindability and fusibility of ash, REEs with low concentrations in coal and coal wastes have never been considered in this context. In this study, the contents of REEs in coal and coal wastes according to their grindability differences will be investigated. Evaluation of the differences in the grindability index values of coal and coal wastes and the differences in REE content will provide guiding data for better selection of promising samples in terms of extraction potential from alternative sources.

18.2. (14:20-14:40) Characterization of REE and Coal in İmbat Coal Washing Wastes in Soma Region

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Rare earth elements (REEs) have a wide range of uses and strategic importance thanks to their properties. China, which is the leading country in rare earth element (REE) production and reserves, has imposed restrictions on exports, creating a need for resources for high technology-producing countries. Therefore, interest in secondary sources has increased in recent years to meet the growing demand for REEs. These sources consist of coal-fired thermal power plant waste, coal washing waste, ore enrichment plant waste, by-products from phosphate-producing mining sites, and electronic waste. The type, character and discharge limits of these wastes are very important for successful waste management. In addition, methods developed to eliminate these solid, liquid and gaseous wastes for the Zero Waste process target are important. The recovery of the coal in these waste materials will reduce the waste storage problems and cost. After all, the coal in the waste is an energy source. It is very important to establish technologies and processes that will enable the selective extraction of coal and REE from coal and coal by-products, which is a reliable and cheap energy source. In Türkiye, there is significant potential for gaining coal and REE from coal by-produts. Therefore, in this study, firstly, characterization studies were carried out to determine the potential REE and coal content of the Imbat washing plant slurry sample. X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) analyses were performed to determine the major oxide and REE contents. While the total REE content of the slurry sample was 146 g/t, it decreases to 20 g/t in coarse sizes and increases to 184 g/t in fine sizes with a recovery of about 93%. According to the particle size analysis, the d80 size of the slime sample was found about 57 µm, and approximately 75% of the amount was below 38 µm. The particle size analysis showed that as the fraction size decreases, the REE content increases in parallel with the increase in ash, Al2O3, and SiO2 content. For coarse particle size fraction, preliminary physical beneficiation tests were performed to enhance the content of coal. As a result of the coarse particle size enrichment test, approximately 77% of the feed material was obtained at a calorific value of approximately 5800 kcal/kg.

18.3. (14:40-15:00) The Mode of Occurrence of Vanadium (V) in Sinanpaşa coal (Afyonkarahisar, Türkiye)

Naşide Merve SÜTÇÜ, Research Assistant, ITU, TÜRKİYE
Mustafa Kumral, Prof. Dr., ITU, TÜRKİYE
Ali Tuğcan Ünlüer, Research Assistant, ITU, TÜRKİYE
Zeynep Döner, Ass. Prof. Dr., ITU, TÜRKİYE

Considering it is feasible to extract and offer a wealth of domestic resources, coal resources, one of TÜRKİYE's most vital energy resources, continue to be in higher demand yearly. Considerable research has been put into investigating the possibility of removing critical elements such as rare earth elements, U, V, Ga, Ge, etc. from coal mines in the context of promoting environmental sustainability and renewable energy options. Vanadium stands out as a particularly significant resource among these elements. Due to its many uses, including vanadium redox batteries, the transition metal vanadium shows great promise. In this context, Sinanpaşa (Afyonkarahisar, Türkiye) coal occurrences can attract attention to the economic possibilities of vanadium related to the Plio-Miocene aged extensional tectonic regime. The studied outcrop coal samples were collected for analysis. The vanadium contents of studied coals are up to 274 µg/g. The vanadium in this basin is considered a strata-hosted V-U deposition. The V element positively correlated with As, Mo, U, and P. There is a lack of correlation with REE, Th, Cr, Fe, Ni, Al, and Si. These elements are mostly mobilized by hydrothermal fluids percolating through highly permeable volcanic and volcanoclastic rocks. The mediocre to high As values indicate the effect of meteoric hydrothermal solutions that were expelled from cooling felsic-volcanic rocks. The precipitation process, on the other hand, is triggered by the extreme reducing conditions that took place in the upper parts of coal seams and it can be supported by high values of Mo and S contents. On the contrary rare earths excluding Ce and fluid immobile Zr are pretty low, and the detrital contribution is not very high. The Ce enrichment is probably caused by the terrestrial sediments that contain immobile Ce+4 ions that moved into the coalification environment.

Keywords: Vanadium, Uranium, Sinanpaşa coal, Strata-hosted V-U deposition, Afyonkarahisar-Türkiye

18.4. (15:00-15:20) Depression AND Dewatering Characteristics of Kaolinite IN Electrolyte Concentrated Process Water: a Perspective for Water Recirculation in Coal Flotation and Tailings Dewatering

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Kaolinite, a phyllosilicate clay mineral, is present in significant quantities as a gangue mineral in most South African coal ultrafines. The presence of kaolinite in coal ultrafines poses serious challenges in coal processing due to its adverse effects on the flotation process and the quality of the final coal product. Efficient depression of kaolinite is thus necessary to separate it from ultrafine coal particles during flotation. Furthermore, considerations for closed water circuits in coal flotation and dry stacking of tailings have gained much prominence owing to the need to minimise water consumption and enhance waste management practice in line with SDG 6, 12, 13 and 14. Therefore, it stands to reason that effective depression of kaolinite during coal flotation is crucial in achieving high-quality coal products with reduced impurities. This research considers kaolinite depression and dewatering characteristics in inorganic electrolyte concentrated process water in view of process water recirculation in coal flotation and the need for dry stacking of mine tailings. This research focuses on the strategies that coal mine operations need to employ to depress kaolinite for the implementation of closed water circuits and explores kaolinite dewatering characteristics as these are important when considering dry stacking of coal mine tailings generated from the processing of coal ultrafines. Understanding the behavior of kaolinite in these contexts is vital for sustainable coal processing and environmental stewardship.

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4th Annual - 1987	$30.00
5th Annual - 1988	$30.00
6th Annual - 1989	$30.00
7th Annual - 1990	$30.00
8th Annual - 1991	$30.00
9th Annual - 1992	$30.00
10th Annual - 1993	$30.00
11th Annual - 1994	$30.00
12th Annual - 1995	$30.00
13th Annual - 1996	$30.00
14th Annual - 1997	$30.00
15th Annual - 1998	$30.00
16th Annual - 1999	$30.00
17th Annual - 2000	$30.00
18th Annual - 2001	$30.00
19th Annual - 2002	$30.00
20th Annual - 2003	$30.00
21st Annual - 2004	$30.00
22nd Annual - 2005	$30.00
23rd Annual - 2006	$30.00
24th Annual - 2007	$30.00
25th Annual - 2008	$30.00
26th Annual - 2009	$30.00
27th Annual - 2010	$30.00
28th Annual - 2011	$30.00
29th Annual - 2012	$30.00
30th Annual - 2013	$30.00
31st Annual - 2014	$30.00
32nd Annual - 2015	$30.00
33rd Annual – 2016	$30.00
34th Annual – 2017	$30.00
35th Annual – 2018	$30.00
36th Annual – 2019	$50.00
37th Annual – 2020	$50.00
38th Annual – 2021	$50.00
39th Annual – 2022	$50.00
40th Annual – 2023	$50.00

ANNOUNCING

FORTY-FIRST ANNUAL INTERNATIONAL PITTSBURGH COAL CONFERENCE

Hosted by:

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Location: TBA
Date: TBA

Abstracts must be submitted by March 1, 2024. Please submit a one-page abstract, including title, topic area, authors, affiliations, and contact information via a valid email address to: Conference Office: ipcc@pitt.edu

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