ENGineering and INdustry Innovative Training for Engineers (ENGINITE)

PROJECT NUMBER
2017-1-CY01-KA202-026728

B3 course

Applied Process and Product Optimization

Prepared by TUC

Co-funded by the Erasmus+ Programme of the European Union

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Contents

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1. PART A: General Information

Title: "Applied Process and Product Optimization"

Keywords (4-5): process optimization, product optimization, sustainability, circular economy, PBL approach

Authors: Prof. Konstantinos Komnitsas

Duration: 1 day online reading/study on Google Classroom, 1 week f2f

Language of materials: English and Greek

Type & number of sessions:

Day 1	• Get to know each other; brief presentation of participants (studies, employment, expertise, etc) • Applied process and product optimization: present the approach, present problems to participants and discuss; reflect on answers • Understanding process, Explain the 2 case studies, select groups, identify who is involved and how, set initial deadlines for subtasks • 20 min discussion
Day 2	• Summarizing progress of day 1 • Set targets for day 2 (for each case study) • Groups members get different roles and targets • Interaction with each group member • Interaction between groups (comparing progress and results) • Assessment of progress • Summary – discussion – need for additional work/corrective action?
Day 3	• Summarizing progress of day 2 • Set targets for day 3 (for each case study) • Groups members get different roles and targets • Interaction with each group member • Interaction between groups (comparing progress and results) • Assessment of progress • Summary - discussion– need for additional work/corrective action?
Day 4	• Summarizing progress of day 3 • Set targets for day 4 (for each case study) • Groups members get different roles and targets • Interaction with each group member • Interaction between groups (comparing progress and results) • Assessment of progress • Summary – discussion – finalizing case studies • Qualitative and quantitative evaluation

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Day 5	• Presentations • Questions and Answers (Q&A) with other groups • Final remarks • Overall assessment of the module • Providing guidelines / explanations / tips for the placement in industries / SMEs • Discussing of potential projects • Closing

Number of participating engineers: 20-25 engineers

Group's setting: Mixed gender, multidisciplinary groups of engineers, 5-7 members in each group (per guidelines of PBL literature)

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2. PART B: Module Overview & Key Learning Outcomes

I. Module Overview

The module aims to enrich engineers' knowledge and capabilities in *Applied Process and Product Optimization* and enable them to successfully participate in or lead complex projects with tight schedule, limited resources, yet with high quality results. Besides, in real-world industrial workplaces parameters constantly change and problems have to be overcome, thus the engineers need to be properly trained. For this purpose, real industrial projects in combination with the Problem Based Learning (PBL) approach will be used during the course, to equip the engineers with the required skills. Great organizational and analytical skills, understanding of leadership, management and teamwork, along with a holistic grasp of the project-at-hand are just some of the capabilities that engineers need and will acquire through this course. Good practices will also be available as participants' tools.

II. Key learning outcomes:

Upon completion of the module, participants will be able to:

- Understand what *Applied Process and Product Optimization* is and its benefits for the business (with particular emphasis on SMEs), the employees and the society, through targeted case studies
- Design and implement the required steps to meet the objectives as well as validate their approach
- Optimize a process by working in one multidisciplinary case study
- Optimize a product by working in one multidisciplinary case study
- Take into account all sustainability issues involved in each case, as required by the principles of sustainable development and circular economy

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3. PART C: Problem – Based - Learning Scenarios

Case Study 1. Optimized Ferronickel (FeNi) production with emphasis on process footprint reduction

