## Scope of the Lecture

1. World balance of primary energy sources; General characteristics of solid fuel conversion processes, status and perspective of gasification technologies.
2. Solid fuels for gasification processes: characteristics, classification and methods of laboratory analysis.
3. Fundamentals of biomass and coal gasification: mechanism and reactions of gasification, coal and biomass pyrolysis, thermodynamic and kinetic aspects of gasification, bed types, feed systems, process classification, process selection, gasification criteria, co-firing.
4. Overview of industrial gasification technologies.
5. Unit operations in production systems integrated with solid fuel gasification;
    a) Coal/fuel upgrading,
    b) Oxygen production,
    c) Gas conversion and cleaning, gas quality requirements for chemical syntheses and IGCC
6. Environmental performance of coal gasification; air emissions, solid by products utilization
7. Power systems
    a) Combustion processes (IC, Gas turbines, steam cycles)
    b) Integrated Gasification Combined Cycle (IGCC),
    c) CHP systems
8. Chemical systems
    a) Hydrogen production,
        i. Solid fuel/coal gasification
        ii. NG reforming (steam/oxygen)
        iii. Coke oven to hydrogen
    b) methanol production - gasification
9. UCG – Underground coal gasification.
10. Biomass gasification: type of fuel, fuel input, application, feedstock related problems
11. Overview of commercial gasification technologies of biomass gasification and co-gasification of coal and biomass.
12. Techno-economic assessment of coal gasification processes
13. Development directions; new technologies; R&D activities in Poland.

## Description of the lecture

1. The group will be divided into 6-person teams (identical with teams operating during the “Project” class – modeling of gasification processes in ChemCAD).
2. The lecture - 1.5h (2x45 min) will be divided into two parts:
    a. The first approximately 45min -1h will be the traditional lecture in form of slide show,
    b. The second is a short test in the scope of current and / or previous lectures or work on special projects related to the scope of the lecture (PBL).
3. The test will contain approximately 5 multi-choice questions. After writing the tests, the selected team will present and comment the answers. The tests will prepare students for final test at the end of semester (part of the exam).
4. The topics of projects will be prepared individually for each of the project group (projects for classes 2018 is attached below).
5. Work on the projects will include: discussion on current status, problems, proposed solutions etc.
6. During the semester each group will present results of the work twice: in the middle and at the end of the project implementation (see detailed schedule of the meetings)
7. Students will prepare projects (in groups) on the basis of knowledge from the lecture and literature review and independently acquired knowledge from their own analyzes.
8. Two meetings (4x45 min) will be prepared by students and will include 30-minute presentations (10 minutes of discussions) of results of the projects developed by them. The results, the knowledge and skills received will be helpful during the "ChemCAD – Project" meetings (see short description bellow)
9. One meeting will have the character of an Oxford debate - Details below.

***Basic schedule of the lecture***

| No of the lecture | Scope | Test | Project work/presentation |
|---|---|---|---|
| 1 and 2 | 1. Introduction<br>2. World balance of primary energy sources; General characteristics of solid fuel conversion processes, status and perspective of gasification technologies.<br>2. Solid fuels for gasification processes: characteristics, classification and methods of laboratory analysis. | No | Team work |
| 3 and 4 | 3a. Fundamentals of biomass and coal gasification: mechanism and reactions of gasification, coal and biomass pyrolysis, bed types, feed systems, process classification, process selection, gasification criteria, co-firing. | Yes | Team work |
| 5 and 6 | 3b. Thermodynamic and kinetic aspects of gasification | | Team work |
| 7 and 8 | 4a. Overview of industrial gasification technologies | Yes | Team work |
| 9 and 10 | 4b. Overview of industrial gasification technologies | No | Presentation team #1 |
| 11 and 12 | 4c. Overview of industrial gasification technologies<br>5a. Unit operations in production systems integrated with solid fuel gasification; | No | Presentation team #2<br>Presentation team #3 |
| 13 and 14 | 5a. Unit operations in production systems integrated with solid fuel gasification; | No | Presentation team #4<br>Presentation team #5 |
| 15 and 16 | 6. Environmental performance of coal gasification; air emissions, solid by products utilization | Yes | Team work |
| 17 and 18 | 7. Power systems<br>a. Combustion processes (IC, Gas turbines, steam cycles)<br>b. Integrated Gasification Combined Cycle (IGCC),<br>c. CHP systems | Yes | Team work |
| 19 and 20 | 8. Chemical systems<br>a. Hydrogen production,<br>i. Solid fuel/coal gasification<br>ii. NG reforming (steam/oxygen)<br>iii. Coke oven to hydrogen<br>b. methanol production - gasification | Yes | Team work |
| 21 and 22 | Students project presentation and discussion (2/3 groups) | - | |
| 23 and 24 | Students project presentation and discussion (2/3 groups) | - | |

