



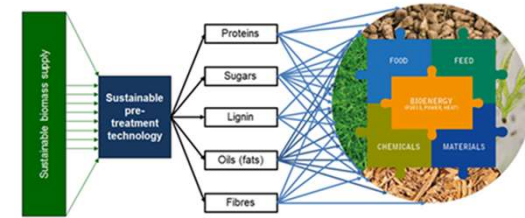
IEA Bioenergy
Technology Collaboration Programme

Task 42
Biorefining in a circular economy



Task42 Biorefining in a circular economy

Overview



Bert Annevelink, Michael Mandel & Ed de Jong

Golden, USA, 6-8 November 2023

The IEA Bioenergy Technology Collaboration Programme (TCP) is organised under the auspices of the International Energy Agency (IEA) but is functionally and legally autonomous. Views, findings and publications of the IEA Bioenergy TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

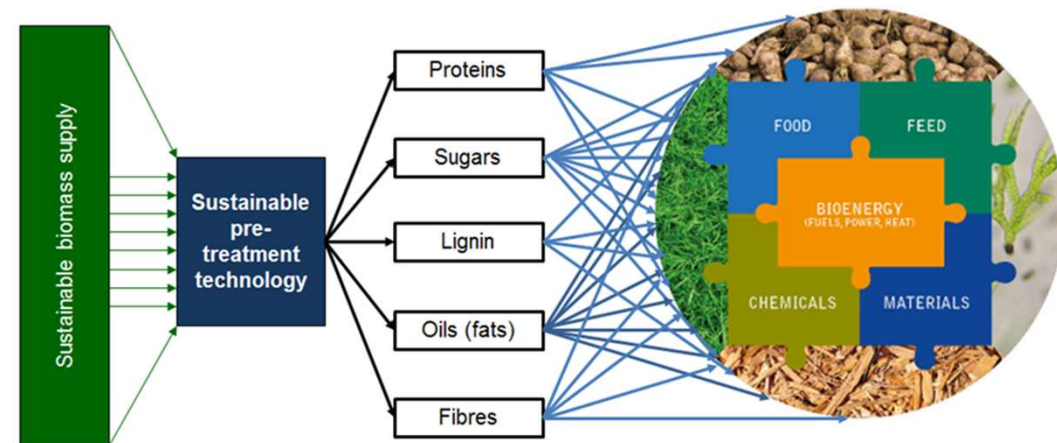
Technology Collaboration Programme
by **iea**

Content

- General introduction
- Global Biorefinery Status Report 2022
- WP1. Techno Economic Environmental (TEE) assessment of biorefineries and dissemination of results
- WP2. Global Biorefineries Atlas portal
- WP4. BIOCarbon-to-Chemicals by Integration of biorefineries and green hydrogen (BIOCCI)

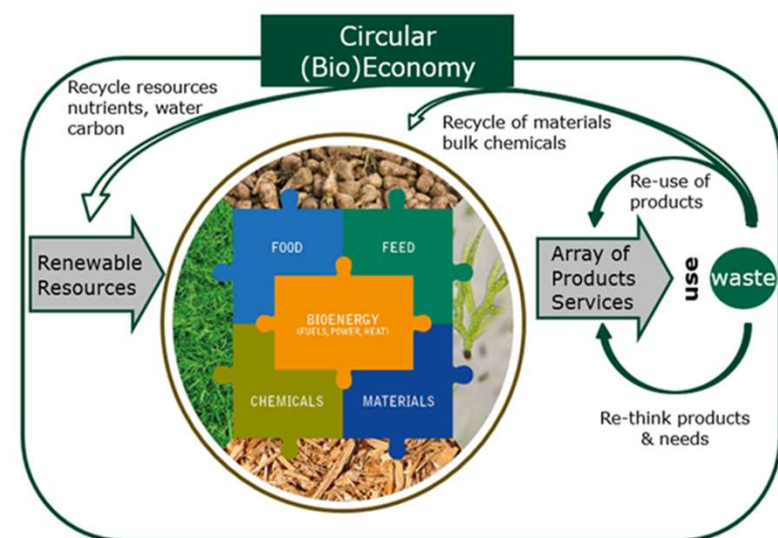
Task 42 - Introduction

- **Task 42 definition of Biorefining:**
Sustainable processing of biomass into a portfolio of marketable biobased products (food and feed ingredients, chemicals, materials, minerals, CO₂) and bioenergy (fuels, power, heat)
- IEA Bioenergy Task 42 ‘Biorefining in a circular economy’ started in Triennium 2007-2009
- Member countries 5th Triennium were:
 - Austria, Australia, Denmark, Germany, Ireland, Italy, The Netherlands & Sweden
- Changes in the 6th Triennium:
 - Observer: Australia
 - Joining: US, Turkey
 - Leaving: Sweden