a. General Aspects

Ferronickel (FeNi) is predominantly produced from nickeliferous laterite ores which are converted into a product with a nickel content of around 20%. Currently, only 42% of world primary Ni production is processed from laterite ores (oxide ores with approximately 1-2% Ni) mainly through pyrometallurgical routes, with FeNi holding the highest share (~72%) among all nickel-based products. However, pyrometallurgical laterite ore processing is much more energy intensive compared to sulphide ore processing and it results in the production of large volumes of greenhouse gas (GHG) emissions and solid wastes. In its efforts for energy conservation, emission reduction and process sustainability, metal industry has used several approaches to quantify its performance, that include among others Ecological Risk Assessment (ERA), environmental performance and operational indicators, Cost Benefit Analysis (CBA), Materials Flow Analysis (MFA), and Life Cycle Assessment (LCA).
Greece is the only FeNi producer in the European Union, the third largest producer in Europe and one of the seven largest in the world. In 2012, approximately 95,000 t of granulated FeNi with 20% average Ni content were produced by the General Mining and Metallurgical S. A. LARCO from domestic nickeliferous laterite ore deposits. Ferronickel production at LARCO accounts for 32% and 4% of the European and world production, respectively and covers nearly 5% of the European annual market Ni demand.

b. Objectives

You have to find all required information which is pertinent to the following objectives

1. Understand the process
2. Find options to reduce cost
3. Find options to reduce energy consumption and environmental footprint

c. Period of Implementation

1 week

d. Potential Plan

You may use the following steps

1. Check all inputs – outputs
2. Carry out, if possible, and energy balance per sub-process
3. Consider aspects such as raw materials production, transport, waste management etc)
4. Calculate (or estimate), if possible, Greenhouse (GHG) emissions per process

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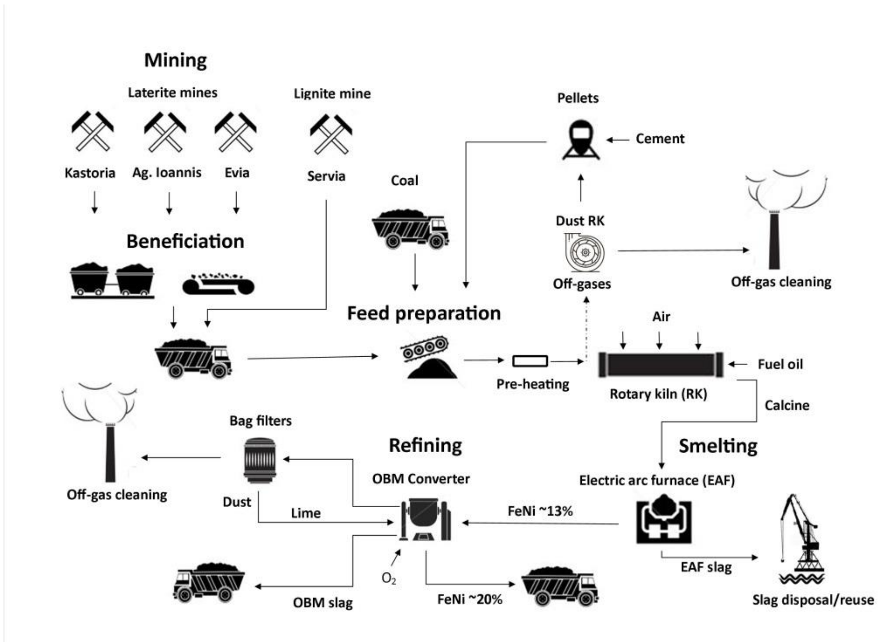
5. Consider alternative sources of energy (renewable energy and fuels)
6. Consider as indicators the most important impact categories: Global Warming Potential (GWP), Acidification Potential (AP) and Primary Energy Demand (PED)
7. Take into account relative principles of circular economy (waste reduction – waste valorization, energy savings etc)

e. Note

Please consider that the above steps can be applied in numerous other processes and products in various industrial sectors.

f. Final outcome

When you are ready, please present your findings (for 30 mins), using a ppt presentation



