Triennium 2022-2024
Task / Strategic Project (SP)* Proposal Summary Sheet – First draft for ExCo 87

Task: Task 36 Material & Energy Valorisation of Waste in a Circular Economy **Proposer: Inge Johansson & Mar Edo**

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Endorsement by ExCo Member (Operating Agent) of participating country
Country: Sweden **Name: Jonas Lindmark** **Signature:**

Objective

Task 36 follows the integration of the Energy from Waste (EfW) in a circular economy by means of material and energy valorisation of waste, and its contribution to the global deployment of bioenergy.

The Task is designed to facilitate exchange of information on strategic technical and non-technical issues related to the integration of energy into waste management decision-making and operations. While stakeholders contributing to this exchange of information include researchers, the waste and recycling and recovery industry, the energy from waste sector, policy makers and local decision makers. The Task proposes to prioritise information for policy and decision makers.

The Task is aware of issues that influence energy from waste that are covered in other Tasks in IEA Bioenergy as well as by other international organisations in the field and is working together with them.

Work scope

The proposed 2022–2024 programme for Task 36 focuses on the effect that circular economy initiatives along the waste and energy value chain will have in the deployment of bioenergy globally. The following challenges will be covered in the work in 2022–2024:

- Transitioning from a linear economy towards a circular one generates possibilities to both implement existing and new solutions in new settings. Just because it is technically possibly does not mean that that solution is viable or the best in the larger picture. Reaching a better understanding of economic, societal, and environmental aspects derived from different EfW and material recycling technologies/strategies adopted will help in avoiding potential suboptimizations.

- The role of EfW in a linear economy has been to sanitize and decrease the volume of waste while generating useful power and/or heat in the process. Despite there will still be room for traditional solutions for waste that most probably cannot be handle in a safe matter in any other way in a circular economy; the role of EfW has to evolve and open to other opportunities to include new aspects and combinations of energy and material valorisation. This new role can encompass the development of new technology pathways to deliver high value products together with energy, but also changes in the waste amounts and compositions when waste minimisation, re-utilisation, and recycling increases. The stakeholders need to prepare for these changes. This work was begun in 2019–2021 but will continue into the new period.

- Another clear trend is the increased use and capability of different digitalisation tools. The sensors evolve as do the algorithms for the use of image recognition and big data mining. The waste and energy sector needs to be more aware about the role of smart/digital technologies in enabling transition of sectors towards circularity.

Work programme

The work programme will be divided into a number of main topics (Work packages) some of them are larger than others and are broken down in number of subtopics.

WP1. The role of EfW in the circular economy

- WP1.1 Integration of EfW and material recycling/recovery into industry
- WP1.2 Potential synergies between EfW and material recycling
- WP1.3 Resource recovery from residues generated by EfW
- WP1.4 The potential of Carbon capture and utilisation (CCU) within EfW

WP2. Sustainability

- WP2.1 Sustainability metrics and public acceptance
- WP2.2 Environmental performance of different waste management strategies
- WP2.3 Impact of new technologies: economical and societal aspects

WP3. Evaluation of new technology pathways

- WP3.1 Hydrogen from waste
- WP3.2 High value products from waste
- WP3.3 Organic waste – current options and solutions under development
- WP3.4 Sewage sludge valorisation
- WP 3.5 Mixed waste plastics recycling and utilization

WP4. Future scenarios: new waste streams, composition, and amounts

WP5. Smart technologies for waste sorting

Deliverables and Target Groups

The main deliverables for the programme proposed for the 2022-2024 triennium are listed below:

- Workshop Reports:
  - *Integration of EfW and material recycling/recovery industry*
  - *Sustainability metrics*
  - *Public acceptance*
  - *Sewage sludge valorisation*
  - *Framework for strengthening waste to resource management*
  - *High value products from waste*

- Case studies:
  - *Potential synergies between EfW and material recycling*
  - *Environmental performance of different waste management strategies*

- Topic Reports:
  - *Sustainability*
  - Topic Report about *Smart sorting technologies*
  - Topic Report on *Food waste – current practices and future solutions*
  - Topic report on *Future scenarios: new waste streams, their composition, and amounts*

- *Final report* summarizing all the content collected/generated during the triennium

- Intertask report / Topic reports:
  - *The potential of carbon capture and utilisation (CCU) within EfW*
  - *Hydrogen from waste*

- Newsletters
- Webinars under IEA Bioenergy

Dissemination Plan
The Task will use different channels to spread out the information gathered during the triennium.

- Task 36 website provides the background of the Task and it is the place where all the activities carried out by the Task will be documented.

- Newsletters will get out the work done by the task but also important pieces of information about on-going initiatives in the field all over the worlds.

- Participation in webinar under the IEA Bioenergy umbrella. For the first time, the task will also organize a series workshop to focus on local/regional topics.

- The task members will spread the information collected by the Task in conferences and relevant national and international events.

- Communication platforms will be used to increase visibility of the task and reach a new and wider audience.

- For the first time, the Task will try dissemination of short films with, for instance, the main outcomes of a deliverable.

Management Qualifications
Task Leader: Mar Edo
Task Assistant: Inge Johansson

Annual Budget US$136,000; **Budget per participant**; US$17,000, assuming 8 countries participate (6 confirmed).

DETAILED PROPOSAL

Task	**Task 36 Material & Energy Valorisation of waste in a Circular Economy**

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1. Background and rationale

1.1 Current state-of-the-art and future potential

By 2025, it is estimated that 2.2 billion tons of solid waste will be globally generated[1]. Global efforts are aiming to raise awareness of the problem of a steady increase of waste generation, and the Circular Economy model is considered to be the way to design out waste and pollution[2]. Yet, according to The Circularity Gap Report 2020[3] recently published, only 8.6% of the global economy is circular and identifies "low levels of end-of-use processing and cycling" as one of top three reasons for preventing/slowing down the transition, meaning that there is still a long way to go before the problem is solved. Material and energy valorisation of waste is one of the pieces of the puzzle for increasing circularity.

Moving from a linear to a circular economy requires changes in the whole value chain, from consumers habits, products and material design, regulations, technologies, waste/resource management and business models. Changes in one part also affect other parts in the chain since the different parts are intertwined and crosslinked, creating a complex system to consider. A continuous 'check in' process needs to be included so to ensure that new, more severe, environmental impacts are not created in the context of increasing process and product cycle development. The changes will not be limited to technical ones but will also create a demand for new business models and new value chains. The waste management sector must adapt accordingly and be pro-active in expanding boundaries and transition towards an increased resource focus. The economic value in materials needs to be retained or even upgraded, at the same time as the materials need to be safe to use. That means that hazardous substances need to be removed from circulation.