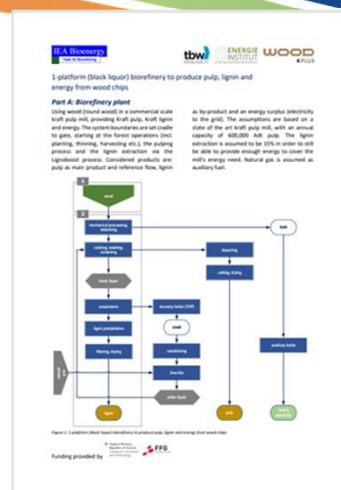
Task 42 - Introduction

- Biorefining is one of the **key enabling strategies** of the Circular Economy, **closing loops** of raw biomass materials, minerals, water and carbon
- Biorefining is the optimal strategy for large-scale **sustainable use of biomass** in the BioEconomy
- Biorefining will result in **cost-competitive co-production** of food/feed ingredients, biobased products and bioenergy combined with **optimal socio-economic and environmental impacts** (reduced GHG emissions, efficient use of resources, etc.)



Task 42 - Objectives and Work programme

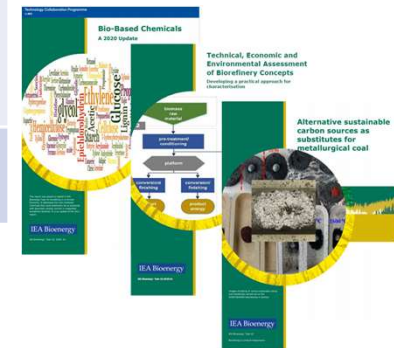
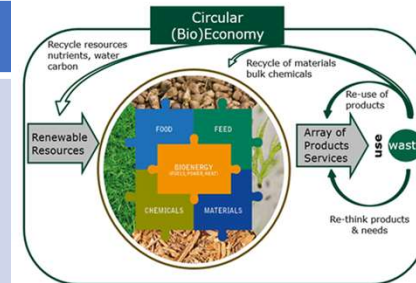
| Key objectives | Work programme |
|---|---|
| Provide quantitative, scientifically sound, and understandable data | <p>WP1. Techno Economic Environmental (TEE) assessment of biorefineries and dissemination of results</p> <ul style="list-style-type: none"> T1.1) Update and maintain TEE assessment methodology (TL: AT) T1.2) Factsheets (TL: AT) |
| Describe global implementation status | <p>WP2. Global Biorefineries Atlas portal</p> <ul style="list-style-type: none"> T2.1) Update and maintain Global Biorefineries Atlas portal (TL: IT) |
| Describe global implementation status, and show solutions for major deployment barriers | <p>WP3. Current status of biorefinery deployment and best practice identification</p> <ul style="list-style-type: none"> T3.1) Biorefinery country reports (slide decks) (TL: NL) T3.2) Green biorefinery status report (TL: DK) T3.3) Barriers and incentives for market diffusion (TL: AT) |



Task 42 - Objectives and Work programme

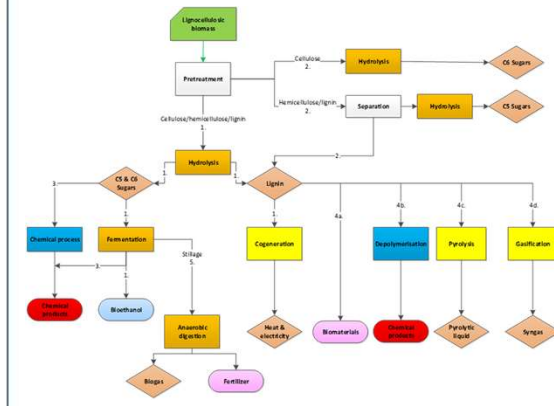
| Key objectives | Work programme |
|--|--|
| Provide quantitative, scientifically sound, and understandable data | WP4. BIOCarbon-to-Chemicals by Integration of biorefineries and green hydrogen (BIOCCI) <ul style="list-style-type: none"> T4.1) Integration of biorefineries with renewable electricity systems (TL: IT) |
| Provide an international platform for cooperation and information exchange | WP6. Dissemination & Communication |
| | WP7. Task Management |