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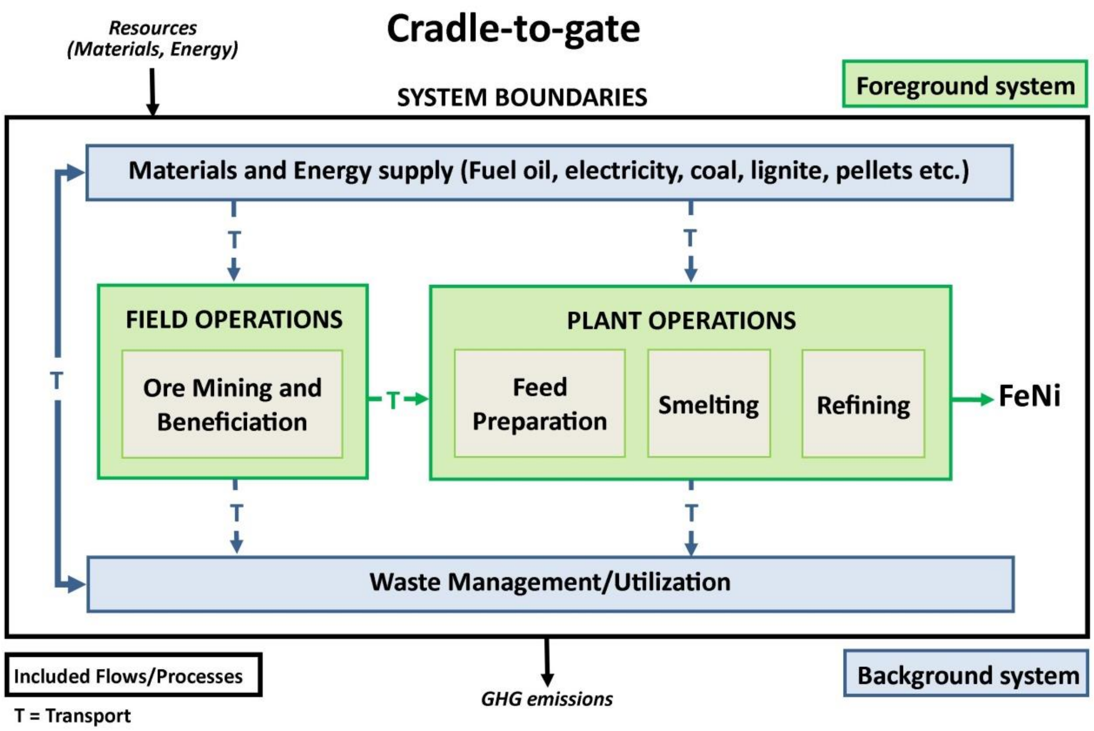