As Circular Economy principles become more established and commonplace, more will be required from Energy-from-Waste (EfW) systems in terms of material, nutrient, and energy recovery. It is unlikely that this will be possible using incineration technologies alone – this task will continue to consider how incineration-based systems can evolve to meet CE principles but will also consider the role of new and emerging technologies, and the opportunities they represent for the waste management sector.

Material Valorisation

Traditional recycling of waste fractions like plastics is often seen as material downcycling where the material is kept "in-the-loop" but is used to produce lower quality products. In this process, a reject fraction with no value for material reuse/recovery is generated and is landfilled or incinerated. There is a continuous development in both the effort to get more materials to recycling as well as increasing the quality of the recycling. Those developments can be through improved source separation or the development of more advanced/smart sorting processes that generate cleaner fractions to be recycled, thus increasing the possibility to high quality recycling of the material. In addition, regions like Europe face a lack of recycling capacity preventing the increase of recycling rate revealing the need of building capacity and/or finding new paths to promote reuse over recycling[4]. There is a role here for alternative technologies, such as gasification, to contribute to new 'chemical recycling' pathways, provided they offer sustainable, cost-effective solutions.

Biogenic waste such as food waste, sewage sludge or garden waste represents opportunities to keep carbon and nutrients "in-the-loop". Over the last years, there is a trend of preventing biowaste from being landfilled and used for land applications and new strategies and processes for these streams are developed. To realize the vision of the circular economy and expand a sustainable deployment of

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[1] What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050, Kaza, S.; Yao, L. C.; Bhada-Tata, P.; Van Woerden, F. Urban Development; Washington, DC: World Bank. © World Bank., 2018. Link here.

[2] Ellen Mac Arthur Foundation, website checked on 2nd of March 2022. Link here.

[3] The Circularity Gap Report 2020, PACE- Platform for accelerating the Circular Economy, 2020. Link here.

[4] Trends and drivers in alternative thermal conversion of waste. Staph, D. IEA Bioenergy Task 36 report, 2020. Link here.

bioenergy, there is a need to find new pathways to treat these waste streams. These new pathways would ultimately lead to high-value products such as biochemicals or bioproducts in addition to being a source of bioenergy. There is interest for non-energy products from waste, but at the same time both the economic viability and lack of appropriate policy support restrict the development of the market and new approaches[5]

Molecular valorisation

In addition to the more traditional material recycling, there is a trend towards exploring the possibilities for "recycling" of the molecules/elements in the waste. In particular, this is true for carbon/hydrocarbons. In these cases, the materials are broken down into molecules that then could be used as building blocks for fuels, chemicals, or materials. Such pathways are not possible using traditional incineration technologies, and require new approaches based on gasification, pyrolysis, or biological systems. Synthetic fuels and feedstock recycling are upcoming, but are in a very early commercial state, with quite few examples in operation around the world.

In particular, bioproducts, chemicals, and materials deliver additional value and revenue to early adopters of these technologies. This accelerates the deployment of circular processes through higher returns on investment to early adopters since these processes are inherently riskier. There might also be a need to make policy adaptations to accelerate this transition to renewable products, much like what have been done in the field of renewable energy (green certificates, feed-in tariffs, quota demands etc.).

Energy Valorisation

Any circulation of material requires the input of energy. In a sustainable circular economy, this energy input shall be renewable or recovered, as efficient as possible and thus economically affordable. Today, waste and non-waste biomass is a key renewable energy source and EfW in different forms can contribute to a sustainable energy system. In the future, waste management systems have to be designed for optimum support of the Circular Economy, making the most of the inherent materials while recovering the energy from materials and molecules that cannot be recycled in a safe, resource efficient way.

The role for EfW is evolving from being a method where you largely sanitise waste and reduce the volumes of waste going to landfill to being methods that treat those fractions of waste that cannot be recycled or recovered and recover the chemically bound energy in those materials in different forms. That recovered energy can be used in different forms like power, heat and cooling as well as transport fuels, and play a role in emerging growth opportunities such as hydrogen. Thus, the EfW concept is evolving to encompass more than traditional incineration. EfW can also provide energy and feedstock (such as syngas or hydrogen) to ensure the processing required for reuse, refurbishment or recycling is available. In particular, heat, cooling, and heavy duty/aviation transportation fuels are sectors that have been difficult to decarbonize. Even in a fully functioning circular economy there is a need for energy and process inputs. During the transition period towards the circular economy (and maybe also afterwards) there will still be a function of detoxifying waste, reducing waste volume, and concentrating substances that should and could be stored/treated in a safe way.

This means that there will be a need to adapt EfW, so that a solution to dealing with residual waste is provided, whilst at the same time it provides some of the energy that will be needed for further processing of materials and resources within a circular economy. The processes also have to take into account the mixture of biogenic and fossil materials and to be clear about the origin and work to minimise the fossil emissions of CO_2. In this context CCS/U (Carbon Capture Storage/Utilization) is also foreseen to have a potential to be a useful set of technologies, that potentially can sequester CO_2 making the EfW net CO_2 negative (direct emissions).

[5] Waste for feedstock recycling: Challenges and Opportunities, Hoffman, B.; Dyer, B. IEA Bioenergy Workshop Report, 2020. Link here.

1.2 Challenges and opportunities

All countries are unique in terms of resource availability, and how they are handled before and after they turn into waste. Economic and societal factors, technology innovation/availability, policy or environmental aspects determine the strategies that each country will adopt to enable transition to a circular economy and, by extension, in the deployment of bioenergy globally. The challenges faced by operators and policy makers might vary considerably between countries. Yet, the challenges can be grouped:

1. In addition to the regional and seasonal variation in waste composition, the continuous increase in reuse, recycling, and recovery in most parts of the world has also an impact on the waste composition. For those countries that already have started their journey towards the circular economy, new complex materials designed to last longer are being developed and may be challenging for the waste management systems and, in particular, the recycling systems that need to be able to cope with this variability and any future changes.

2. In some places such as Australia, South Africa and US, there is still a poor public perception of EfW. Lack of transparency during the decision-making process or not inviting residents and stakeholders to be part of the project as well as lack of information exchange between the operators and the clients may lead to poor public acceptance. Developing scientifically based sustainability metrics to give a more unbiased basis for the discussions might also facilitate the acceptance.

