INPUT PAPER

DeCarb
Interreg Europe

European Union
European Regional Development Fund

For the 1st study visit on the potential of 'cleaner coal' and Carbon Capture and Storage technologies

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PREPARED BY KSSENA

KSSENA

DECARB - SUPPORTING THE CLEAN ENERGY TRANSITION OF COAL-INTENSIVE EU REGIONS

DECARB ACTIVITY 3.4

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1 THE STUDY VISIT

1.1 Overview

For DeCarb activity 3.4, two study visits will be organised on the potential of ‘cleaner coal’ and Carbon Capture Utilisation and Storage (CCUS) technologies, during the 5th semester of the project. The first one will be organised by the Energy Agency of Savinjska, Šaleska and Koroška Region (KSSENA), for which this input paper will be used as preparation; the other will be organised by Eszak-Alfold Regional Energy Agency Nonprofit Ltd (ENEREA) at a later time.

During the study visit, participants will have the opportunity to exchange views with their peers and familiarise themselves with existing policy measures and strategies, to co-shape a common approach for policy improvement regarding decarbonisation. All project partners will participate with members of their stakeholder groups, external experts, and policymakers to discuss regional decarbonisation strategies that employ technologies able to reduce the carbon output of energy production from coal. The study visits will also attempt to provide insight on existing regional potentials that could support the process of the phasing out of coal. This will expand the perspective beyond the level of generic technology use cases to understand their potential role to facilitate the development of other relevant areas such as education, innovation in entrepeneurships, tourism and others (how these potentials will be effected by the energy transition and they could be best applied in order to support it).

Table 1: Overview of the study visit

DeCarb - 1st study visit on the potential of ‘cleaner coal’ and Carbon Capture and Storage technologies	
Thematic focus	Decarbonisation pathways through the application of clean coal and Carbon Capture technologies (Storage and Utilisation)
Host organisation	Energy Agency of Savinjska, Šaleska and Koroška Region
Date	November 2020
Venue	Various sites
Number of participants	20-30 participants

Type of participants	Public authorities' officials, stakeholders, external experts
Format	Field visits and roundtable discussions
Language	English
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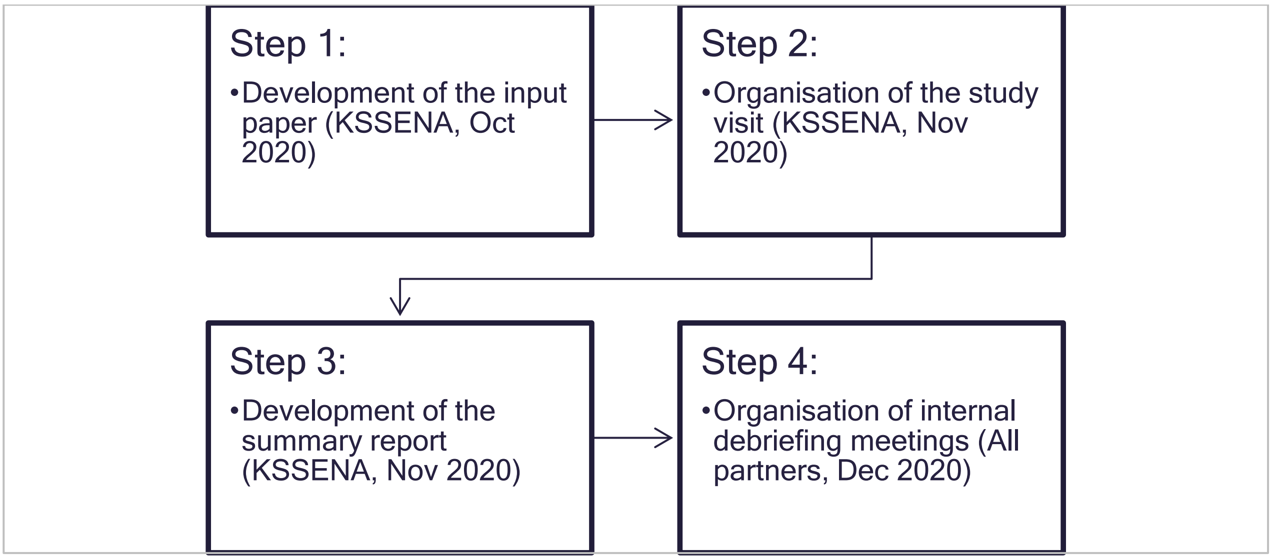
After the study visit, KSSENA will develop a summary report on the main points discussed and the conclusions reached during the visit. This report, in turn, will function as the main dissemination tool for debriefing meetings in each DeCarb partner's organisation. The following figure outlines the process to be followed for the successful completion of the 3.4 activity:

Figure 1: Outline of the DeCarb 3.4 activity



1.2 Scope and objectives

The purpose of the DeCarb A3.4 study visit is to function as an in-depth discussion platform for introducing clean coal technologies with a special focus on potential carbon capture pathways in the partnership regions' coal-fired power plants. In recent years, CCUS in particular has been proposed as a potential technological solution to the problems of the ever-growing energy demand – especially in EU regions heavily dependent on non-renewables– and anthropogenic CO_2 emissions. Efforts, both on the EU level and worldwide, have already been put forth to capture and sequester CO_2 from large sources, especially power plants. The utilisation of CO_2 as a feedstock to make valuable chemicals, materials, and transportation fuels is also promising and desirable, providing another long-term solution to sequestration, as the products of CO_2 utilisation can supplement or replace chemical feedstocks in the fine chemicals, pharmaceutical, and polymer industries.

On the supply side, other applicable technologies have also been progressed to the point at which they are now viewed as providing great potential to support the process of the phasing out of coal by utilizing the existing infrastructure as much as possible. These include hydrogen and fuel cell technologies, technologies for the energy utilization of waste management such as co-firing (SRF, RDF) and gasification, primary fuel substitution with renewables (biomass) and others.

KSSENA, as the host organisation will organize the presentations of these potentials on which the phasing out of coal in the Savinjsko-Šaleška region will likely be based upon.

These will be coupled with field trips and discussions, where the relevant topics will be highlighted from different angles (e.g. economic feasibility, environmental impact, barriers to implementation, needs assessment, employment potential etc.) and will be discussed amongst participating exprers.

The objectives of the study visit are to:

- Familiarise DeCarb partners, policymakers, and stakeholders with existing potentials of clean coal technologies and other technologies that can support the phasing out of coal
- Inform partners and stakeholders on the policy gaps that hinder the implementation of observed technolgoies.
- Showcase the potential of decarbonisation pathways in the partnership territories.
- Indicate exploitation pathways of CCUS to sustainably support existing value-chains in DeCarb economies.
- Highlight the barriers and areas of improvement of CCUS.

1.3 Added value

DeCarb study visits have been designed to provide partners and participating stakeholders with valuable practical experience, enhancing the learning process on promising decarbonisation pathways. The Interreg Europe programme encourages this type of exchange of experience and suggests that sharing knowledge and expertise should be an indispensable component of regional authorities' efforts to drive sustainable policy development.

Study visits pose an excellent opportunity for regional stakeholders, policy makers, and experts, to communicate, exchange ideas, discuss the regional issues and examine potential solutions for various social, economic, environmental, or other challenges concerning policy development. This type of activity can, therefore, play a crucial role in policy making and the implementation of potential advancements and/or change. The relevant discussions and hands-on experience can facilitate the involvement and possible contribution of key stakeholders in shaping action plans and, in the long-run, after the project's completion.

Each study visit is a two-way beneficial process. Local actors will benefit from the participation of the international experts, who in turn will have a unique opportunity to exchange and discuss ideas directly and efficiently with local stakeholders. The A3.4 study visit is expected to foster capacity building with regards to the decarbonisation of partnership regions through the sharing of experience, project replication and technology uptake. These visits are anticipated to inform policy change, allowing coal-dependent power plants to mitigate their environmental impact.

2 THEMATIC BACKGROUND

2.1 Carbon Capture Utilisation and Storage potential

Carbon capture refers to technologies that can capture up to 90% of the CO_2 emissions produced from the use of fossil fuels in electricity generation and industrial processes, preventing the carbon dioxide from entering the atmosphere. Carbon capture technologies have been primarily promoted for their application to power generation. Nevertheless, many of them can also be applied for CO_2 separation in industrial sites. There are two carbon capture pathways, Carbon Capture and Storage (CCS) and Carbon Capture and Utilisation (CCU).

The most common way that CCS and CCU can be used is in coal-fired power plants. The concept is to capture CO_2 produced by burning the coal in the power station, compress it, pipe it away from the power plant and then store it deep underground or use it for a variety of other reasons (e.g. fuel production). Most EU countries are considering this option to reduce CO_2 emissions as it will allow them to continue to use coal to provide electricity to maintain economic growth and living standards.

2.1.1 Carbon Capture Storage

CCS refers to technologies that focus on the selective removal of CO_2 from gas streams (power plant, factory), its compression into a supercritical condition, and finally its transportation and storage in geologic formations, onshore or offshore. Storage options include amongst others deep saline aquifers, deep coal bed methane (enhanced), combined or used in Enhanced Oil Recovery (EOR) in depleted oil/gas reservoirs.

