



Teaching Resources on the
Sustainable Management of Critical Raw Materials

Trainer's Manual for
Circular Economy

January 2020

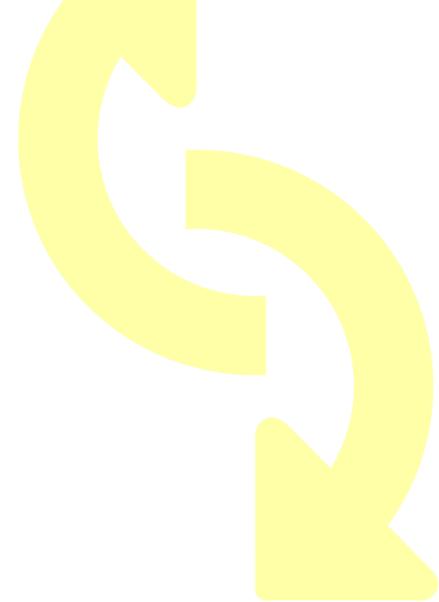
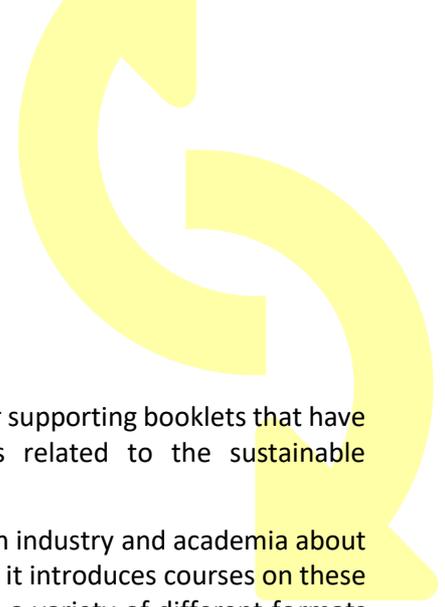


Table of Contents

1	3	
1.1	4	
1.2	4	
1.3	5	
1.4	5	
1.5	5	
2	9	
3	16	
INTRODUCTION		10
GOAL AND SCOPE DEFINITION		10
INVENTORY ANALYSIS		10
Process flow diagram and process data		10
IMPACT ASSESSMENT		12
INTERPRETATION		13
4	19	
5	19	
6	19	



1. Context and Introduction to Training

This booklet is supplementing the teaching materials and the set of further supporting booklets that have been developed to support teachers in conducting training courses related to the sustainable management of critical raw materials.

SusCritMat aims to educate people from Master's student level up, both in industry and academia about important aspects of sustainable critical raw materials. In a novel concept, it introduces courses on these complex and interdisciplinary topics in a modular structure, adaptable to a variety of different formats and accessible to both students and managers in industry. These courses will develop new skills, which will help participants to better understand the impact and role of critical raw materials in the whole value chain; enabling them to identify and mitigate risks. Understanding the bigger picture and the interconnected nature of global business and society is increasingly necessary to and valued by industry.

SusCritMat is an EU-funded project that brings together the technical and pedagogical expertise of leading educational institutions and business partners. It uses and creates teaching materials which can be combined into different course formats.

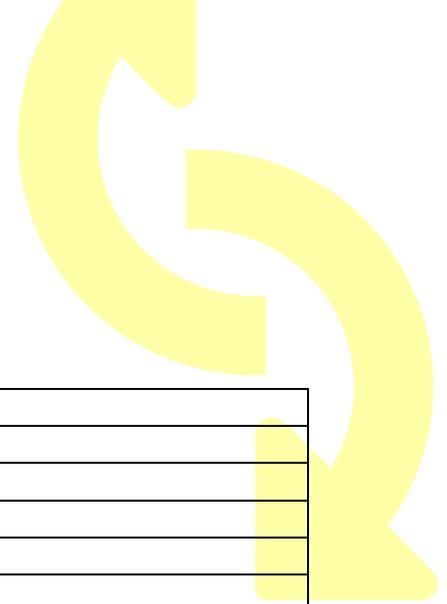
The collection of training manuals presents the key messages related with the sustainable management of critical raw materials in three major sections:

- Introduction to criticality
- Analysis of criticality
- Solutions for sustainable management

In particular, the solutions part will be in the focus. The intention is to underline the possibilities that are available to approach and implement a circular economy for critical raw materials and the products bearing these. Doing so the concrete actions, i.e. the things that can be done, are highlighted, instead of only mentioning all sorts of associated problems or barriers in the context of CRMs.