3. Incineration with energy recovery is a small part of the Circular Economy. However, EfW is much more than incineration. As example, Hydrogen from Waste and feedstock recycling show the potential of new technologies to extract and capture energy from waste. With new technologies entering the market, new policies and regulations and business models need to be developed.

4. To keep materials in-the-loop, smart collecting and sorting systems need to be developed and implemented. This need arises no matter if you have chosen a path towards a citizen driven source separation scheme (where communication and education of the citizens also is a vital factor) or a centralised sorting solution. The waste management systems need to become smarter to handle the challenges. Finding the right smart technology for waste sorting is something that all the waste managers need to do and there might be considerable differences between countries depending on how developed their waste management system are and which technologies are available and affordable.) In addition, ensuring the collecting and sorting systems are compatible with downstream recycling or upgrading processes requires system-level coordination.

5. In many emerging and developing economies, waste management is poorly developed and to a large extent based on landfilling or dump sites of waste. A rapid increase in waste generation in urban environments in these economies accentuates the need for alternatives in the waste management. Then, in many cases, acute situation, might tempt decision makers to try a find a single solution like a mass-burn facility to solve the situation. However, such a solution would not be sustainable even if it meets an acute need today. There is a need to develop appropriate sustainable waste management strategies that very well may include integration of energy recovery into solid waste management. Therefore, there is a need for data on waste, composition, and calorific values; as well as a need for to skills development and understanding through appropriate training. A proper decision framework integrating all the main aspects of sustainability (economy, environment and social) is an enabler to ensure that the developed strategies are not sub-optimized in favour of short-term solutions.

6. Waste streams are present in many forms in the society, however most of the waste streams that today are treated in EfW plants are mixed streams containing both biogenic and fossil materials.

When used in combustion processes this will generate a contribution to greenhouse gases that could be countered with technologies like carbon capture and storage or utilisation (CCS/U). The use of CCS/U would also potentially contribute to a WtE with negative net CO_2 emissions, since the biogenic CO_2 also will be captured. An increased recycling of fossil materials is another pathway to decrease those direct emissions.

7. Sector coupling is emerging as a feature of decarbonisation strategies around the world. We are already seeing transport and electricity sectors come together in an unprecedented way, as battery electric vehicles become mainstream in some parts of the world. As CE principles become more established, and technology pathways emerge, waste management can be integrated into the manufacturing, agriculture, transport, and power sectors in a manner that offers significant emissions reduction as well as avoidance of landfill.

1.3 Realising the IEA Bioenergy Strategic Plan

Biogenic resources from waste are a renewable resource routinely generated in society. It can be used to provide bioenergy that is integrated into the lives of the population, securing energy supply, and using local resources. Its management and conversion into energy products is very relevant to growing cities; and its management changes as the needs of the local population evolve. In addition, waste is generally regarded as a sustainable biomass/renewable source (although the large amounts of waste generated is not sustainable in itself). It can therefore play an integral role in security of sustainable energy supply and helping nations to reach their targets on renewable energy. However, considerations also must be made to the fact that normally only part energy recovered from the waste is from biomass/biogenic resources. A significant part also comes from fossil sources (mainly plastics), which poses challenges. Furthermore, each approach brings with it different environmental and social implications, which need to be considered in the context of increasing bioenergy production from wastes.

A better and more resource efficient waste management (including actions to prevent waste being generated) could for example decrease the amount of land needed for food production. The role waste management and waste-to-energy play in a circular economy also relates to aspects about bioenergy in the circular economy as well as about resource efficient solutions that could lead to a decrease in consumption of fossil energy. The IEA technology roadmap points out waste as one important part in delivering sustainable bioenergy. In this report, the potential of waste in 2060 is estimated to10-15 EJ, and that is only considering the effect of energy recovery in different forms. It does not include the indirect effects like savings in use of energy achieved through an efficient waste management system (with prevention, re-use and efficient recycling).

2. Objectives

During 2022–2024, Task 36 will focus on the effect that circular economy initiatives along the waste and energy value chain will have in the deployment of bioenergy globally.

The specific objectives for the proposed programme are:

- Understanding economic, societal, and environmental aspects derived from different EfW and material recycling technologies/strategies adopted.
- Highlight the role of EfW in a circular economy.
- Evaluation of new technologies pathways for turning waste into high valuable products.
- Forecast waste streams composition and amounts generated as circular economy is unfolding.
- Raise awareness within the waste and energy sector about the role of smart/digital technologies in enabling transition of sectors to circularity.

3. Work programme

The core focus of the Task 36 programme for 2022–2024 is on the effect that circular economy initiatives along the waste and energy value chain will have in the deployment of bioenergy globally. The programme for this new triennium has been developed taking the global trends discussed above into account as well as local trends of importance to participating countries. An overview of the priorities is given in Figure 1Figure 1**Fel! Hittar inte referenskälla.**. The programme will be divided into a number of sub-tasks that will be covered through different actions. All the knowledge generated and gathered during the triennium will be summarized at the end of the triennium in a report.