The proposed 'WP5. Systems perspective on biorefineries based on lignocellulosic waste and side streams in a circular economy' was cancelled due to lack of budget



Task 42 - Biorefinery classification system updated

| 1. Feedstock | 2. Conversion Process | 3. Platform | 4. Product |
|--|--|--|---|
| <p>1.1. Primary biomass:</p> <ul style="list-style-type: none"> • Aquatic biomass • Lignocellulosic from croplands and grasslands • Lignocellulosic wood/forestry • Oil crops • Starch crops • Sugar crops • *Other primary biomass <p>1.1. Secondary Biomass:</p> <ul style="list-style-type: none"> • Microbial biomass • Residues from agriculture • Residues from aquatic biomass • Residues from forestry and forest-based industry • Residues from nature and landscape management • Residues from recycled bio-based products • *Other organic residues | <p>2.1. Biochemical:</p> <ul style="list-style-type: none"> • Aerobic conversion • Anaerobic digestion • Enzymatic process • Fermentation • Insect-based bioconversion • Other biochemical conversion <p>2.2. Chemical:</p> <ul style="list-style-type: none"> • Catalytic • Esterification • Hydrogenation • Hydrolysis • Methanation • Chemical Pulping • Steam reforming • Water electrolysis • Water gas shift • *Other chemical conversion <p>2.3. Mechanical and thermomechanical:</p> <ul style="list-style-type: none"> • Blending • Extraction • Mechanical & thermomechanical disruption & fractionation • Mechanical pulping • Separation processes • Other mechanical and thermomechanical conversion <p>2.4. Thermochemical:</p> <ul style="list-style-type: none"> • Combustion • Gasification • Hydrothermal liquefaction • Pyrolysis • Supercritical conversion • Torrefaction & Carbonization • *Other thermochemical conversion | <ul style="list-style-type: none"> • Biochar • Bio-Coal • Bio-Crude • Biogas • Bio-oils • Bio-hydrogen • Bio-Naphtha • C5/C6 sugars • Carbon dioxide • Lignin • Oils • Organic Fibres • Organic Juice • Protein • Pyrolytic Liquid • Starch • Syngas • *Other platform | <p>4.1. Chemicals:</p> <ul style="list-style-type: none"> • Additives • Agrochemicals • Building blocks⁶⁸ • Catalysts & Enzymes • Colorants • Cosmeceuticals • Flavours & Fragrances • Lubricants • Nutraceuticals • Paints & Coatings • Pharmaceuticals • Solvents • Surfactants • *Other chemical product <p>4.2. Materials:</p> <ul style="list-style-type: none"> • Composites • **Fibres • Organic Fertilizers • Polymers • Resins • *Other material product <p>4.3. Food</p> <p>4.4. Animal Feed</p> <p>4.5. Energy:</p> <ul style="list-style-type: none"> • Cooling agents • Fuels • Heat • Power • *Other energy product |



Pathway E: Three platform (C5 sugars, C6 sugars and lignin) biorefinery pathway using lignocellulosic biomass