| | | | |
|---|---|---|---|
| 25 and 26 | 9. UCG – Underground coal gasification.<br>10. Biomass gasification: type of fuel, fuel input, application, feedstock related problems<br>11. Overview of commercial gasification technologies of biomass gasification and co-gasification of coal and biomass. | Yes | |
| 27 and 28 | Oxford Debate | - | |
| 29 and 30 | 12. Techno-economic assessment of coal gasification processes<br>13. Development directions; new technologies; R&D activities in Poland. | Yes | |

***Test:***

*Example of test questions:*

The main product of the coal gasification is gas, which is a fuel or chemical feedstock. In the case of oxygen gasification, main components of produced gas are:

| | |
|---|---|
| 0 | a) CO2 and water |
| 1 | b) H2: molar concentration 25 - 30 %, |
| 3 | c) CO and H2: total volume fraction 50 - 90% and in lower amount of water and carbon dioxide, |
| 2 | d) CO and H2 |

**Student projects:**

***Project no 1: Why air gasification could be better for industrial power system.***

Key issues/ content:

1. Advantages of oxygen and air gasification
2. Selected examples of IGCC systems
    a. Detailed description / diagrams
    b. Gasification and power generation efficiency
    c. Application possibilities
    d. Investment and operating costs
3. Summary

The project should be based on scientific publications, eg Elsevier database, NETL sources and others.

***Project no 2: How to decrease $CO_2$ emission from IGCC Plant without $CO_2$ separation***

Key issues/ content:

1. Development of a parametric model for calculating relative CO2 emissions from the IGCC system (Excel)
2. The model should take in to account:
    a. The efficiency of electricity generation
    b. Fuel selection (in the context of its CO2 emissivity)
    c. Parameters and Fuel consumption
    d. Analysis of CO2 reduction possibilities
        i. Efficiency Increase
        ii. Selection of fuels including renewable and waste
3. Summary

The project should be based on scientific publications, eg Elsevier database, NETL sources and others.

***Project no 3: Concept of the hydrogen production plant integrated with coal gasification***

Key issues/ content:

1. Development of the concept of a hydrogen production system integrated with coal gasification
    a. Selection of main technological nodes and their process parameters
    b. Development of a parametric model for hydrogen production using coal gasification (assuming a representative composition of raw gas)
    c. The model should include:
        i. Parameters of the CO-shift process

ii. The efficiency of CO2 separation
iii. The efficiency of H2 separation

2. Analysis of the process parameters on hydrogen production efficiency
3. Determination of the relative CO2 emission (direct emission).
    a. Determination of the influence of CO2 emissions on the hydrogen production cost.
4. Summary

The project should be based on scientific publications, eg Elsevier database, NETL sources and others.

***Project no 4: Development of the tool for power consumption and investment costs estimation of hydrogen production plant***

Key issues/ content:

1. Literature review - data acquisition
    a. electric energy consumption in relation to process parameters for basic technological nodes
    b. Investment costs of the basic technological nodes
2. Development - adoption of a method for estimating energy consumption and investment costs
3. Summary

The project should be based on scientific publications, eg Elsevier database, NETL sources and others.

***Project no 5: How to choose proper gasification technology for different coals. Elaboration of the selection diagram***

Key issues/ content:

1. Analysis of literature and development of a decision diagram
    a. Justification of the adopted selection algorithm
2. The algorithm should include:
    a. Solid, fluid bed and entrained flow reactors
    b. Hard coal, lignite, biomass etc.
    b. Application of the system: production of energy, chemical substances
    c. CO2 separation
3. Summary

The project should be based on scientific publications, eg Elsevier database, NETL sources and others.