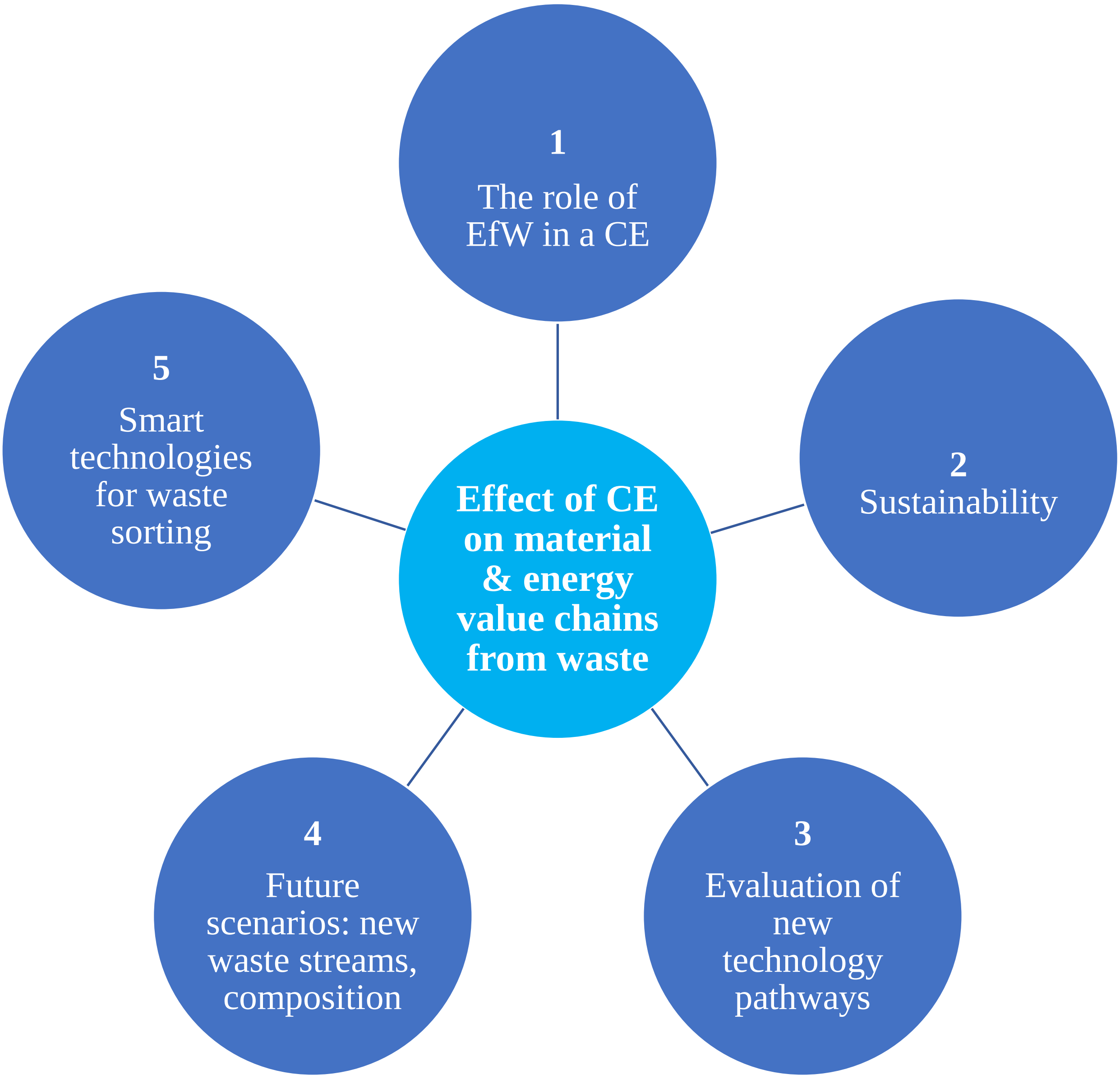

Figure 1. Topics of interest for the next triennium in *Task 36 Material & Energy Valorisation of waste in a Circular Economy*

3.1 The role of EfW in a Circular Economy

This sub-topic aims to bring light to the role of EfW in a future of a circular economy in which the energy industry might stand back and leave room for other industries to be become key players.

Importantly, this activity recognises that EfW can be more than incineration, and that by considering a diversity of technological pathways we can support an improved alignment of waste management with CE principles. Some of the questions that this sub-task will try to answer are: how should the EfW industry prepare to be part of the Circular Economy? Which kind of waste will be part of it? Which products will be targeted in these EfW processes? Which EfW technologies will be required to achieve this transition? All these questions will be addressed in topics of interest within these sub-topics:

Integration of EfW and material recycling/recovery into industry
Nowadays, EfW pathways lead in most of the cases to energy products in the form of electricity, biogas etc. However, in a circular economy, attention should be given to processes that result in recycling of material and better recovery options. To achieve this goal, it is important to increase the potential of the used technologies in terms of recycling of specific material fractions and, at the same time, to find new options for the use of energy products, syngas, biogas, etc. as resources to be used in other industries.
Type of work item: Workshop (potential participation of Task 33, 34 and 42)

Potential synergies between EfW and material recycling
Public perception of EfW projects is a complex matter, with many underlying reasons behind a lack of support for specific projects. Emissions and environment concerns are often a significant part of this; however, there are considerable data available in support of statements suggesting that modern, well-run plants are clean and effective. Another argument against recovering energy from waste streams is that such operations 'cannibalise' recycling efforts and have a negative impact on overall recycling rates which leads to outcomes inconsistent with the waste hierarchy.

The work of this Task will study some best-practice examples of well-managed EfW installations as part of overall waste management strategies, with the view to generating data that can demonstrate the impact of EfW on recycling rates, as part of a wider information piece to help inform communities and governments of the impacts of EfW on waste management systems.
Type of work item: Case study

Resource recovery from residues generated by EfW
Traditional EfW processes based on incineration normally generate a significant amount of residues (typically 15-25% wt. of the incoming waste). In general, the bottom ash can be used in some countries used as secondary raw materials for construction purposes. However, due to different policies, the use differs a lot between different countries and in some cases the material is just landfilled. The fly ash has traditionally been treated as a hazardous waste and been landfilled or used to refill old mines.
When the focus shifts towards circularity, and to the role that EfW can play in a circular economy, the recovery of resources from these streams becomes more important. The safe handling of these residues will always be the primary target, but to be able to replace virgin materials with resources extracted from these residues will be imperative for the future of EfW. The task will follow the development in this area as well as keep on top of issues that might arise from residues generated from new EfW technologies.
Type of work item: The development to be followed and discussed during a Task meeting.

The potential of Carbon capture and utilisation (CCU) within EfW
Because it is (in most cases) mainly biogenic, EfW combined with CCUS offers the potential of negative CO_2 emissions, an important weapon to reach the Paris Climate Agreement goals. In the previous triennium, an Intertask report summarising key aspects of different Bioenergy carbon capture utilization and storage (BECCUS) case studies was published, highlighting the background, economy, advancement, and remaining challenges (technical or not) to large-scale implementation. In the next triennium, a similar approach could be advantageously employed to focus on one or more aspects specific to BECCUS, e.g.: EfW CCS initiatives in Norway/Scandinavia/Europe; the full-scale CCS

project in Norway (EfW CCS, FOV, Northern Lights, Long Ship); CCS technologies & EfW – an overview or BREF BAT WI & CCS.
Type of work item: Intertask study if possible, otherwise a Topic report.

3.2 Sustainability

The main topic sustainability will be dealt with in a Topic report that summarizes the work done in the subtopics below.