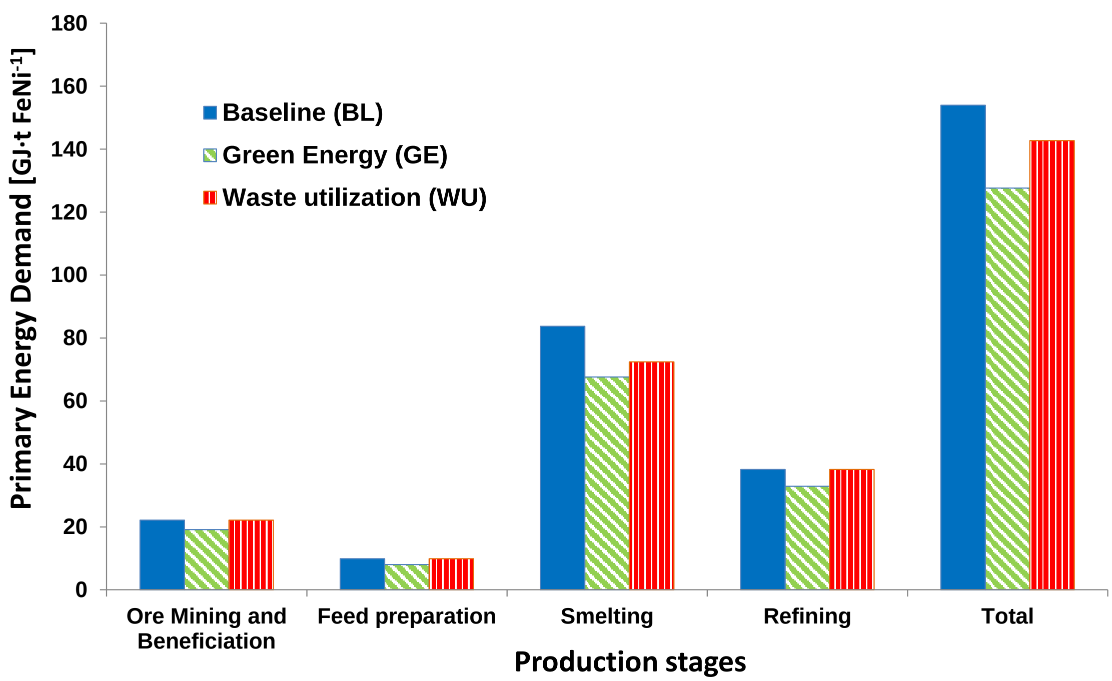

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Case Study 2. Improved alkali activation of construction and demolition waste (C&DW) for the production of building elements

a. General aspects

Alkali activation of aluminosilicates at relatively low temperature results in the production of cementitious materials, usually called geopolymers or inorganic polymers, which are characterized by a partially or fully amorphous polymeric structure consisting of Si–O–Al bonds. Their properties such as high early strength, chemical and high temperature resistance, depend mainly on the mineralogy of the raw materials as well as on the strength of the alkaline activator used. Other parameters affecting their structure are the curing process and the ageing period.
Alkali activated materials have attracted considerable attention in the last three decades due to their properties that render them suitable as alternative binders in the construction industry, as fire/corrosion resistant materials or as matrices for the encapsulation of hazardous elements. Recent research efforts have mainly focused on the valorization of a wide variety of wastes and the production of materials with appropriate physico-chemical, mechanical and thermal properties.

b. Objectives

You have to find all required information which is pertinent to the following objectives

1. Consider which C&D wastes are feasible. Assess their annual volume at country level
2. Understand the process
3. Find out the most important parameters that can be improved
4. Find out what kind of products can be produced and based on their properties propose potential uses

c. Period of Implementation

1 week

d. Potential Plan

You may use the following steps

1. Determine all raw materials that can be used
2. Assess the main steps of alkali activation
3. Find out the potential range of the most important process parameters
4. Determine what modifications are required to optimize the process
5. Check if C&D and other wastes can be co-valorized
6. Take into account the main principles of circular economy (waste reduction – waste valorization, energy savings etc)

e. Note

Please consider that the above steps can be applied in several other processes pertinent to solid waste valorization.

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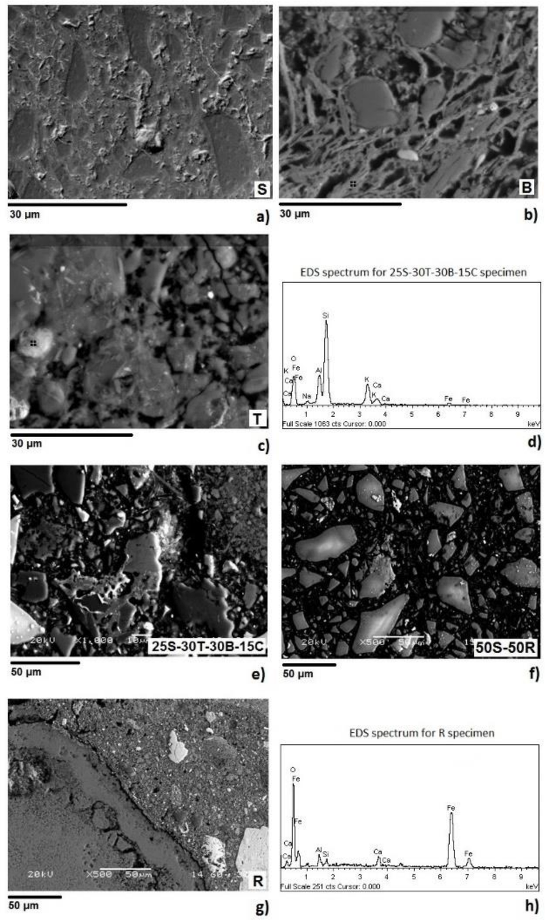
f. Final outcome