The overall goal of the SusCritMat project is to qualify lecturers to teach the topics themselves. Therefore, the teaching resources do not only provide an introduction and improved insight into selected thematic issues, but also deliver a set of teaching materials "ready-to-use".

- Learning targets that will be reached after having taught the courses
- Presentations on the specific topics including also notes on how to present the slides and key messages.
- Group work exercises including the task or question to work on, if applicable further reading on the methodology and the solutions in case of tasks requiring calculations.
- Assessment questions and the correct answers for each specific topic.
- Additional reading for each topic.



1.1 Training Materials List

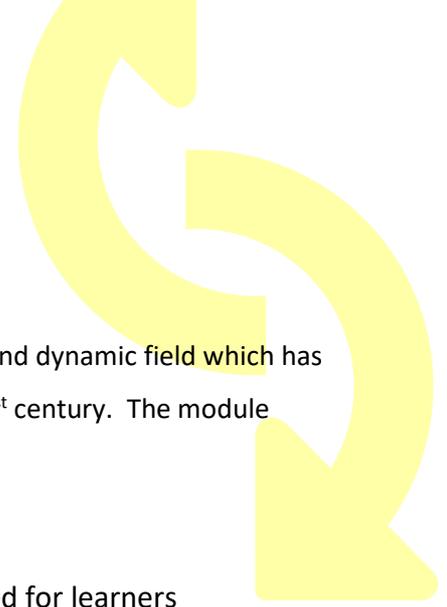
The *SusCritMat* project developed the following teaching materials:

1	Critical Resources for emerging technologies
2	Circular Economy
3	Criticality
4	LCA
5	Responsible Mining
6	Responsible Sourcing/Certification
7	Closing Loops on Product Level
8	MFA
9	Geopolitical aspects
10	Metals & CRM scenarios
11	Sustainability Assessment
12	Waste Management
13	Simulation-based Design for Recycling
14	Restricted Substances Legislation
15	Historical solutions for CRM
16	Characterizing the Urban Mine
17	Environmental Aspects
18	Process Models based on LCA
19	Responsible Business Practices
20	Supply chain resilience
21	Sustainable materials usage
22	CRM and Sustainable Development
23	Circular Business Models
24	Economy of rare metals
25	Supply Risk factors
26	Recycling
27	Good Use of Data

1.2 Suggested timetable

The agenda contains a recommended timing for the lecture and exercises. However, depending on the pre-existing knowledge or group size the time can be extended.

- Lecture: 40 minutes
- Exercise: 95 minutes (including 15 minutes break). The exercise can be performed in groups or be an individual assignment.
- Recap: 20 minutes



1.3 Key Messages

This training module introduces the field of circular economy, a complex and dynamic field which has potential to contribute towards mitigating critical materials risks in the 21st century. The module includes:

- A presentation giving an overview of circular economy
- A class based exercise to explore tensions and lessons learned for learners
- Key guiding topics for teachers in the class based exercise

This module presents an overview of some of the main circular economy frameworks which have been developed. After this overview, an example of possible materials assessments follows. Further models are considered, including a consideration of 'refuse'. Critical materials use in circular cities is reviewed and this includes consideration of the time aspect. The 'fields of tension' is opened up at the end to show going circular is not easy or without risks. It also shows that without careful consideration going circular could contain critical materials risks.

For teachers and learners who are more familiar with working with circular economy teaching or learning, respectively, there is an opportunity to extend the class based exercise to explore current challenges around going circular and the resources needed to achieve sustainability goals. This could be further developed to explore future scenarios.