Sustainability metrics and public acceptance

There is a need of introducing common indicators to measure sustainability in a complex field like the waste management. This process includes a lot of actors concerning economy, social aspects, and environment protection. Economical concerns alone cannot solve problems like public acceptance and environment preservation.
Resource and energy recovery from waste is often handled at a local and community level. A critical aspect of project success is ultimately ensuring that the local stakeholders are engaged early and often throughout the project feasibility, development, and deployment phases of a project. The task will explore varying public perceptions on transitions to circular waste recovery schemes and what environmental and social sustainability indicators are most critical in building trust.

Balanced indicators can help the decision makers but should be flexible because the relative importance of the three legs of sustainability is strongly related to local conditions.
Type of work item: Workshop series aimed at learning about regional/local differences on this topic.

Environmental performance of different waste management strategies

The studies on relative environmental performance of waste management strategy can be done by applying consolidated methodologies like LCA and cost-benefit analysis. One of the problems is that not all the existing strategies can be implemented everywhere, although if the best one from an environmental point of view. This may depend on social factors or public acceptance.

The present state-of-the-art in assessment of waste management systems is characterised by fragmented efforts, not fully analysing the full life-cycle requirements or impacts, and by implemented processes that are far from the modern concepts of the circular economy[6]. Consequently, new systems for waste management must be developed to minimise environmental trade-offs during the transition to sustainable circularity. Central to this are the life cycle assessment (LCA) studies, which will consider environmental impacts across the full life cycle of the waste management technologies/systems to avoid 'burden shifting' or trade-offs when choosing between pathways for circularity. Environmental data will be collected for conventional waste management systems which will be affected by market uptake of the new technologies/systems to allow for quantification of the environmental benefits arising from the avoided use of these systems. The LCA work will examine synergies and trade-offs between using waste for energy generation and within the circular economy and will highlight possibilities to minimise trade-offs by considering the impacts of circular economy principles and cascading.
Type of work item: Case studies

Strengthening waste to resource management frameworks/models with lessons learnt from other countries

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[6] Plakas, K. V., et al. (2016). "Sustainability assessment of tertiary wastewater treatment technologies: a multi-criteria analysis." Water Science and Technology **73**(7): 1532.

An important factor in the transition towards a waste to resource decarbonised and circular economy is the need to build the capacity of municipalities, local authorities, and the private sector in the decision-making process for the insertion and correct localisation of EfW appropriate technologies and strategies. The members of Task 36 are advisors to their respective governments in the development of Waste-to-Energy Roadmaps, and in the case of South Africa, also the developer of a comprehensive Waste to Resource Management Framework (The WROSE model - Waste and Resource Optimisation and Scenario Evaluation Model) that assists municipalities and national government in the implementation of Integrated Waste Management Plans through the evaluation of best case scenarios that respond to all 4 levels of sustainability (Environmental, Technical/Economic, Social and Institutional). In this work item, Task 36 will facilitate sharing of lessons learnt among the members on the development and application of such waste to resource management frameworks, with the objective to strengthening their capabilities and applicability to various contexts, to create more reliable national and international databases (GHG Emission Factors, Waste Data, Technical/Economic Indicators, Social Indicators) in support to the correct insertion of technology across the member-countries.
Type of work item: workshop

Impact of new technologies: economical and societal aspects
Overall societal willingness to address environmental problems is well-documented[7], for example a recent Eurobarometer survey noted protection of the environment as a key priority for 94% of respondents, with changing consumption, production and trade habits highlighted as the most effective means to address environmental issues[8]. However, we know very little about the overall attitudes and social acceptance of new waste management technologies. For a new waste treatment technology/system to be considered socially sustainable, it should boast wider social acceptance than comparable/existing systems. Most of the literature contributions regarding transition to a circular economy are from a science perspective with social aspects and perspectives significantly lacking[9]. Social impact and potential benefits of new waste treatment technologies can be quantified using quantitative LCA methods.
Type of work item: LCA will be included in the work items in the topic 3 "Evaluation of new technology pathways".

3.3 Evaluation of new technology pathways

Hydrogen from waste
Hydrogen has emerged as a technological solution to a range of decarbonisation challenges across the power, transport, and industrial sectors. Much of the interest is in so-called 'power-to-X', where (renewable) electricity is used to produce hydrogen via electrolysis and that hydrogen is used for a range of applications such as mobility, production of green methane, fuels, or chemicals, or in decarbonising heavy industries such as steelmaking.

The global demand for hydrogen is projected to grow significantly: the global Hydrogen Council has estimated that by 2050 we could have a global hydrogen demand of 80 EJ – a 10x increase on the demand from 2015, a significant diversification in usage patterns, and most of this driven by the desire for the hydrogen to be 'carbon-free' (see Figure).

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[7] Capstick, *et al*. (2015) International trends in public perceptions of climate change over the past quarter century. *Wiley Interdiscip Rev Clim Change*, 6, 35–61; Poortinga, *et al*. (2019) Climate change perceptions and their individual-level determinants: A cross-European analysis. *Glob. Environ. Change*, 55, 25-35; Pidgeon (2012) Public understanding of, and attitudes to, climate change: UK and international perspectives and policy, *Clim. Policy*, 12, S85-S106.
[8] EC (2020) *Special Eurobarometer 501: Attitudes of European Citizens towards Environment.*
[9] Bugge, *et al*. (2016) What is the bioeconomy? A review of the literature. *Sustainability*, 8(7), 691.

To meet such an enormous demand for low-carbon hydrogen a range of pathways will be needed: it is likely that this demand will not be met by solar and wind alone. Bioenergy has a role to play here, and the pathways that support bio-hydrogen are varied. They include waste and biomass gasification, with the syngas processed to produce H_2, or biogas upgrading and conversion. Pyrolysis pathways have the potential to create plastic-to-hydrogen opportunities, and there are other emerging pathways based on microbiological and enzymatic processes.

As the Task considers how 'linear' waste-to-energy processes can be adapted or converted to be more consistent with circular economy principles, bio-hydrogen as a product from waste management will be considered from technoeconomic and sustainability perspectives. These pathways can be energy – where the hydrogen is used as a transport fuel or as a source of heat or power – or from a manufacturing perspective, where hydrogen is used as a feedstock. The outcomes from these analyses will be important to supporting the planning and decision-making processes for new bioenergy and bio-hydrogen initiatives around the world.