The CCS chain consists of three parts; capturing the carbon dioxide, transporting the carbon dioxide, and securely storing the CO_2 emissions. First, capture technologies allow the separation of CO_2 from gases produced in electricity generation and industrial processes by one of three methods: pre-combustion capture, post-combustion capture, and oxyfuel combustion. Carbon dioxide is then transported by pipeline or by ship for safe storage. The carbon dioxide is then stored in carefully selected geological rock formations that are typically located several kilometres below the earth's surface.

Capture

Pre-combustion capture

A pre-combustion system involves first converting solid, liquid, or gaseous fuel into a mixture of hydrogen and carbon dioxide using specific processes such as ‘gasification’ or ‘reforming’. Reforming of gas is well-established and already used at scale at refineries and chemical plants around the world. Gasification is widely practiced around the world and is similar in some respects to that used for many years to make town gas. The hydrogen produced by these processes may be used, not only to fuel our electricity production, but also in the future to power cars and heat homes with near-zero emissions.

Post-combustion capture

CO_2 can be captured from the exhaust of a combustion process by absorbing it in a suitable solvent. This is called post-combustion capture. The absorbed CO_2 is liberated from the solvent and is compressed for transportation and storage. Other methods for separating CO_2 include high-pressure membrane filtration, adsorption/desorption processes, and cryogenic separation.

Oxy-fuel combustion systems

In the process of oxy-fuel combustion, the oxygen required is separated from the air before combustion, and the fuel is combusted in oxygen diluted with recycled flue-gas rather than by air. This oxygen-rich, nitrogen-free atmosphere results in final flue-gases consisting mainly of CO_2 and H_2O (water), so producing a more concentrated CO_2 stream for easier purification.

Transport

Once captured, carbon dioxide (CO_2) must then be transported by pipeline or ship for storage at a suitable site. The technologies involved in pipeline transportation are the same as those used extensively for transporting natural gas, oil, and many other fluids around the world.

In some cases, it may be possible to re-use existing but redundant pipelines. Carbon dioxide is currently transported for commercial purposes by road tanker, ship, and pipeline. Each CCS project would choose the most appropriate method for transporting carbon dioxide and be subject to planning and health and safety regulation. Large commercial networks of carbon dioxide pipelines have been in operation for more than 30 years with excellent safety and reliability records.

There is significant potential for the development of local and regional CCS pipeline infrastructure, leading to CCS "clusters" where CO_2-intensive industries could locate. Developing clusters, where infrastructure can be shared by several industrial sources of carbon dioxide emissions, will result in the most cost-effective way to deliver CCS infrastructure development and ultimately lower costs to consumers.

Storage

Once the carbon dioxide (CO_2) has been transported, it is stored in porous geological formations that are typically located several kilometres under the earth's surface, with pressure and temperatures such that carbon dioxide will be in the liquid or 'supercritical phase'. Suitable storage sites include former gas and oil fields, deep saline formations (porous rocks filled with very salty water), or depleting oil fields where the injected carbon dioxide may increase the amount of oil recovered. Depleted oil and gas reservoirs are more likely to be used for early projects as extensive information from geological and hydrodynamic assessments is already available. Deep saline aquifers represent the largest potential carbon dioxide storage capacity in the long term but are currently less understood.

At the storage site, the carbon dioxide is injected under pressure into the geological formation. Once injected, the carbon dioxide moves up through the storage site until it reaches an impermeable layer of rock (which cannot be penetrated by carbon dioxide) overlaying the storage site; this layer is known as the cap rock and traps the carbon dioxide in the storage formation. This storage mechanism is called "structural storage".

Structural storage is the primary storage mechanism in CCS and is the same process that has kept oil and natural gas securely trapped under the ground for millions of years providing confidence that carbon dioxide can be safely stored indefinitely. As the injected carbon dioxide moves up through the geological storage site towards the cap rock some of it is left behind in the microscopic pore spaces of the rock. This carbon dioxide is tightly trapped in the pore spaces by a mechanism known as "residual storage".

Over time the carbon dioxide stored in a geological formation will begin to dissolve into the surrounding salty water. This makes the salty water denser and it begins to sink to the bottom of the storage site. This is known as "dissolution storage". Finally, "mineral storage" occurs when the carbon dioxide held within the storage site binds chemically and irreversibly to the surrounding rock.

As the storage mechanisms change over time from structural to residual, dissolution and then mineral storage the carbon dioxide becomes less and less mobile. Therefore the longer carbon dioxide is stored the lower the risk of any leakage.

2.1.2 Carbon Capture Utilisation

CCU refers to technologies that turn captured CO_2 into valuable products instead of permanently storing it. The primary utilisation routes can be classified as fuel production, enhanced oil/gas recovery, chemical conversion, mineralisation, and desalination. CO_2, as a source of carbon, has the potential to be used in the manufacture of fuels, carbonates, polymers, and chemicals; CCU represents a new economy for CO_2, as raw material.