1.4 Learning Objectives

After following this course, the learner should be able to:

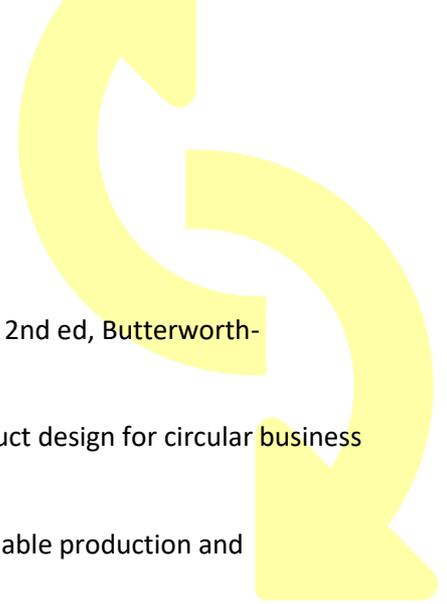
- Reproduce the 'butterfly model' of a circular economy;
- Explain the desired outcomes of a circular economy.
- Describe the concept of hierarchies and most to least desirable options
- Describe the interlinkage between CE and CRM
- Critically assess the tensions in the field of CE and in particular in relation to critical materials.
- Describe the CE actions which can mitigate CRM challenges in the future.

1.5 Additional Reading

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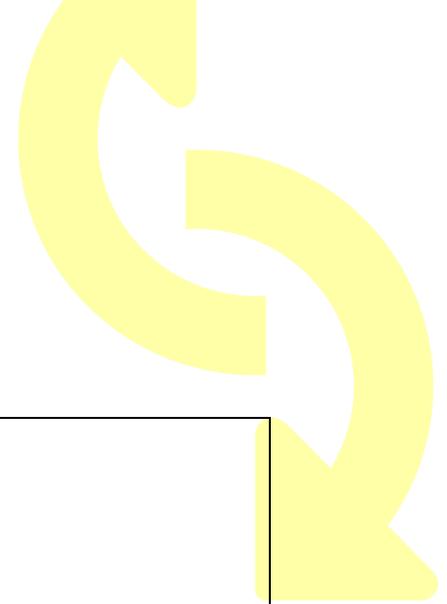
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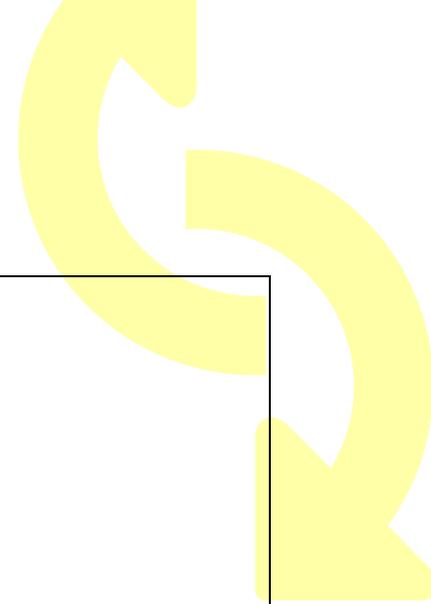
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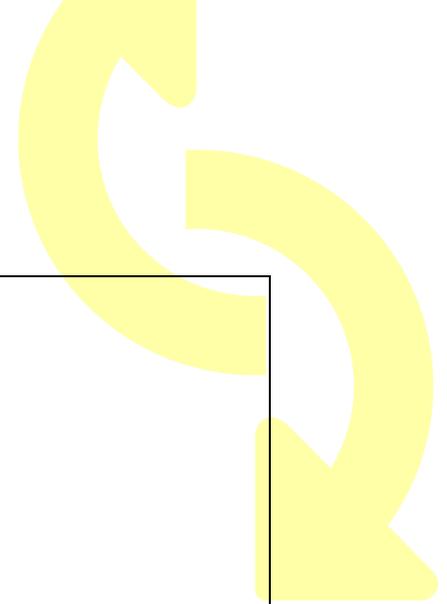
2. Slides and Notes

Slides are supplied in ppt format with annotations.