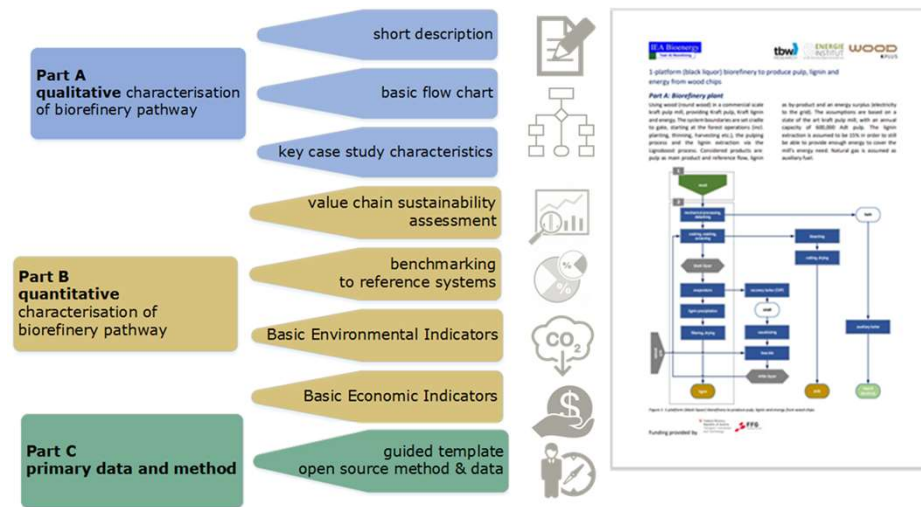
Source: EU Biorefinery Outlook to 2030 , 2021

www.ieabioenergy.com
<http://task42.ieabioenergy.com>

Task 42 - TEE Biorefinery assessment methodology

Objectives:

- Underpin the sustainability claim of integrated biorefineries through Technical, Economic and Environmental (TEE) Assessments
 - quantitative environmental and economic assessment approach
 - with generic initial biorefinery models for iterative refinement
 - encourage stakeholders to participate in the assessment of biorefinery technologies
- Provide an open access approach
- Factsheets, e.g., for gasification based biorefinery systems



Technical, ecological and economic assessment of biorefinery cases

A continuing attempt to accentuate the characteristics of the combined production of biobased products and bioenergy

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Biorefining and the momentum of sustainable recovery towards the circular economy

Despite the worldwide challenges of the COVID-19 pandemic, the topic of sustainable energy supply and production systems is still prominent. Concerning sustainability, the sustainable development goals (SDGs) developed by the United Nations in particular address economic, social and environmental aspects regarding a sustainable development, and there is also a goal defined that concerns sustainable energy (11). The global challenges concerning global warming and

Task 42 - Biorefinery Fact Sheets

Recent Fact Sheets:

- 3-platform biorefinery (pulp, lignin, energy) using woodchips for pulp, lignin and energy (LignoBoost process)
- 2-platform biorefinery (C5 & C6 sugar, lignin) using corn straw for the production of bioethanol and electricity & heat
- 2-platform biorefinery (C5 & C6 sugar, biogas) using sugar beet or cane for the biopolymer PHB and electricity & heat
- 2-platform biorefinery (C5 & C6 sugar, biogas) using maize for the production of biopolymer PLA and electricity & heat
- ... and more to come!

Part A: Biorefinery plant

2-platform (C5&C6 sugars, lignin) biorefinery to produce bioethanol, electricity & heat from corn stover

Ethanol is produced based on corn stover. The milled corn stover is pre-treated in a dilute acid pre-treatment process. Enzymatic hydrolysis is used to convert the hemicellulose and cellulose into monomeric C5 and C6 sugars and lignin. Cellulase is produced on-site. The fermentation uses metabolically engineered strains of *Saccharomyces cerevisiae* microorganisms that are capable of co-fermenting xylitol and glucose to ethanol, whereas a separate hydrolysis and fermentation process (SHF process) is applied.

Finally, the fermentation broth is fed into a distillation process. Distillation columns and molecular sieves are used to produce 99.5 % ethanol. The lignin is fed into a CHP plant in order to produce thermal energy and electricity which is used as process energy for the biorefinery process. The residue by-product from the distillation process is used as an agricultural fertilizer. If the residue is dried, it may also be used as energy carrier.