Fuels production

CO_2 conversion into fuels is considered the best route in CO_2 utilisation. Methane, methanol, syngas, and alkanes are some of the compounds that can be produced by utilising captured CO_2 as a feedstock. The fuel produced can be used in various sectors, including fuel cells, power plants, and transportation. There are tremendous pathways for producing fuels by CO_2 utilisation. Given that CO_2 is a thermodynamically stable molecule, its utilisation requires the application of a large amount of heat and catalyst inventory to obtain high fuel yields. In the context of fuels production from captured CO_2, hydrogenation and the dry reforming of methane (DRM) are the two most important pathways.

CO_2 hydrogenation is a very promising route for CO_2 utilisation, mainly because it offers the possibility of recycling CO_2, storing H_2, producing fuel, and solving the issue of electric energy storage. However, hydrogenation of CO_2 from fossil fuel appears to be problematic, since this can itself lead to an increase in CO_2 emissions to the atmosphere; renewable energy (e.g. solar, wind, biomass) can be alternatives to fossil sources to mitigate additional CO_2 emissions during this process.

Enhanced oil & gas recovery (EOR & EGR)

Enhanced oil and gas recovery refers to a procedure in which a substance is injected into a reservoir to repressurise rock formation and to release any oil/gas that may have been trapped in the formation. During the CO_2 EOR process, the injected CO_2 mixes with the oil and releases it from its otherwise hard-to-recover rock formation. This stream is then pumped to the surface, and the CO_2 emerging with the oil is separated and resupplied into the cycle to repeat the process. This process often yields more barrels per reservoir than the traditional oil-recovery methods. CO_2 flooding is one of the most common and efficient methods used in EOR, as it mixes with the oil, which expands it and makes it lighter and easier to recover. Most CO_2 EOR systems use naturally occurring CO_2, but later research has focused on using CO_2 captured from potentially hazardous gas streams, such as flue gas and other industrial gas effluents. Two commonly used CO_2 EOR methods are continuous gas injection (CGI) and water alternating gas (WAG), and the latter method yields better oil recovery. In CO_2 EOR, the addition of an intermediate hydrocarbon such as propane can improve displacement efficiency and the diffusion coefficient, which thereby further increases the recovery efficiency. In general, the efficiency of CO_2 EOR depends largely upon the temperature and pressure of the reservoir involved.

Chemical conversion

CO_2 can be converted to many other products via chemical reactions. This process of using CO_2 in chemical reactions to create other useful products is known as a chemical feedstock. Some of the products produced using this method are polycarbonates and other organic compounds like urea and acetic acid. For example, Novomer, a chemical company, uses CCU to create and produce a diverse set of plastic products.

The most important applications are urea, inorganic carbonates, polyurethane, acrylic acid and acrylates, polycarbonates, and alkylene carbonates. Urea, as a major fertilizer, has the largest market for CO_2 utilization. It is also widely used as a feedstock in polymer synthesis, pharmaceuticals, fine chemicals, and inorganic chemicals such as melamine.

Another important chemical that can be obtained through CO_2 utilization is formic acid. Hydrogenation of CO_2 into formic acid has recently attracted some interest mainly due to the mild reaction conditions, the lack of formation of by-products, the ability to store hydrogen in liquid form, and the easy decomposition of formic acid into hydrogen and CO_2.

Biological utilisation of CO_2 offers another pathway for the production of biodiesel and various biomass-derived commodity chemicals (used as food, silage, biogas, and fertilizer). The advantages offered by this approach include higher growth rate, shorter growth cycle, no competition on land with other plants, and the production of different valuable by-products. However, captured CO_2 should be purified before feeding into a photo-bioreactor to remove pollutants such as SOx, NOx, and heavy metals that are toxic to the growth of microalgae.

Mineralisation

CO_2 mineralisation, also known as carbonation, is one of the less known CCU technologies. Mineralisation processes can transform CO_2 into valuable products for the construction industry, in a real application of the circular economy and without requiring any significant external energy input. Carbonation is a natural phenomenon, where calcium- or magnesium-containing minerals react with CO_2 to produce calcium or magnesium carbonate, also known as limestone or dolomite, one of the most abundant rock types on earth. This natural carbonation reaction, which happens in nature over thousands of years, can be purposefully accelerated to take only a few minutes in man-made manufacturing processes (accelerated carbonation) by using high CO_2 concentrations and optimized reaction conditions. The reaction is exothermic, meaning that it releases energy as heat and leads to the creation of stable products in which the CO_2 is permanently captured. Over the last 15 years, novel industrial processes have been developed to use CO_2 as an input in the manufacture of products which meet the technical requirements of the building sector. Unlike other CCU technologies, these carbonation processes do not need any significant input of renewable energy.