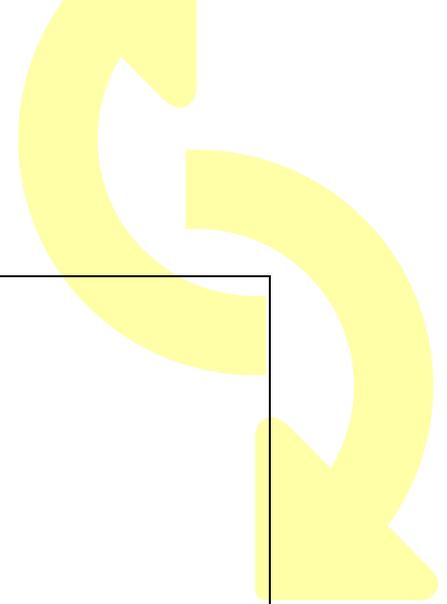
<p style="text-align: right;">SusMat Crit</p> <p>CIRCULAR ECONOMY</p> <hr/> <p>PROF. DAVID PECK, LAYLA VAN ELLEN (TU DELFT), JAMES GODDIN (GRANTA DESIGN)</p> <p><small> This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small></p>	
<p>Overview</p> <ul style="list-style-type: none"> • introduction of the concept • relationship with CRM's • quantifying the CE • examples • exercise <p><small> This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small> © Peck, van Ellen, Goddin 2</p>	
<p>Introduction</p> <div style="display: flex; justify-content: space-around; text-align: center;"> <div> <p>LINEAR ECONOMY</p> </div> <div> <p>RECYCLING ECONOMY</p> </div> <div> <p>CIRCULAR ECONOMY</p> </div> </div> <p><small> This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small> © Peck, van Ellen, Goddin 3</p>	
<p>Closing the loop</p> <p>CIRCULAR ECONOMY</p> <p>many definitions, which vary with the scope and stakeholders, but essentially, it means closing the loop(s)</p> <p><small> This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small> © Peck, van Ellen, Goddin 4</p>	



<p>Closing the loop</p> <p>CIRCULAR ECONOMY</p> <p>many definitions, which vary with the scope and stakeholders, but essentially, it means closing the loop(s)</p> <p>→ What are the loops? Where are they?</p> <p><small>FlowMaterials ACADEMY</small> This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation. © Peck, van Eilen, Goddin 5</p>	
<p>Ellen McArthur Scheme (Butterfly model)</p> <p><small>FlowMaterials ACADEMY</small> This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation. © Peck, van Eilen, Goddin 6</p>	
<p>Ellen Macarthur Scheme (Butterfly model)</p> <p>Biosphere</p> <p><small>FlowMaterials ACADEMY</small> This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation. © Peck, van Eilen, Goddin 7</p>	
<p>Ellen Macarthur Scheme (Butterfly model)</p> <p>Technosphere</p> <p><small>FlowMaterials ACADEMY</small> This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation. © Peck, van Eilen, Goddin 8</p>	
<p>Sustainability</p> <p>Important to know:</p> <p>Circular Economy is a tool towards a set goal (a research question)</p> <ul style="list-style-type: none"> • CE is not the end goal in itself • CE also does not mean that what is done is always sustainable <ul style="list-style-type: none"> • It should be, but some have other agendas..... <p><small>FlowMaterials ACADEMY</small> This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation. © Peck, van Eilen, Goddin 9</p>	



<h3>Desired outcomes of a Circular Economy</h3> <ul style="list-style-type: none"> • waste is prevented • materials and products are used for a longer period (product life extension) • increased efficiency and optimisation • which means value increases • promotes diversity of offer <p><small>eit FlowMaterials Academy This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation © Peck, van Ellen, Goddin 10</small></p>	
<h3>Steps towards a Circular Economy</h3> <ul style="list-style-type: none"> • closing and connecting material flows (for example, using MFA) • urban mining (using the stocks around society) • using the r-ladder <p><small>eit FlowMaterials Academy This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation © Peck, van Ellen, Goddin 11</small></p>	
<h3>R-Ladder</h3> <ul style="list-style-type: none"> • Most circular • Least circular <p><small>eit FlowMaterials Academy This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation © Peck, van Ellen, Goddin 12</small></p>	
<h3>Critical Materials (elements to energy generation)</h3> <p><small>eit FlowMaterials Academy This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation © Peck, van Ellen, Goddin 13</small></p>	
<h3>Trace elements vs. combinations</h3> <p><small>eit FlowMaterials Academy This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation © Peck, van Ellen, Goddin 14</small></p>	



Changing risks with time, properties at risk

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Circular Economy – A focal point for optimisation

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Circular Economy – further framework Options

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Refuse – A new set of aspirations? Or does refuse mean no product / service?

What we aspire to today

To minimise resource use – what should we aspire to?

Companies that don't adapt to these new aspirations – will become superfluous, and be replaced.