Key characteristics

2-platform (C5&C6 sugars, lignin) biorefinery to produce bioethanol, electricity & heat from corn stover

| Process | Ethanol (t/ha) | Electricity (MWh/ha) | Heat (MWh/ha) | Acetic acid (t/ha) | Chemical oxygen (t/ha) |
|---------------|----------------|----------------------|---------------|--------------------|------------------------|
| Pre-treatment | 4,400 | 110 | 110 | 0.273 | 0 |
| Hydrolysis | 387 | 110 | 110 | 0 | 0 |
| Fermentation | 422 | 140 | 0 | 0 | 0 |
| Distillation | 46 | 140 | 0 | 0 | 0 |
| Residue | 28 | 140 | 0 | 0 | 0 |
| Labour | 2 | 140 | 0 | 0 | 0 |

Part B: Value Chain Sustainability Assessment

2-platform (C5&C6 sugars, lignin) biorefinery to produce bioethanol, electricity & heat from corn stover

Conventional reference system

The diagram compares the biorefinery process (left) with a conventional reference system (right). The biorefinery process includes steps like pre-treatment, hydrolysis, fermentation, and distillation, leading to ethanol, lignin, and electricity & heat. The reference system includes steps like pre-treatment, hydrolysis, and fermentation, leading to ethanol, lignin, and biogas.

Key characteristics of biorefinery value chain

| Indicator | Value |
|--|-------------------------------|
| Greenhouse gas emissions (New material sourcing from stover) | 2,851 tCO ₂ e/ha |
| Greenhouse gas emissions (Reference system) | 368,793 tCO ₂ e/ha |
| Greenhouse gas emissions (Reference system) | 233,285 tCO ₂ e/ha |
| Renewable energy demand (Total) | 30 TWh |
| Renewable energy demand (From stover) | 1,200 TWh |
| Renewable energy demand (Reference system) | 2,827 TWh |
| Specific costs (Ethanol) | 127 M\$/t |
| Specific costs (Electricity) | 0.45 M\$/MWh |
| Specific costs (Heat) | 0.22 M\$/MWh |
| Specific revenues (Ethanol) | 140.7 M\$/t |
| Specific revenues (Electricity) | 70.8 M\$/MWh |
| Specific revenues (Heat) | 0 M\$/MWh |

Task 42 - Biorefinery Atlas Portal

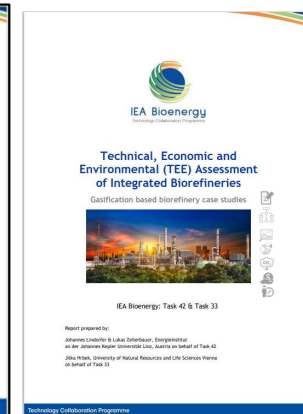
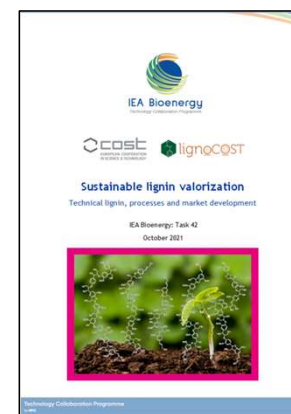
- The Task 42 Biorefinery Atlas Portal gives an overview of the world-wide biorefinery deployment status
- Possibility to display only the chosen plants by selecting the desired attributes on the legend
- Possibility to display features for feedstock, production capacity, TRL refining technology and product, download self selected data subset
- BR Outlook database not yet included
- Start exploring the Portal at:
<https://task42.ieabioenergy.com/databases/>

The screenshot shows the 'BioRefinery Plant Portal' interface. At the top, it includes the IEA Bioenergy logo and the ENEC logo. The main area is a world map with numerous purple and blue dots representing biorefinery locations. A legend on the right side of the map allows users to filter plants by feedstock type: Primary Biomass (checked), Secondary Biomass (checked), Multifedstock (checked), and N.A. (unchecked). Below the map, a detailed data table is displayed for a specific plant named 'Mater-Biopolymer'.

| | |
|----------------------|--|
| Name: | Mater-Biopolymer |
| Country: | Italy |
| City/State: | Patrica |
| Owner: | Novamont |
| Production (Kt/y): | 100 ktons/year |
| Feedstock: | Vegetable Oil |
| TRL: | TRL 9 Commercial |
| Refining Technology: | Chemical, Biochemical |
| Main Product: | Biomaterials: Polymers |
| Status: | Operational |
| WEB Site: | https://www.novamont.com/page.php?id_page=181 |
| Source: | IEA Task 42 Country report (https://task42.ieabioenergy.com/) |

Task 42 - Technical reports 5th Triennium (2019-2021)