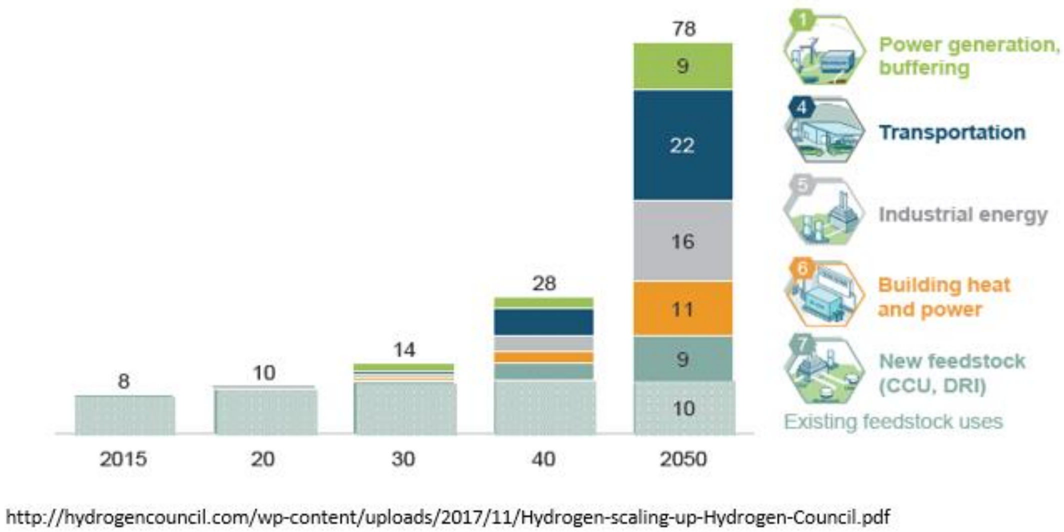

Figure 2. Forecast of global energy demand supplied with Hydrogen (EJ)[10]

Type of work item: *Potentially Inter-task report.*

High value products from waste

Compared to energy products such as heat, power, or liquid fuels, products can deliver significantly higher revenues to technology providers and investors therein. These increased revenues can potentially accelerate the deployment of technologies to 'keep molecules in the loop' and increase effective rates of resource recovery from waste. Potential technologies include chemical recycling methods such as pyrolysis or solvent technologies, gasification and upgrading of syngas to products or chemicals, and modified digestion technologies that produce other intermediates instead of biogas. *Type of work item*: Suggested as a joint workshop (or even series of workshops) with other tasks (33,34,42) with a summarizing workshop report.

Organic waste – current options and solutions under development

Organic waste like food waste and garden waste is treaded very differently around the world. Still a lot of it ends up in dumpsites or landfills where it generates methane. When there is a dedicated treatment for the organic waste that is usually either composting or anaerobic digestion. However,

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other options are also under development and the interest in biochar, hydrogen, and other higher value products are drivers for that development. This area contains natural interlinkages with the high value products from waste as well as potentially the evaluation of technology pathways for the valorisation of sewage sludge.
Type of work item: Topic report

Sewage sludge valorisation
There is a limited amount of phosphorus available that is feasible to extract with today's price of phosphorus. However, phosphorous can also be found in waste streams such as food waste and sewage sludge. By suitable treatment, sewage sludge might ensure the circulation of this nutrient. The direct distribution of sewage sludge is controversial from a health and safety aspects with risk of contaminating the farmland with pathogens as well as metals like cadmium. Other uses like energy recovery are hardly applicable because of the high content of moisture that can reach up to 99%. Pre-drying by recovered high-temperature air streams can help if not recovered in other processes. Filter pressing can reduce the moisture content, and the technology has been largely implemented in recent years (e.g. multi-disc screw press sludge dewatering), but results in high cost and the obtained pressed sludge still has low calorific values. The recovery of phosphorus as a by-product of other treatments like hydrothermal carbonization can help in reducing the cost and this opportunity should be well investigated.
Type of work item: Case study and/or potential workshop with T34 since they also have expressed interest in technology pathways to treat sewage sludge/recover phosphorous.

Mixed waste plastics recycling and utilization
Flexible waste treatment technologies being capable of dealing with mixed feedstocks that vary in composition and relevant properties are key enablers of a circular economy. This includes solutions for pyrolysis and for gasification and upgrading of syngas. Waste feedstocks are residual biomass, mixed waste (MSW) as well as mixed plastic waste. Within task 36 we focus on chemical recycling of these feedstocks to sustainable products. Recent developments and lessons learned need to be followed up, conclusions need to be drawn and deployed, and their potential impact on implementing a circular economy for waste needs to be evaluated. Here, we will follow up dynamic development of this field[11] and we will collaborate with T33 and T34, broadening the application scope of the technologies to synthetic transportation fuels and energetic utilization, and to the advantageous economics of co-processing waste and biomass[12].
Type of work item: highly related to the subject of high value products from waste and will be integrated into workshop(s) on the subject.

3.4 Future scenarios for new waste streams, their composition, and amounts

The development of new material and innovative designs to preserve the value of the products for as long as possible play a key role in enabling (the transition to) a circular economy.
Smart products, lightweight materials, nano materials, and other developments in the society challenges the traditional waste management system - both when it comes to material recycling as well as energy from waste. In addition, the fact that products will be designed to be totally or partially repaired, reused, or recycled will have an impact on the amount of waste that will be available for material and energy valorisation. *Forecasting of waste streams compositions and amounts* isn a valuable information when designing future waste management systems and prioritizing the development and deployment of new technologies.

[11] Trends and drivers in alternative thermal conversion of waste, IEA bioenergy report, 2020. Link here.
[12] Pre-treatment of municipal solid waste (MSW) for gasification, IEA bioenergy report, 2019 Link here.

The CE principles combined with social evolution will impact waste and its management. How will the composition and distribution of MSW change in the future? Which impact will social behaviour, legislation, trade/market but also new technologies have?
Type of work item: Topic report.

3.5 Smart technologies for waste sorting

In a circular economy waste is resource, meaning that materials can be recovered and upgraded to new high value products or reused keeping the material in-the-loop as long as it is safe from an environmental and health perspective. Developing and implementing smart sorting technologies in the waste management industry generates new possibilities to keep materials in circulation and create future business opportunities. The main topic smart technologies for waste sorting will be dealt with in a Topic report that summarizes the work done in the subtopics below.

The use of AI and digital tools will have an impact on the waste and energy sector. It might influence the material logistics (waste collection), quality of separation and/or types of materials achieved through automated waste sorting, etc. and it could also be a great help for improving processes related to recovery of materials from waste. Collecting and summarizing which have been the main developments in this area and examples of implementation in the waste and energy industry is a way to show the potential of this new area.