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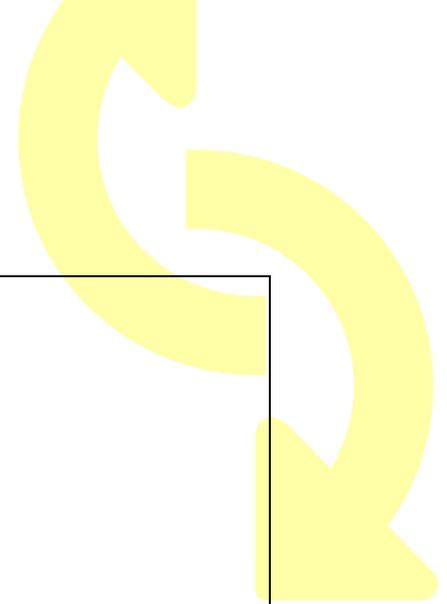
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Quantifying Circularity

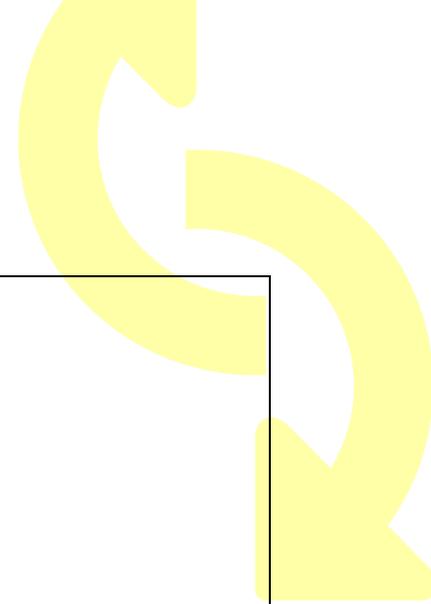
Full Ellen MacArthur & Granta Methodology available on EMF website.

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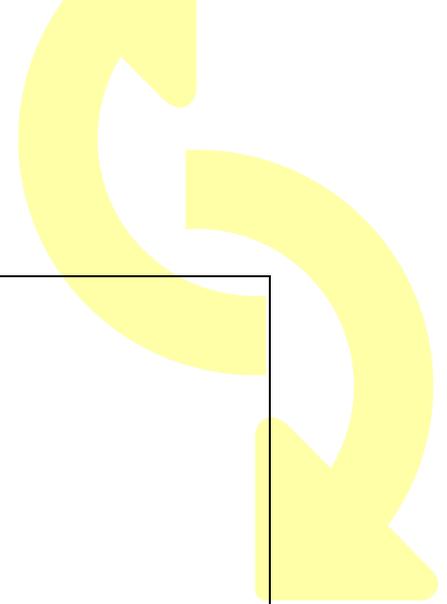


<h3>Circular Economy – Long term thinking</h3> <p>GRANTAMAT View cycle: 5 / 10 Results per Life Cycle</p> <p>Material flows per cycle</p> <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small> © Peck, van Ellen, Goddin 20</p>	
<h3>CE solutions with CRM – the complexity challenge</h3> <p>Components Materials Elements</p> <p>Market Impact Data Quality Data Organization</p> <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small> © Peck, van Ellen, Goddin 21</p>	
<h3>It is not just electronics..... Circular cities = a lot of metal – and CRM</h3> <div style="display: flex; justify-content: space-around;"> <div data-bbox="247 1019 550 1220"> <h4>Steel Construction</h4> <p>Infrastructure 150 Mt 14%</p> <p>Buildings 433 Mt 42%</p> <p>Steel Alloy & CRM? Can include = Mn, Ni, Cr, Mo, V, Si, B & Al, Co, Cu, Nb, Ti, W, Sn, Zn, Pb & Zr.</p> </div> <div data-bbox="566 1019 790 1220"> <h4>AI - Alloy Construction</h4> <p>Buildings 11 Mt 24%</p> <p>AI - Alloy & CRM? 6060 Al-Al = Al, Cr, Cu, Fe, Mg, Si, Ti & Zn source: Allwood & Cullen, 2015</p> </div> </div> <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small> © Peck, van Ellen, Goddin 22</p>	
<h3>Layers – different time scales for a building/city</h3> <p>STUFF often, monthly / yearly SERVICE PLAN 3-5 years SERVICES 7-15 years SKIN 15-20 years STRUCTURE 100-200 years SITE forever</p> <p>based on: Stewart Brand</p> <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small> © Peck, van Ellen, Goddin 23</p>	
<h3>CE and areas of tension</h3> <ul style="list-style-type: none"> • CE wants market forces to decide. <i>See Molycorp. story</i> • CE encourages but not directs. <i>Helium in balloons, IoT, Digital solutions, electric, etc.</i> • CE seeks a wide range of circular options to be available. <i>Markets = waste?</i> • CE does not specify materials. <i>Esp. not CRM's. Use AI-AI in construction = CRM</i> • CE limited on societal engagement. <i>People are just a market? Poverty?</i> • CE does not link strongly to energy (and climate)? <i>Climate emergency vs CRM?</i> • Circular does not always lead to sustainability? <i>More services = lower impact?</i> • CE needs 'economy' and therefore 'refuse' = buy differently? <i>Refuse = not buying?</i> • CE is not supposed to be a 'stop-gap' measure? <i>Isn't it?.....</i> <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation</small> © Peck, van Ellen, Goddin 24</p>	



