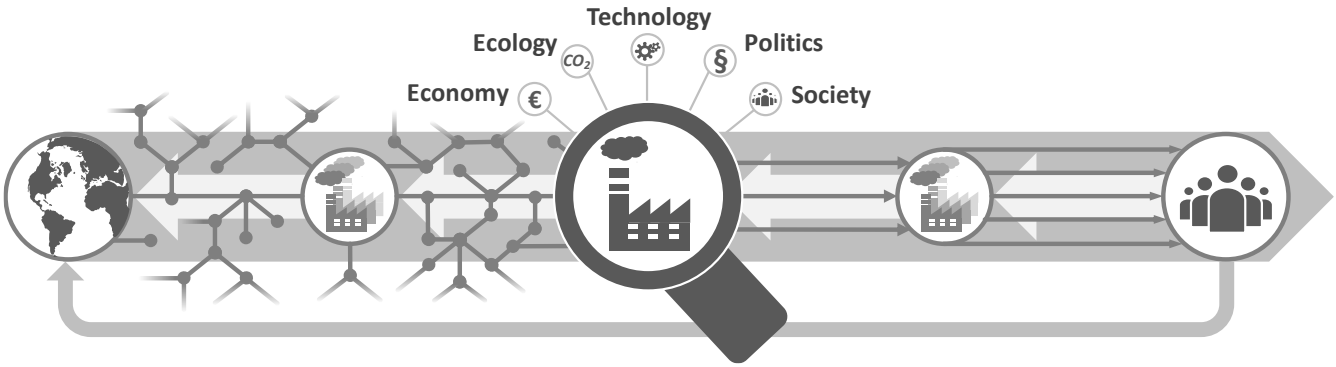
Karlsruher Institut für Technologie

Institute for Industrial Production (IIP)
Chair of Business Administration,
Production and Operations Management
Prof. Dr. Frank Schultmann

Seminar in Summer Semester 2024
Research Group "Sustainable Value Chains"



Design of Industrial Plants and Processes

Background and objectives

The design and optimization of industrial plants and processes stand at the core of engineering excellence and strategic management. This endeavor necessitates an in-depth understanding of both sophisticated engineering concepts and vital economic strategies, indispensable for the successful execution and sustainable operation of industrial enterprises. Given the increasing complexity of global supply chains, rapid technological advancements, and growing pressure towards more sustainable processing methods, the seminar offers business engineers insights into the integration of interdisciplinary knowledge to review innovative industrial solutions. Seminar participants will gain valuable insights into the strategic planning and technological innovations shaping the future of industrial design and process management.

Central to the seminar's curriculum is the requirement to develop case studies and lecture exercises. This hands-on approach not only reinforces theoretical knowledge but also enhances practical skills in real-world problem-solving. By researching, designing, and presenting case studies, students will delve into current industrial challenges, exploring topics such as new industrial concepts (e.g. biorefineries), the implementation of sustainability principles (e.g. CSRD), and the application of advanced evaluation metrics for providing multi-criteria decision support (e.g. MCDA).


Source: Mineralölwirtschaftsverband e.V.

Preparation and assessment

The students work in groups on assigned scientific topics. Some literature will be provided, but should be supplemented by the students' own research. Participation in the seminar includes the preparation of case studies and lecture exercises, which are summarized in a seminar paper and presented at the end of the semester. The assessment of the work is based on both the written seminar paper and the presentations given, which must be in English.

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Topic A
Sustainability in Industrial Plants and Processes

Sustainability and regulatory aspects hold paramount importance in the design of industrial plants and processes for several compelling reasons, reflecting the evolving landscape of global manufacturing practices, environmental concerns, and legal frameworks governing industrial activities. Their relevance stems from both ethical considerations and pragmatic business imperatives, influencing every phase of the industrial design and process management lifecycle by covering environmental stewardship and social responsibility, by increasing economic efficiency and competitive advantage, by fulfilling compliance and regulatory requirements, by driving innovation and technological advancement, and by applying Supply Chain sustainability principles.

Within the framework of the seminar topic A, a maximum of three students will elaborate on the **case study of a medium-sized chemical manufacturing plant**, operating for over two decades, which faces increasing pressure from environmental regulations and market demands for sustainable products. The plant is located in an industrial zone near a large urban area, with growing environmental footprint concerns, particularly air and water pollution. The primary objective is to retrofit the chemical plant to not only meet the new environmental standards and enhance its sustainability profile but also to comply with the CSRD requirements, ensuring transparent reporting and communication of its sustainability practices and impacts.

The following activities shall be performed during the seminar:

1. **CSRD Compliance Analysis**: Identify the specific requirements of the CSRD that are applicable to the chemical manufacturing plant.
2. **Reporting Framework Development**: Design a comprehensive sustainability reporting framework based on CSRD guidelines containing indicators and metrics for reporting on emissions, waste management, energy usage, and social impacts.
3. **Technological and Process Innovation**: Propose and evaluate technological solutions that not only enhance the plant's sustainability but also contribute to robust CSRD compliance.
4. **Economic Implications**: Conduct a financial analysis to estimate the costs associated with retrofitting the plant for CSRD compliance and sustainability improvements.
5. **Lecture slides and exercises:** Prepare education material to introduce sustainability in a lecture dealing with the design of industrial plants and processes.

Supervisor

Dr. Andreas Rudi; E-Mail: andreas.rudi@kit.edu, Tel.: 0721 628-44568

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Topic B
Green Refinery: Shaping Sustainable Solutions for the Future

By 2045, Germany targets climate neutrality, particularly in the transport, chemicals, and refining sectors. Meeting renewable energy demand, especially in challenging sectors like shipping and aviation, necessitates substantially increasing renewable fuel supply. However, a multifaceted approach involving sustainable transport, electric vehicles, and diverse renewable fuel sources is crucial for a successful transition due to limitations in renewable energy and fuels. These **renewable fuels** are often produced alongside other by-products using various technologies and feedstocks.