## ***Oxford Debate***

1. General rules:
    a. At the beginning of the classes, the thesis of the debate will be announced.
    b. Proposed theses will be closely related to the subject of lecture.
    c. The proposed theses are:
        i. "Coal combustion is more attractive technology than coal gasification"
        ii. "The use of fossil fuels does not contribute to global warming"
        iii. "Entrained flow gasification is more attractive than fluidized bed gasification"
    d. Students will choose two teams (5 person each)
    e. A Jury will be selected from the students (five person)
    f. Other students will be play the role of the audience (about 15 people)
    g. The external guests will be also invited
        i. The proposed guests include prof. Wojciech Nowak (director of the AGH Energy Center), prof. Marek Ściążko (Scientific secretary at the IChPW), and research workers from the Department of Fuel Technology at WEiP AGH and from the Institute for Chemical Processing of Coal.
    h. The lecturer will choose the Chairman (who will conduct the debate and ensure observance of the rules) and the secretary of the debate.
    i. The time of the debate is 1 hour
    j. Before the debate the teams “for the thesis” and “against the thesis” will be drawn.

2. The rules of assessment
    a. The evaluation will be carried out by voting
    b. Voting will take place using specially prepared forms.
    c. Three votes will take place (Vote: the audience, the chairman and the secretary)
        i. First vote: For the thesis before the debate
        ii. Second vote for the thesis after the debate
        iii. Third for the best team
    d. The award for winning the debate will be a diploma
3. The course of the debate
    a. Welcome of all participants by the Chairman - presentation of participants, with special emphasis on external guests.

b. Draw of teams for and against the thesis. Teams know the thesis of the debate before meeting, but they do not know whether they will defend its or whether they will be its opponents
c. After the draw, the teams go for a 10-minute consultation (outside the room).
d. During the consultation of the parties, the Chairmen give the floor to the Secretary, who explains to the public the rules of the debate and voting procedure.
e. The Chairman starts the first vote - for the main thesis. Voting takes place by raising hands - for / against / abstention. The secretary counts the votes . The result will be announced after the debate.
f. The parties return and the Chairmen orders the beginning of the debate by giving the floor to the first speaker for the Proposition.
g. From this moment, the parties speak alternately (according to the rules of organization of the debate described at the beginning by the Secretary).
h. Each of the speakers has about five minutes to speak
i. The last speaker from each team ends the speech with a summary of the team's argumentation.
j. After completing the summaries, the Chairman orders the next votes - first on the thesis, then on the winner and gives the floor to the Secretary who reiterates the voting rules.
k. Voting in the presence of teams is secret and takes place using the prepared forms.
l. After collecting and counting the votes from the audience and the Jury, the Secretary shall provide information about the results to the Chairman (on the page).
m. The Chairman announces the results - first, which thesis won before and after the debate, and then which team won.
n. The Chairman and the Secretary congratulate the participants and give the diplomas.
o. Thank you to the audience (Chairman) ends the debate.

## ***Description of the class: project - ChemCAD***

- Students will design the flow sheet of coal gasification technology in ChemCad process simulator.
  - Raw gas production system with $CO_2$ separation option
  - The system includes: coal drying, gasifier, gas cooling, CO-shift process, $H_2S$ i $CO_2$ removal (parametric model) and $CO_2$ compression.
- Students then will calculate basic process parameters
  - Cold gas efficiency
  - Conversion efficiency (CO-shift process)
- and prepare:
  - Mass balance
  - Elemental balance
  - Energy balance
- The results should by prepared in form of the short report

## ***Overarching Learning Outcomes***

**• Innovation skills and competencies (EIT OLO 4) The ability to use knowledge, ideas and technology to create new or significantly improved products, services, processes, policies, new business models or jobs.**

**• Research skills and competencies (EIT OLO 5) The ability to use cutting-edge research methods, processes and techniques towards new venture creation and growth and to apply these also in cross-disciplinary teams and contexts.**

**• Intellectual transforming skills and competencies (EIT OLO 6) The ability to transform practical experiences into research problems and challenges.**