Non-destructive chemical-physical technologies, applicable to fluxes of composite materials are already available on the market and some of them have been already tested and validated in waste sorting facilities. Useful instrumental techniques include non-destructive analysis of metals by compacted XRF (X-ray fluorescence) devices with silicon drift detector and sophisticated software that can reduce the matrix effect and increase sensitivity and selectivity. As an example, Near Infra-Red detectors (NIR) are already used to estimate the values of a number of parameters including moisture content and calorific value as well as to sort not recyclable fraction of plastic like PVC.
The use of digital tools mentioned above will lead to significant breakthrough in material recovery if applied to non-segregated waste streams such as mixed of plastics. The efficiency of the separation process itself could be improved through implementation of digital/smart sorting technologies. The use of smart tools in the sorting process will decrease the manual sorting having an impact on social and economic aspects.
Type of work item: case studies included in the topic report.

4. Deliverables and schedule

Details of the deliverables over the Task are presented below. Similar information is also included in the Gannt Chart (see page 18). *Q* stans for quarter of a year (1-4).

M – Minutes from the Task meetings
M1-M12 Minutes from task meetings, spread out through the triennium.

WR –Workshop reports
WR1 – Integration of EfW and material recycling/recovery into industry, Q1-2, Year 1
WR2 – Sustainability metrics, Q3-4, Year 1
WR3 – Public acceptance (workshop series), Q1-2, Year 2
WR4 – High value products from waste, Q3-4, Year 2
WR5 – Sewage sludge valorisation, Q1-2, Year 3
WR6 – Framework for strengthening waste to resource management frameworks, Q3-4, Year 2
For this new triennium, we will give the possibility to attend to the workshops physically (in combination with other events, i.e., conferences, meetings) or virtually with the aim to reaching a

wider audience.

CS – Case studies
CS1 – Potential synergies between EfW and material recycling, Q1-2, Year 2
CS2 – Environmental performance of different waste management strategies, Q4, Year 2- and Q1, Year 3

TR – Topic report
TR1 – Report on Sustainability, Q1-2, Year 3
TR2 – Report on Smart sorting, Q2-3, Year 1
TR3 – Food Waste- Current practices and future solutions, Q3-4, Year 1
TR4 – Report summarizing the work during the triennium, Q2-3, Year 3
TR5 – Future scenarios: new waste streams, composition, and amounts, Q4, Year 1 – Q1, Year 2

ITR – (Potential) Intertask reports that might turn into topic reports if it is not possible to have an intertask.
ITR1 – The potential of Carbon capture and utilisation (CCU) within EfW, to be determined
ITR2 – Hydrogen from waste, to be determined

Newsletter- 2 times per year in Q2 and Q4
Webinar under the IEA Bioenergy Framework – availability to be checked.

5. Dissemination

During the triennium 2022-2024 the goal of 2 newsletter each year set in the previous triennium will remain. Apart from being sent to those subscribed, the links to the newsletters will be shared in media such as the task members LinkedIn profiles.

The Task 36 homepage will be constantly updated with new information: news, events, reports, workshops, participation in conferences etc. Summaries together with presentations/proceedings from workshops will be published openly. Topic reports will be published openly and coordinated with communication through newsletter or other channels.

The task will aim to contribute two subjects for webinars within the IEA Bioenergy framework during 2022-2024 and will arrange our own webinars.

Task meetings will be documented in notes and available for countries participating in the task in the Task members website.

Members of the task will look for opportunities to contribute to relevant national and international events and conferences to communicate the work of the task.

Task members will continue using communication platforms such as LinkedIn and try to find new ways of communication to increase visibility of the Task, reach a wider audience and promote the work and existence of IEA Bioenergy in general, and specifically the work being done by Task 36. A new way of communication that might be tried is the dissemination of short films in which one of the NTL summarizes, for instance, the main outcomes of one of the deliverables (i.e. report, case study).

6. Collaboration and linkages

6.1 Collaboration with other Tasks of IEA Bioenergy

There are a number of potential areas in the programme that could be beneficial to coordinate or cooperate around with other tasks:

WP1 – The role of EfW in a Circular Economy: In this work package we see the potential for cooperation primarily about a workshop on the integration of EfW pathways (including both energy and materials) into other industries. Primarily Task 33,34 and 42. However one of the subtopics is also CCS/U which could be relevant for an intertask with more tasks involved.

WP2 – Sustainability: in the field of sustainability there could be a good connection with Task 45; and public acceptance can also be relevant for other tasks, although the aspects on public acceptance of waste can differ towards those of bioenergy in general.

WP3 – Evaluation of new technology pathways: in this work package there are a multitude of openings, many of the new technology pathways available or under development are related to general work in T33, T34 and T42, but also T37 and potentially T39. Here we also see participation in one potential Intertask on Hydrogen and another (lead) on high value products from waste.

Intertasks: As mentioned above there are at least discussions about three potential intertask projects on different subjects:

- Hydrogen – and for our part Hydrogen from waste
- BECCS/U

6.2 Collaboration with other TCPs, other international organizations, networks and industry

During the triennium efforts will be made to associate meetings and workshops with important networks and stakeholder events. Also, relevant networks and industry will be invited to actively participate in workshops organised by the task.

7. **Task management** (to be decided)

The proposed Task Leader for this prolongation is Mar Edo of RISE (Research Institute of Sweden), Sweden

Short description/bio/merits
Mar works on national and international projects aimed at minimizing waste generation and improve waste handling for achieving an efficient use of the resources. Her main interest is on solid waste composition and the effect that the minimization of waste generation will have on it in the future. Mar has participated in IEA Bioenergy Task 36 since 2018 as task-leader assistant.

The proposed Task Leader assistant for this new triennium is Inge Johansson of RISE (Research Institute of Sweden), Sweden

Short description/bio/merits.
Inge has extensive experiences from resource efficiency and waste related matters. His focus is on the residual fractions being used for energy recovery and the residues (ashes) generated from the energy recovery. A lot of the questions Inge works with relates to the future role of energy recovery in a circular economy and how to avoid sending fractions that could be recycled to energy recovery. Challenges around recovering resources from ashes, or the potential utilisation of ashes as secondary raw materials are other hot topics Inge is working on.

Inge is convenor of ISO TC300 WG2 dealing with standardisation around solid recovered fuels (SRF). He has participated in IEA Bioenergy Task 36 since 2013 and lead the task since 2016. In addition, Inge also manages the strategic network Waste Refinery.

8. Budget and interest of ExCo members

The budget below is the best current estimate and might be subject to significant change both depending on how many countries that might participate as well as which countries. The topics in the work programme is a result of the interests of the members currently participating in the task.