In **seminar topic B**, three students will explore a case study on a newly established green refinery or retrofitting an existing one, potentially like the MiRO in Karlsruhe. They'll focus on the viability of two new feedstocks, **Methanol and Fischer-Tropsch Crude**, aiming to identify products, estimate costs, and assess ecological impacts. Students will calculate Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) for the “Green Refinery" and conduct a concise techno-economic analysis using the Net Present Value (NPV) method. Armed with this knowledge, they will decide on the more profitable feedstock.

The following activities shall be performed during the seminar:

Select Technology and Process	•Generate the flow sheets for the different process routes with the most important feedstocks, products (mass and energy balances).
Integration	•Integrate the 2 most promising process routes into an existing refinery.
Economic Implications	•Conduct a financial analysis to estimate costs and profits: CAPEX, OPEX, NPV, and energy efficiency analysis.
Ecological Implications	•Conduct ecological effects by utilizing Methanol and FT-crude as feedstock.
Lecture slides and exercises	•Prepare education material to introduce a Green Refinery in a lecture dealing with the design of industrial plants and processes.

Supervisor

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Topic C
Conception of a Power-to-Methanol Production Plant

Its wide range of application causes methanol (MeOH) as one of the most commonly used basic chemicals worldwide. Today, MeOH is predominantly produced by conventional processes using fossil resources, while the contribution of renewable methanol production technologies is non-substantial. Facing global sustainability goals it is inevitable to use the leverage of methanol to reduce environmental impacts by accelerating regenerative production technologies. Therefore, in this seminar topic the conception and design of a plant producing methanol based on renewable electricity (Power-to-MeOH) should be developed. A cost estimation and energetic optimization are conducted, giving insights into the techno-economic potential of the process.

In seminar topic C a maximum of three students delve into the case study of a **Power-to-MeOH plant**. The work is basically divided in the following activities:

Conception and design of the production plant
- Define the process, its functional unit and system boundary
- Set of *mass and energy balances*
- Plant and equipment conception

Cost estimation
- Determining the investment costs by *factor methods*
- Quantification of operational costs

Plant optimization
- Identification of energy (heat) flows
- Energetic optimization by *pinch analysis*

Apart from gaining insights into project management and learning about general procedures during the early project phases, the aim of this seminar is to prepare a workflow that can serve as educational material for the design of industrial plants and processes.

Supervisor

M.Sc. Alexander Schneider, E-Mail: alexander.schneider@kit.edu, Tel.: 0721 608 44587

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Topic D
Investment estimate in Industrial Plant Design

Biodiesel and ammonia plants play pivotal roles in sustainable energy and agriculture. Biodiesel, derived from renewable sources, contributes to cleaner transport fuels, reducing environmental impact. Ammonia, a key component in fertilizers, supports global food production. Both industries align with a sustainable future, addressing energy and agricultural challenges. Understanding the financial dynamics of these plants is crucial for informed investments, driving advancements in green energy and food security.

Systematic evaluation of investments plays a pivotal role in shaping the success of plant and process design. This topic delves into the methodologies of investment estimation, focusing on the multifaceted considerations that underpin decision-making in the design of industrial facilities. Understanding and implementing robust investment methods are imperative for business engineers, as they navigate the complexities of resource allocation, cost forecasting, and risk management in the pursuit of optimal plant and process design.

The following activities shall be performed during the seminar by maximal three students:

1. **Plant Component Prices and Price Indices:** Gain a thorough understanding of the processes and plant designs. Investigate current prices of components for both biodiesel and ammonia plants. Research the latest price index values related to these types of chemical plants. Identify reliable sources such as engineering magazines, price index publications, and databases, etc.
2. **Currency Tables:** Gather currency exchange rates, considering potential fluctuations. Create tables highlighting historical trends and current values for relevant currencies.
3. **Investment Estimate Methods:** Familiarize yourself with various investment estimation methods. Choose the most suitable method for each plant, justifying your selection based on project characteristics and financial objectives.
4. **Conduct Investment Estimations:** Implement and apply the selected investment estimation methods in MS Excel to conduct basic financial projections for both biodiesel and ammonia plants while taking parameter uncertainties into account.
5. **Critical Analysis:** Provide a critical analysis of the chosen estimation methods, discussing their strengths and limitations. Evaluate the sensitivity of your projections to changes in component prices, cost indices, and exchange rates.
6. **Lecture slides and exercises:** Prepare education material to introduce investment estimate methods in a lecture dealing with the design of industrial plants and processes.

Supervisor

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Grading

The grading takes several parts into consideration. Both the active participation in the events and the presentation are included in the grade. However, the main part is the written seminar paper, which, like the presentation, is prepared in groups of up to 3 people. The total workload corresponds to 3 ECTS points.

Application

Please apply with a CV, a short letter of motivation and a current transcript of records. Master's students must enclose the final grade transcript from their Bachelor's degree. Please briefly answer the following questions in your letter of motivation:

- Why should you be a participant in this seminar?
- Do you already have previous knowledge?
- What is your favorite topic?
- What do you expect to learn?

If you wish, you can also specify the group members you would like to join in your letter of motivation. However, admission to the seminar is on an individual basis.

Dates

- Kick-Off event: **3 pm, 23. April 2024** at the IIP (Westcampus, Geb. 06.33) in Room 103
- The day of final presentations will be agreed with the seminar participants at the Kick-Off event. The presentations are expected to take place at the end of July or beginning of August.
- Students are required to be present on all days of the event.

Contact for organizational questions:

Dr. Andreas Rudi
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