<p>MODULE 2 CIRCULAR ECONOMY</p> <p>THANK YOU</p> <p>SusMat Crit</p> <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation.</small></p> <p><small>© Peck, van Ellen, Goddin</small></p>	
<p>MODULE 2 CIRCULAR ECONOMY</p> <p>EXERCISE</p> <p>SusMat Crit</p> <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation.</small></p> <p><small>© Peck, van Ellen, Goddin</small></p>	
<p>Consider the list of CE 'tensions' proposed below:</p> <ul style="list-style-type: none"> • CE wants market forces to decide. <i>See Molybdenum story</i> • CE encourages but not directs. <i>Helium in balloons, IoT, Digital solutions, electric, etc.</i> • CE seeks a wide range of circular options to be available. <i>Markets = waste?</i> • CE does not specify materials. <i>Esp. not CRMs. Use AI in construction = CRM</i> • CE limited on societal engagement. <i>People are just a market? Poverty?</i> • CE does not link strongly to energy (and climate)? <i>Climate emergency vs CRM?</i> • Circular does not always lead to sustainability? <i>More services = lower impact?</i> • CE needs 'economy' and therefore 'refuse' = buy differently? <i>Refuse = not buying?</i> • CE is not supposed to be a 'stop-gap' measure? <i>Isn't it?.....</i> <p>In your group / pairs / individual answer the following questions and feedback on a flip chart:</p> <ol style="list-style-type: none"> 1. Which strategies could reduce these tensions? 2. Can you add more tensions? <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation.</small></p> <p><small>© Peck, van Ellen, Goddin</small></p>	
<p>Reminder of CRMs</p> <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation.</small></p> <p><small>© Peck, van Ellen, Goddin</small></p>	
<p>Figure A1: Economic importance and supply risk results of 2017 criticality assessment</p> <p><small>This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation.</small></p> <p><small>© Peck, van Ellen, Goddin</small></p>	

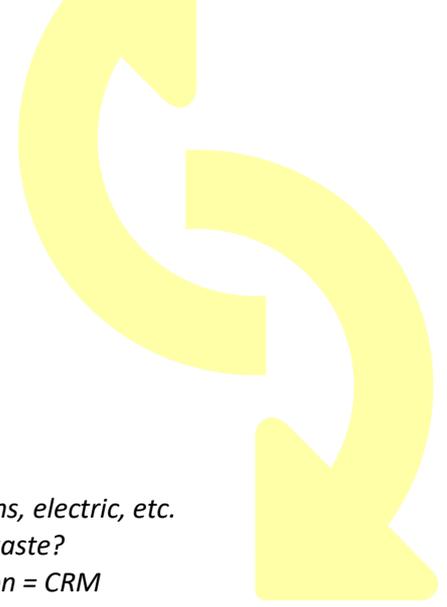
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3. Circular economy exercise notes

The exercise:

A list of tensions;