From a circular economy perspective, accelerated carbonation can bring a significant contribution to three major societal challenges: the mitigation of climate change, the management of waste materials, and the reduction of the consumption of natural resources. CO_2 can be taken directly from flue gas emissions coming from industrial processes (such as power, steel, cement, or chemical plants). It can remain diluted among other flue gas components, so there is no need for expensive concentration or purification steps. The CO_2 used in the carbonation process gets permanently sequestered (under the form of stable carbonate) in the end products and this CO_2 is therefore no longer emitted to the atmosphere (climate mitigation benefit). Mineral waste coming from various industry sectors are transformed into valuable construction materials, so they no longer have to be disposed of in landfills (waste management benefit). Similarly, construction and demolition waste can also be looped back into the production of fresh construction materials and diverted from landfills. This also reduces the need for extracting fresh mineral resources from quarries (natural resources benefit).

Desalination

As another promising utilisation approach, captured CO_2 can be used to remove total dissolved solids (TDS) and to transform brine into water. The resulting potable water can be utilised in places where there is a deficiency. Whereas most desalination plants do not employ CO_2 to perform desalination owing to economic constraints, new technologies are being developed for the cheap and efficient utilisation of CO_2 in this process. If seawater, mixed with ammonia (to weaken the salt molecules), is exposed to CO_2, already-weak bonds start to form, which leads to the removal of the ions from the water phase. The products formed (Na_2CO_2 and NH_4Cl) are heavy and, thus, can easily settle to the bottom of the tank. The latter (NH_4Cl) can be recycled by thermal operations with calcium oxide or be used as a feedstock for the synthesis of ammonia and chlorine.

The hydrate-forming method is another technique that is used for desalination, and it involves the formation of hydrates by using CO_2 to separate the salts from water. In this approach, CO_2 can be in either the gas or liquid form. The CO_2 hydrates are either dumped into the ocean or transported elsewhere.

The ammonia-carbon dioxide forward osmosis process is yet another desalination technique that employs CO_2. In this process, the driving force is osmotic pressure instead of hydraulic pressure in reverse osmosis, and by using a “draw” solution, the brine and freshwater are separated.

Other utilisation routes

- Microalgae is being considered as a serious source of renewable energy while also working as a CO_2 sink. Microalgae feed on a diet of carbon dioxide, which can be sourced via CCU. The biofuel roughly uses 1.8 tonnes of carbon for every metric tonne of dry algae produced. However, since microalgae is a biofuel, its usage eventually leads to the release of carbon. Nevertheless, this amount is lesser than the input required for the growth of the algae. While this technology is still at a nascent stage, the possibilities of microalgae and its ability to trap CO_2 are many.
- Utilising CO_2 as a fluid without conversion into chemicals has found applications in many industries, including the air-conditioning (as coolant), solvent, dry-washing, food-preservation, and beverage industries. However, this utilisation route has not been exploited extensively within the CCU framework, as other routes are more appealing economically.

2.1.3 Policy goals

For the EU to reach its decarbonisation objectives, employment of ‘cleaner coal’ technologies, namely Carbon Capture and Storage (CCS) and Carbon Capture and Utilisation (CCU), will be crucial. To achieve 2°C scenarios in 2050 set by the climate conference in Paris (COP21, November 2015) and reaffirmed in the following UN climate conferences, almost 6 billion tonnes of CO_2 should be captured and stored each year across all sectors. The European Commission's (EC) strategy for long-term greenhouse gas emission reductions (COM(2019) 640, COM(2018) 773) sets the tone for EU climate ambition and presents CCUS as part of the solution in the efforts to decarbonise Europe’s economy and energy system. The 2030 climate and energy policy set a steep target to be achieved by 2030: a 40% reduction in greenhouse gas emission; CCUS is recognised as being vital for climate change mitigation pathways.

Storage

In 2009, the 2009/31/EC Directive (also known as CCS directive) established a legal framework for the environmentally safe geological storage of CO_2, to contribute to the fight against climate change. It covers all CO_2 storage in geological formations in the EU and the entire lifetime of storage sites. It also contains provisions on the capture and transport components of CCS, though these activities are covered mainly by existing EU environmental legislation, such as the third amendment of the Environmental Impact Assessment (EIA) Directive (2009/92/EC Directive).

Utilisation

The Indirect Land Use Change (ILUC) amendment to the Renewable Energy Directive (RED, 2009/28/EC Directive) and the Fuel Quality Directive (2009/30/EC Directive) considered CO_2 utilisation for the production of fuels for transport such as renewable fuels of non-biological origin. The Renewable Energy Directive revision, specifically, opened possibilities for CO_2-based fuels to be counted towards national renewable energy targets and to be supported by the fuel blending quotas if they are recognised as renewable.