- Bio-Based Chemicals: A 2020 Update
- Technical, Economic and Environmental Assessment of Biorefinery Concepts: Developing a practical approach for characterization
- Alternative sustainable carbon sources as substitutes for metallurgical coal
- Sustainable lignin valorization: Technical lignin, processes and market development
- Global Biorefinery Status report 2022
- TEE Assessment of Integrated Biorefineries: Gasification based biorefinery case studies



Task 42 - Other activities

- Biorefinery country slide decks provide local information
- Cooperation with the EC-Biorefinery Outlook project (focusing on chemicals and material-driven BRs)
- Cooperation with Mission Innovation Integrated Biorefineries
- Cooperation with IETS Task XI on Industry-Based Biorefineries
- Dedicated Task 42 website



Country Report - DENMARK

Status July 2021

Solange I. Mussatto
Technical University of Denmark

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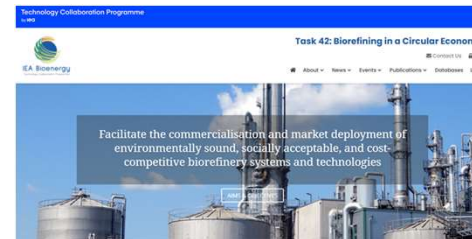
Technology Collaboration Programme



**INTEGRATED
BIOREFINERIES**
MISSION



Task XI on Industry-Based Biorefineries




Task 42 provides an international platform for collaboration and information exchange between industry, SMEs, NGOs, WFOs and universities concerning biorefinery research, development, incorporation and policy analysis. This includes the development of networks, dissemination of information and provision of science based technology analysis, as well as support and advice to policy makers, involvement of industry, and encouragement of membership by countries with a strong biorefinery infrastructure and appropriate policies. Gaps and barriers to deployment will be addressed to successfully promote sustainable biorefinery systems market implementation.



WP6 Dissemination - Website


Technology Collaboration Programme
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Task 42: Biorefining in a Circular Economy

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Facilitate the commercialisation and market deployment of environmentally sound, socially acceptable, and cost-competitive biorefinery systems and technologies

AIMS & OBJECTIVES

Task 42 provides an international platform for collaboration and information exchange between industry, SMEs, GOs, NGOs, RTOs and universities concerning biorefinery research, development, demonstration and policy analysis. This includes the development of networks, dissemination of information, and provision of science-based technology analysis, as well as support and advice to policy makers, involvement of industry, and encouragement of membership by countries with a strong biorefinery infrastructure and appropriate policies. Gaps and barriers to deployment will be addressed to successfully promote sustainable biorefinery systems market implementation.

MORE INFORMATION ON TASK 42

News and Highlights

PRESENTATIONS AVAILABLE OF MISSION INNOVATION WEBINAR ON BIOREFINERIES EFFICIENCY IMPROVEMENT

Sep 1, 2023

On the 13th of July 2023 Natural Resources Canada hosted a webinar on Biorefineries efficiency improvement. Following the publication of the Mission Innovation's roadmap, Natural Resources Canada, in collaboration with representatives of other member countries, the...
[read more](#)

RECORDING AVAILABLE OF MISSION INNOVATION INTEGRATED BIOREFINERIES WEBINAR

Jun 29, 2023

In 2022, the Integrated Biorefineries Mission presented its roadmap, which

Recent Events

IFIB - INTERNATIONAL FORUM ON INDUSTRIAL BIOTECHNOLOGY AND BIOECONOMY

Mar 16, 2023

The International Forum on Industrial Biotechnology and Bioeconomy will be held in the stunning Italian city from September 28 to September 29. The registration is open. More information can be found here.
[read more](#)

ITALIAN BIOECONOMY DAY 2023

Mar 16, 2023

The fifth edition of the National Bioeconomy Day is celebrated on Thursday 25 May 2023. The Bioeconomy Day involves the organization of numerous events, initiatives and on-site and online demonstrations throughout the national

Latest Publications and Reports

IRELAND COUNTRY REPORT JULY 2023

Aug 29, 2023

Ireland country report July 2023 Syron et al - 2023 - IEA 42 Ireland country
[read more](#)

GERMANY COUNTRY REPORT 2023

Aug 24, 2023

Germany country report 2023 Stichnothe - 2023 - IEA Task 42 Germany country report
[read more](#)

MORE PUBLICATIONS

Task management in Triennium 2022-2024

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