Triennium Budget Table

TRIENNIUM 2022 - 2024

TASK 36

BUDGET

	2022	**2023**	**2024**
Number of participants	8	8	8
Annual cost per participant	17 000	17 000	17 000
Task income	136 000	136 000	136 000
Less 10% to Strategic Fund	13 600	13 600	13 600
Net Task income	122 400	122 400	122 400
Funds carried forward	0	-100	1 800
Outstanding funds for preceding year(s)	0	0	0
Other income (strategic contribution to intertasks)	5 000	12 500	2 500
Net available funds	127 400	134 800	126 700

SPEND vs BUDGET BREAKDOWN

	Budget Year 1	**Budget Year 2**	**Budget Year 3**
1a Salaries / benefits - Task Management	30 000	30 000	30 000
1b Salaries / benefits - Dissemination	11 000	11 000	11 000
2. Support services	0	0	0
3. Materials / supplies	0	0	0
4. Travel	6 000	4 000	6 000
5. Other expenditure	4 000	4 000	4 000
6. Meeting and workshop costs	10 000	5 000	7 000
7. Overhead	0	0	0
8. Projects / Subcontracts / Consultants	56 500	44 000	60 000
9. Intertask projects	10 000	35 000	8 000
TOTAL	127 500	133 000	126 000
APPROXIMATE YEAR TO YEAR CARRYOVER	-100	1 800	700

ExCo Member Interest

The following table summarizes the result of the enquiry that was sent out to all ExCo members in middle of 2020. We have currently no more updated data on the possible participation.

		Participates in current triennium	Indicated participation	Interested
1	**Australia**	x	x	
2	**Austria**			
3	**Belgium**			
4	**Brazil**			
5	**Canada**			
6	**China**			x
7	**Croatia**			
8	**Denmark**			
9	**Estonia**			
10	**EC**			
11	**Finland**			
12	**France**			
13	**Germany**	x	x	
14	**India**			
15	**Ireland**	x	x	
16	**Italy**	x		x
17	**Japan**			
18	**Korea**			
19	**Netherlands**			
20	**New Zealand**			
21	**Norway**	x	x	
22	**South Africa**	x		x
23	**Sweden**	x	x	
24	**Switzerland**			x
25	**UK**			
26	**USA**	x	x	
	TOTALS	8	6	4

TABLE 1: Identify the actions in the Strategic Plan 2020-2025 that would be addressed by the proposed Task / SP by inserting the WP # in the 'Tick' column for each relevant row.*

OBJECTIVE	**ACTION**	**TICK**
Objective 1: <u>A sustainable system for bioenergy and biomass materials supply</u>		
a. Demonstrating the key role of bioenergy in a decarbonising world	a.1 Develop and explore the complementary roles of bioenergy and other renewable energy supply, the potential of bioenergy carbon capture and storage or utilisation, and the pricing of these specific functions	X
b. Embedding bioenergy into the broader bio-economy	b.1Enable the transition to a low-carbon, energy-secure economy and broaden recognition that bioenergy systems are common components in value chains or production processes that also produce food and other biobased products (e.g., at biorefineries)	X
c. Incorporating the security, flexibility, and stability provided by bioenergy in the fuels, electricity, gas and heating systems	c.1Enable baseload and just-in-time production of bioenergy for different energy grids and renewable energy systems	
	c.2 Gradually enable the greening of the natural gas grid	
Objective 2: <u>Innovative Technologies</u>		
a. Enabling the development and application of innovative technologies	a.1 Ensure that Task networks serve as the basis for enabling collaboration and information exchange to catalyse commercialisation with industry	X
	a.2 Showcase best practices to enable deployment	X
b. Developing Advanced Biofuels for Mobility	b.1 Stimulate the development of biofuels from lignocellulosic biomass and wastes and consider the role of biofuels in sectors that require high energy-density fuels (e.g., aviation, marine, and long-distance transport)	X
Objective 3: <u>Sustainable Supply Chains</u>		
a. Developing sustainable biomass supply chains	a.1 Incorporate effects of land use (change) and landscape management in the analysis of supply chains	
	a.2 Facilitate the reclamation and reuse of abandoned agricultural land and the use of fallow land	
	a.3 Enable increased production of biomass in a sustainable way in agriculture and forestry, while maintaining or improving carbon storage and sequestration	
	a.4 Stimulate the development of logistics to harvest under-used residues	
	a.5 Support certification to prove sustainability of supply chains	
	a.6 Promote the market deployment of viable and efficient biobased value chains	X
Objective 4: <u>Operational Optimisation</u>		
a. Engaging all relevant stakeholders in a dialogue	a.1 Collaborate closely with other international agencies, IEA TCPs, and/or actions in this area	X
	a.2 Organise workshops with international institutes, governments, NGOs, and industry	X
	a.3 Proactively provide timely science-based analyses to inform political/public debates	X
b. Expanding the outreach to emerging and developing countries	b.1 Realise increased membership to support outreach	X
	b.2 Work closely with other international organisations to enhance outreach	X
c. Ensuring the optimal use of communication channels	c.1 Continue with a well-functioning website as the central channel, and improve the TCP's outreach through social media	X

Deliverables Gantt Chart

Project No.	Topic	Status	2022				2023				2024			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
M1-M12	Minutes from the task meetings	Planning												
WR1	Integration of EfW and material recycling/recovery into industry	Planning												
WR2	Sustainability metrics (workshop series)	Planning												
WR3	Public acceptance (workshop series)	Planning												
WR4	High value products from waste	Planning												
WR5	Sewage sludge valorisation	Planning												
WR6	Framework for strengthening waste to resource management	Planning												
CS1	Potential synergies between EfW and material recycling	Planning												
CS2	Environmental performance of different waste management strategies	Planning												
TR1	Report on Sustainability	Planning												
TR2	Report on Smart sorting technologies	Planning												
TR3	Food Waste- Current practices and future solutions	Planning												
TR4	Report summarizing the work during the triennium	Planning												
TR5	Future waste scenarios: new waste streams, composition, and amounts	Planning												
ITR1	The potential of Carbon capture and utilisation (CCU) within EfW	Planning	?	?	?	?	?	?	?	?				
ITR2	Hydrogen from waste	Planning	?	?	?	?	?	?	?	?				
	Newsletter	Planning												
	Reporting ExCo	Planning												
	Webinar under IEA Bioenergy	Planning												