Policy tools

The EU Emissions Trading System (EU ETS) is the cornerstone of the EU policy to reduce greenhouse gas emissions cost-effectively. It is the world's first major carbon market and remains the biggest one.

The EU ETS works on the 'cap and trade' principle. A cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap is reduced over time so that total emissions fall. Within the cap, companies receive or buy emission allowances, which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances available ensures that they have a value.

After each year a company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company that is short of allowances. Trading brings flexibility that ensures emissions are cut where it costs least to do so. A robust carbon price also promotes investment in clean, low-carbon technologies.

2.1.4 Policy gaps

Although there has been a significant development in the EU regulatory framework over the last decade, there seems to be a lack of incentives and still some perceived hurdles for full-scale deployment. As a result, the realisation of large-scale CCS projects in the EU has been challenging, with many being slowed down or canceled by financial restrictions, lack of public acceptance, and lack of incentives.

At the moment, stakeholders utilising CO_2 in their industrial processes represent relatively modest quantities of CO_2 and the activities are not initiated for–nor result in– any climate change mitigation. The question is to what extent the regulatory framework, as it stands, can positively or negatively impact the development of promising CCU technologies, whether it should be adapted to accommodate and incentivise CCU activities as climate change mitigating measures, and if that should be done by amending the current regulatory framework for CCS or by introducing new instruments.

So far, the only clear link of EU policies that incentivise CO_2-capture technologies is through the upcoming Innovation Fund. In general, there is limited specific policy support that promotes the consideration of CO_2 as raw material and specifies how utilisation processes emissions/characteristics should be evaluated, factors which may delay market development.

2.1.5 EU Green Deal

The EU Green Deal Communication suggests an initial list of key policies and measures for achieving climate neutrality by 2050. It's not a static document and is expected to be updated as needs evolve and the policy responses are formulated. This overview provides a summary of the key impacts that the Green Deal will likely have on CCUS.

- The revision of EU's 2030 climate target means that CCUS technologies will need to be deployed sooner. According to DG CLIMA's estimations, raising the 2030 climate target to 50-55% in the upcoming Climate Target Plan will mean that the new 2030 target will be a point in the net-zero trajectory that –under the current -40% target– would only be reached around 2035-2037. This means that the emission reduction activities previously foreseen for the second half of 2030s would need to happen in early 2030s.

Mature technologies like CCS, where the process has moved on from demonstration to rolling out commercial deployment in several of its applications, are well-positioned to be scaled up earlier. Clean hydrogen is another enabler of decarbonisation and DG CLIMA sees both green and blue hydrogen as part of the solution – it is useful to keep as many technologies as possible in play. The scale-up of different technologies will depend on the cost of technology and the price of hydrogen. The increasing demand for clean hydrogen should deliver the gradual build-up of the hydrogen infrastructure, and major investments will be needed across the value chain in the coming decade.

- The EU will need a significant amount of CO_2 removal. The upcoming work on the regulatory framework for certification of carbon removals is the next big undertaking on this front. The climate policy in the EU has been built up through sectoral policies, which are designed to deliver emission reductions and they do not incentivise carbon removals. Policymakers and stakeholders are beginning to notice that there is no existing framework that looks at all aspects of carbon removals and informs the policy making process to incentivise carbon removals. However, a significant amount of carbon removals will be needed to achieve climate neutrality by 2050 and negative emissions thereafter. To address this missing element, the EC is planning to propose a regulatory framework for the certification of carbon removals by 2023. This is listed as one of the key actions under the new Circular Economy Action Plan and aims to deliver robust and transparent carbon accounting to monitor and verify the authenticity of carbon removals.
- The solution to include non-pipeline CO_2 transportation under the EU ETS is underway. One of the barriers in the current legislation is the fact that only those projects where the CO_2 is transported by pipelines can benefit from the EU ETS carbon price. Facilities that plan to transport CO_2 for storage by other means than pipelines, for example by ship or truck, would still need to pay for captured CO_2 emissions. A good example here is the Norwegian full-scale project which will transport CO_2 by ship.