- CE wants market forces to decide. *See Molycorp. story*
- CE encourages but not directs. *Helium in balloons, IoT, Digital solutions, electric, etc.*
- CE seeks a wide range of circular options to be available. *Markets = waste?*
- CE does not specify materials. *Esp. not CRM's. Use AI-AI in construction = CRM*
- CE limited on societal engagement. *People are just a market? Poverty?*
- CE does not link strongly to energy (and climate)? *Climate emergency vs CRM?*
- Circular does not always lead to sustainability? *More services = lower impact?*
- CE needs 'economy' and therefore 'refuse' = buy differently? *Refuse = not buying?*
- CE is not supposed to be a 'stop-gap' measure? *Isn't it?.....*

In your group / pairs / individual answer the following questions and feedback on a flip chart:

1. Which strategies could reduce these tensions?
2. Can you add more tensions?

1. INTRODUCTION

In this exercise the learners are asked to consider a list of tensions that a transition to a circular economy could create. The tutor can add or change this list depending on the learners' prior knowledge / course content.

This guide will provide guidance on both parts of the exercise separately.

2. PART ONE – Which strategies could reduce these tensions?

This can provide an extensive and lengthy exercise for the learners, depending on their level and prior knowledge. The teacher should be ready to guide the learners to perhaps pick some tension examples which suit the course best / or are of real interest / concern to the group / individual. As the list is derived from actual tensions in the research field there are no 'right' answers. A guide for the teacher could be to remind the learners that the sustainable development goals provide a useful framework. If a learner proposes a strategy does it contradict the SDGs?

It may not take learners long to begin questioning the very basis of 'an economy' and asking if a circular economy can work in a material and energy constrained world. They may begin to question the entire

financial system, profit, growth, economic models, etc. That is good but watch out for 'thought paralysis' with learners feeling 'there is no point there is nothing we can do'. Step in and direct towards strategies which can be deployed in the more short term. Depending on the group size / time this can be discussed in plenary.

The final tension around 'stop gap measure' considers the timescales and goals of a CE. Are we building a CE to build a better world into the long term future? Or are we using CE to get us through the current 'emergency'?

3. PART TWO - 'Can you add more tensions?'

This part of the exercise is a more complex challenge. The ideas may flow and the list get long, making the sense of 'we can change things' diminish.

In the context of critical materials there is evidence which shows that companies and markets, if left alone, will not 'fix it'. So this exercise asks what could be even more challenging than going circular? What should actors do? Should the state intervene to ensure security of supply is maintained to keep the CE on the road?

There are no 'right' answers to this part either. It is a contentious issue with policy makers, designers, society, companies and academics.

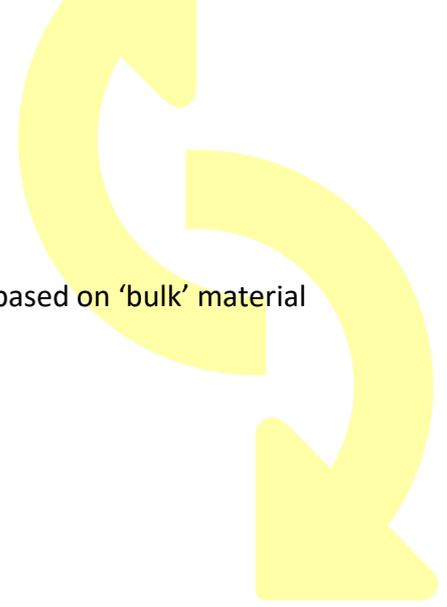
This exercise could open up discussion around 'who owns stuff?'. Who should have access to critical materials and should they share or conserve for themselves? Can CE solve this?

Be ready for lively debate, and moderate if views become too strong, nationalistic or even offensive.

4. RECAP and CLOSE

Return to the butterfly diagram. By the end the learners may be feeling a bit overwhelmed with the complexity (as shown on the slide with the EU ProSUM project). Coming back to the butterfly diagram provides a clearer space for the learners to land. Highlight that whilst the CE aims are helpful the journey in the context of CRM is not easy. CRM can play a role of 'jokers in

the pack' and disrupt the simpler models of CE, which are normally based on 'bulk' material flows.





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5. Citation

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6. Disclaimer

The teaching materials within the SusCritMat project are still in development and undergo several revisions. We therefore currently provide only preliminary versions of teaching manuals, slides and exercises that will be finalized by the end of the project in early 2020.