When you are ready, please present your findings (for 30 mins), using a ppt presentation



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4. PART D: Pre-Module Preparation

Case Study 1. Optimized Ferronickel (FeNi) production with emphasis on process footprint reduction

Scientific papers

1. Main

Bartzas, G., Komnitsas, K. 2015. Life cycle assessment of FeNi production in Greece: A case study, *Resources Conservation and Recycling*, 105:113-122, http://dx.doi.org/10.1016/j.resconrec.2015.10.016

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Warner, A.E.M., Diaz, C.M., Dalvi, A.D., Mackey, P.J., Tarasov, A.V., 2006. JOM World Nonferrous Smelter Survey part III: Nickel: Laterite, Journal of Metals 58(4), 11–20.

4. LCA

Eckelman, M.J., 2010. Facility-level energy and greenhouse gas life-cycle assessment of the global nickel industry. Resources, Conservation and Recycling 54 (4), 256–266.

Econvent, 2014. Swiss Centre for Life Cycle Inventories, Ecoinvent v.3.1 database. Retrieved from www.ecoinvent.ch

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García, R., Pizarro, C., Álvarez, A., Lavín, A.G., Bueno, J.L., 2015. Study of biomass combustion wastes. Fuel 148(15), 152–159.

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https://www.amazon.co.uk/Pyrometallurgy-87-Symposium-Proceedings-Warner/dp/0900488972/ref=sr_1_fkmr0_2?s=books&ie=UTF8&qid=1529924269&sr=1-2-fkmr0&keywords=Nickel+Pyrometallurgy

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http://www.pyrometallurgy.co.za/InfaconXII/671-VonKruger.pdf

http://www.pyrometallurgy.co.za/Pyro2006/Papers/127_Mintek.pdf

http://www.mintek.co.za/Pyromet/Files/2013Jones-NickelRecovery.pdf

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Videos

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https://www.youtube.com/watch?v=xp8_UCJTa9k

https://www.youtube.com/watch?v=0jlNqW_w7Fs

https://www.youtube.com/watch?v=8vI4b2pZEys

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Case Study 2. Improved alkali activation of construction and demolition waste (C&DW) for the production of building elements

Scientific papers

1. Main

Komnitsas, K., Zaharaki, D., Vlachou, A., Bartzas, G., Galetakis, M. (2015). Effect of synthesis parameters on the quality of construction and demolition wastes (CDW) geopolymers, *Advanced Powder Technology* 26(2):368-76, http://dx.doi.org/10.1016/j.apt.2014.11.012

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Directive 2008/98/EC of the European Parliament and of the Council on waste and repealing certain Directives, 19 Nov. 2008, Official Journal of the European Union, L.312/3.

3. C&W Management

M. Bravo, J. De Brito, J. Pontes, L. Evangelista. Mechanical performance of concrete made with aggregates from construction and demolition waste recycling plants. J. Clean. Prod. 99 (2015) 59–74.

H. Dahlbo, J. Bachér, K. Lähtinen, T. Jouttijärvi, P. Suoheimo, T. Mattila, S. Sironen, T. Myllymaa, K. Saramäki. Construction and demolition waste management – a holistic evaluation of environmental performance. J. Clean. Prod. 107 (2015) 333–341.

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5. PART E: Case Study Description

Case Study 1. Optimized Ferronickel (FeNi) production with emphasis on process footprint reduction

Ferronickel (FeNi) and ferrochrome (FeCr) are the two main ferroalloys used for the production of stainless steel. It is predominantly produced from nickeliferous laterite ores which are converted via the pyro-metallurgical route into a product with a Ni content of around 20%. Currently, only 42% of world primary Ni production is processed from laterite ores mainly through pyrometallurgical routes, with FeNi holding the highest share (~72%) among all nickel-based products. However, pyrometallurgical laterite ore processing is much more energy intensive compared to sulphide ore processing and it results in the production of large volumes of greenhouse gas (GHG) emissions and solid wastes. In its efforts for energy conservation, emission reduction and process sustainability, metal industry has used several approaches to quantify its performance, that include among others Ecological Risk Assessment (ERA), environmental performance and operational indicators, Cost Benefit Analysis (CBA), Materials Flow Analysis (MFA), and Life Cycle Assessment (LCA).