2.1.6 Needs and barriers

Demonstrating the feasibility of large-scale CCUS projects remains a challenge, and thus a mature CCUS market has not materialised so far. Oil and gas companies' interest in CCUS has been high, helping them to manage their CO_2 emissions. In the power sector, the rise in interest may not be as high for various reasons, including many plants reaching retirement age, planned and announced phase-outs from coal for many EU Member States as well as carbon allowance prices, so far inadequate to justify investment in carbon capture. The following two tables show the needs and the barriers that exist for developing more efficient and cheaper CCUS methods, with the potential to be more widely applied in the EU:

Table 2: Needs for further developing CCUS

<table>
<tr><th>Needs</th><th>CCS</th><th>CCU</th></tr>
<tr><td>Political</td><td colspan="2">• A comprehensive and robust regulatory framework is needed for CCUS to become feasible and financially realistic.
• Specific policy incentives need to be established.
• A stable carbon pricing mechanism (or carbon market) is needed to enable commercial CCUS deployment.</td></tr>
<tr><td>Economic</td><td>• Achieving significant cost reductions will require a sustained amount of R&D projects and an important level of commercial deployment.
• Financial instruments have to take into account CO_2 monitoring costs for long periods (during and after the injection process) since they have an important effect on the overall operational costs.
• The CO_2 infrastructure (transport and storage), as well as the whole CO_2 capture and storage supply chain, has to be developed to ensure the disposal of the CO_2 and risk management for possible CCS investors.</td><td>• Effective implementation of mechanisms to establish a price of CO_2 may be required. It should be taken into account that in most cases the CO_2 is not removed permanently, and the net contribution is the CO_2 not emitted because of the use of a CCU process instead of its equivalent conventional one.</td></tr>
<tr><td>Technological</td><td>• Assessment and identification of more suitable storage sites is needed.
• The projects that are currently under development must be completed to contribute to the acquisition of knowledge and the formation of the CCS infrastructure.</td><td>• Mostly when coupled with renewable energy, it could make a considerable difference, leading to a net-zero (or negative) emission process. For example, by using very low carbon electricity (wind or bioenergy) it is possible to avoid 99% of CO_2 emissions.</td></tr>
</table>

Social	• Campaigns about advantages, disadvantages, and training are required to increase overall understanding. These campaigns have to bring together researchers, technical staff as well as politicians.

Table 3: Barriers to the development of CCUS

<table>
<tr><th>Barriers</th><th>CCS</th><th>CCU</th></tr>
<tr><td>Political</td><td colspan="2">• Lack of consistent, long-term, and robust climate policy in most Member States.
• Lack of political commitment to CCUS by some Member States, exacerbated by problems regarding permission procedures.</td></tr>
<tr><td>Economic</td><td>• High investment and operational costs and therefore lack of competitiveness compared to other low-carbon technologies.
• There is often no financial compensation for the additional capital and operational costs associated with CCS.</td><td>• It is hard to be economically competitive due to very high infrastructural costs.
• The cost of the synthesised product with CO_2 is highly dependent on the cost or value given to the CO_2 unit. For certain technologies, such as the production of sodium carbonate or methanol, it requires prices over several hundreds of euros per tonne of CO_2 to be competitive.</td></tr>
<tr><td rowspan="2">Technological</td><td colspan="2">• Lack of CO_2 infrastructure (transport and storage) development.
• A market for CO_2 capture technologies is not fully developed.</td></tr>
<tr><td>• Several projects do not reach the final levels of implementation due to technological issues.</td><td>• In a life cycle assessment (including raw materials, construction, decommission), CCU technologies sometimes require a higher amount of CO_2 than the amount that is re-utilised. Thus, all direct and indirect emissions of the whole process should be taken into account.</td></tr>
<tr><td>Social</td><td colspan="2">• Carbon capture remains unknown to the general public.
• Public opinion perceives many environmental risks that concern health and water pollution.</td></tr>
</table>

2.2 Innovative use of existing resources and infrastructures

2.2.1 Hydrogen and fuel cell technologies

In line with GHG emissions targets set by the EU and its member states, many European regions aim to reduce their GHG emissions. The EU's nationally determined contribution (NDC) under the Paris Agreement is to lower GHG rates by at least 20% by 2020, 40% by 2030 and 80 to 95% by 2050.[1] Fuel cells and hydrogen (FCH) technology emerges as a key enabler to make a change in the environment and mobilise a green energy transition.

Thirty years ago, hydrogen was regarded as "a critical and indispensable element of a decarbonised, sustainable energy system" able to provide secure, cost-effective and non-polluting energy.[2] In the 2000s, despite high expectations, FCH experienced a 'lost decade' and even today, energy leaders consider hydrogen as the lowest impact and least certain issue facing the global energy system.[3] Nevertheless, hydrogen could play a key role in low-carbon future: counterbalancing electricity as a zero-carbon energy carrier that can be easily stored and transported; providing the means for a more secure energy system with reduced fossil fuel dependence; with the flexibility to operate across the transport, heat, industry and electricity sectors.

At the current moment, FCH technology is in the process of regaining momentum. Firstly, advances in technology and manufacturing mean that systems which used to be expensive in 2005 now cost 1/6 of the initial price. Secondly, commercial products are becoming widely available, and major uptake is taking place within particular sectors. Thirdly, a renovated interest in global climate change is accompanied with increasing understanding that clean power alone is not enough, due to the complexity of decarbonising heat and transport.