<u>Tips for your approach</u>

1. The problem that you are called to investigate must be addressed through the Applied Process and Product Optimization approach and should be considered in a holistic view
2. You should first define your problem and think of its solution
3. The approach that you are going to follow should be well structured
4. Please try to consider all aspects of the process. It is obvious that if the process is optimized the product will be optimized too. If the product is not optimized in terms of quality or annual production it may be optimized in terms of energy savings and may have a lower environmental footprint. This is also a very important aspect
5. You should focus on the whole system but you should consider all subsystems. Please consider which parameters can be optimized in each subsystem. If you manage to do so, then the whole system will be optimized
6. The resources that you are going to use must be presented as well
7. So, you should follow the steps Understand the process - Find options to reduce cost -Find options to reduce energy consumption and environmental footprint
8. You should also consider the fate of the produced wastes; are they going to be disposed of properly in an appropriate site or there exists a valorization potential? This may offer significant added value to the overall process and reduce also its carbon footprint
9. You should always remember that in each step the principles of circular economy (waste reduction – waste valorization, energy savings etc) should be followed
10. Please bear also in mind that the approach Applied Process and Product Optimization can be applied in many processes and for many products, so the know-how that you will generate can be potentially extrapolated in other industrial sectors

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Try to set realistic objectives, ask questions and try to find some answers, such as:

1. Which process steps can be more easily modified / improved to achieve objectives?
2. How much can cost be reduced? (in €/kg of product). Is for example 10% a feasible target?
3. How much energy consumption can be reduced? (in kWh/kg product). Is for example 20% a feasible target?
4. How can you reduce energy consumption? Which alternative sources of energy are you going to consider? e.g Photovoltaics (PV), alternative fuels?
5. If you consider the use of biochar (as alternative fuel) produced from pyrolysis of agricultural wastes or sludge from a wastewater treatment plant (WWTP), is there such potential in the region considered to produce sufficient quantities of biochar?
6. If sufficient quantities of raw materials exist for the production of biochar are available in a nearby region, which is the transport cost and how does this affect your overall energy balance?
7. How much the environmental footprint can be reduced? Which impact categories apart from Global Warming Potential (GWP) are you going to consider? You can only consider GWP, but you have to justify your decision.

Case Study 2. Improved alkali activation of construction and demolition waste (C&DW) for the production of building elements

The European Commission has identified C&D wastes as a priority waste flow for reuse and highlighted the noticeable environmental benefits of their valorization (Directive 2008/98/EC). These benefits include among others reduction of the consumption of natural resources, minimization of the volume of wastes that will ultimately be landfilled and reduction of the emission of greenhouse gases (GHGs).
The proposed approach "alkali activation of C&DW" is in line with the "zero-waste" and "circular economy" principles of the European Commission and contributes to "closing the loop" of product lifecycles through greater recycling and re-use, while it brings maximum benefits for both the environment and the economy.

As in the previous case study you may use the following tips

Tips for your approach

1. The problem that you are called to investigate must be addressed through the Applied Process and Product Oprimization approach and should be considered in a holistic view
2. You should first define your problem and think of its solution
3. The approach that you are going to follow should be well structured
4. Please try to consider all aspects of the process. It is obvious that if the process is optimized the product will be optimized too. If the product is not optimized in terms of quality or annual production it may be optimized in terms of energy savings and may have a lower environmental footprint. This is also a very important aspect

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5. You should focus on the whole system but you should consider all subsystems. Please consider which parameters can be optimized in each subsystem. If you manage to do so, then the whole system will be optimized
6. The resources that you are going to use must be presented as well.
7. So, you should follow the steps Determine the quality of the raw materials – Improve the most important process parameters –Assess the quality of the final products by also considering environmental aspects
8. You should always remember that in each step the principles of circular economy (waste reduction – waste valorization, energy savings etc) should be followed.
9. Please bear also in mind that the approach Applied Process and Product Optimization can be applied in many processes and for many products, so the know-how that you will generated can be potentially extrapolated for other similar wastes (e.g slags, fly ashes, etc.

Try to set realistic objectives, ask questions and try to find some answers, such as:

1. Which process steps can be more easily modified / improved to achieve objectives?
2. Are there enough quantities of C&DW at regional level to consider such an approach?
3. Which are the most important process parameters that can be modified?
4. Which are the existing products that can be substituted by the materials that will be produced through your process?
5. Are your products going to be competitive in the market? e.g the construction market?
6. Do you products comply with pertinent standards in terms of quality and environmental safety, e.g ASTM, DIN, NEN, BSI?
7. Is there any legislation in your country that allows / reinforces the management of C&DW or the use of such secondary materials?
8. Are there any other wastes that can be co-valorized with C&DW?
9. Which is the environmental footprint of the proposed approach? Do you believe that it is higher or lower compared to existing processes? Can you roughly calculate it?

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6. PART F: Overall Module Presentation

Discussion questions

1. Consider if the supportive material provided is sufficient or more information is required
2. Exchange views and expertise with members of the other group
3. Compare approaches and steps
4. Discuss the feasibility of each approach
5. Discuss aspects of circular economy
6. Discuss and compare technical, environmental and economic aspects
7. Discuss the social aspects of each approach and consider any potential restrictions from the society or the existing legislation
8. Do you anticipate any drawbacks or problems from any industrial sector or the market? (for example in the case of C&DW management for the production of construction elements?)

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7. PART G: Overall Module Presentation

Reflective questions

Initial questions:

- How would you define the problem you are dealing with?
- Which are the objectives?
- Are the objectives feasible?
- What kind of aspects (processes, parameters, legislation, etc) do you want to explore?
- Did you classify/categorize the steps to deal with the problem?
- Did you make a plan?
- Do you think that this plan is correct?

Navigating questions:

- Is the approach considered helpful to achieve the objectives?
- Is this useful?
- Does this make sense?
- Should you make any adjustments based on what you have learned so far?
- Do you get sufficient information from your group members?
- Do you need any additional sources?

Experimental questions:

- Do you have any previous experience from similar problems
- Is there anything important missing?
- Can you obtain all required data? (raw materials, mass and energy balance, process parameters etc)
- How would you deal with the problem if you were the company's CEO, or a chief engineer or an exploitation manager?

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- Is your overall approach correct?
- Did you identify any mistakes?
- Is there sufficient time for corrective action, if needed?

Other questions:

- What is feasible?
- How can you prioritize your steps?
- Who is going to do what?
- Did you identify synergies among team members?
- Other???

Assessment

PBL Assessment

	Poor/Low	**Good**	**Excellent**
Definition of the problem			
Analysis of the problem			
Discover what they need to learn			
Identify, find, use of appropriate resources			
Critical selection of knowledge			
Application of selected information to the problem			
Reflection of gained knowledge effectively			
Self-direct the learning strategies			
Group meetings evaluation			
Participation skills in their teams			
Problem Solved?			

Case study assessment

<u>Please select one case study</u>

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 Case Study 1. Ferronickel (FeNi) production with emphasis on process footprint reduction

 Case Study 2. Improved alkali activation of construction and demolition waste (C&DW) for the production of building elements

		Poor/Low	**Good**	**Excellent**
Applied Process and Product Optimization	Degree of overall appreciation			
	Quality of strategy followed			
	Degree of problem identification			
Case study	Report			
	Project folder			
	Quality of presentation			
	Individual contribution to the presentation			
	Timeline			
	Accuracy of reflective questions			

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