FCH is a mature and well-tested technology. Although FCH has been put into use since the 1960s,[4] its viable, zero-emission and potentially cost-competitive characteristics have relatively recently become widely available.[5] Indeed, FCH technology can accommodate renewable energy on a large scale and use it for energy needs that may range from transport and building heat to electric power industry. Up until today, FCH applications have been launched within the energy and transport sectors, while more applications are under testing

[1] https://ec.europa.eu/clima/policies/international/negotiations/paris_en
[2] https://www.hydrogen.energy.gov/pdfs/greenhyd.pdf
[3] https://www.worldenergy.org/assets/downloads/1.-World-Energy-Issues-Monitor-2017-Full-Report.pdf
[4] http://ieahydrogen.org/pdfs/TechnologyRoadmapHydrogenandFuelCells-(1).aspx
[5] https://www.fch.europa.eu/news/new-study-shows-good-potential-hydrogen-powered-trains-europe

process and expected to make their appearance in the market at later stages. The above applications feature impressive levels of technological sophistication, safety and reliability. An overview of hydrogen and fuel cell technologies applications and how they can be integrated across the energy system are presented in the pages that follow:

Transportation

The suitability of hydrogen and fuel cells varies between modes of transport and reflects the diverse nature of the transport sector, which spans land, sea and air, including cargo and passengers.

- Fuel cell passenger vehicles: Deep decarbonisation of transport must concentrate on private cars, which account for almost half of the global transport sector.[6] Fuel cell passenger vehicles constitute a zero-emissions solution which proffers similar usability with conventional vehicles. Typical fuel cell passenger vehicles refuel within 3-5 minutes and can travel 200-250 miles on a single track.[7] The first commercially assembly-line produced hydrogen fuel cell passenger vehicle dates back in 2014. Yet, the lack of widespread hydrogen infrastructure has impeded the transition to widespread FCPV adoption. Nevertheless, as new infrastructure is developed, FCPV consumption is unavoidably expected to show increase by 2030.
- Motorbikes: Two-wheeled vehicles are common for passenger transport in many regions across Europe. Intelligent Energy has deployed a 4kw fuel cell system in cooperation with Suzuki, recently being exported to the UK.[8] Their low fuel consumption allows for easy refueling through the use of hydrogen canisters from vending machines. FCEV motorbikes could contribute toward achieving air quality and noise pollution targets.
- Refueling stations: A complication for passenger vehicles is the need for expansion of refueling infrastructure to offer the reach and freedom of conventional vehicles. Globally, there are 330 hydrogen refilling stations, the majority of which are based in

[6] https://pubs.rsc.org/en/content/articlelanding/2019/ee/c8ee01157e#!divAbstract
[7] https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/finance/deloitte-cn-fueling-the-future-of-mobility-en-200101.pdf
[8] https://www.intelligent-energy.com/news-and-events/company-news/2019/02/07/intelligent-energy-moves-closer-to-deployment-of-products-for-automotive-market/

Japan and the US.[9] The Hydrogen Council opts for 3000 refilling stations by 2025, sufficient to provide hydrogen for about 2 million FCEVs.[10]

- Fuel cell electric buses (FCEB) are considered one of the most widely adopted fuel cell applications, with more than 7 million kilometres of opertional experience so far across Europe.[11] Typically running on fixed routes, fuel cell electric buses require few refueling stations. Furthermore, by covering long distances and addressing a wide range of passengers, FCEBs serve as a highly-visible, green-society initiative of public transportation.
- Fuel cell trucks typically exceed 150 km in range, enabling them to accomplish most of the inner- and inter-city deliveries of goods.[12] Furthermore, fuel cell trucks can meet environmental requirements and noise regulations in urban areas, which encourages the government and fleet operators to accelerate its adoption. They have very short refueling times, which greatly improves the operational efficiency of a logistics fleet. Mining companies encountering significant decarbonisation challenges are gradually gaining awareness of fuel cell mining trucks as an alternative zero-emission solution. Yet, unlike buses, FCEV trucks have seen lower adoption due to increased costs and limited government intervention.
- Heavy-duty trucks are regarded as a promising segment to develop zero-emission vehicles. The development of fuel cell heavy duty trucks is relatively drop behind other applications. Despite their potential contribution towards a greener climate action change, only limited products have been launched or tested. The relatively slow development of fuel cell heavy duty track can be attributed to a combination of high vehicle cost, high hydrogen cost and limited refueling infrastructure. However, fuel cell heavy duty trucks offer fast refueling times and travel longer distances than conventional electric trucks. This provides fuel cell heavy duty vehicles with the possibility to displace diesel and battery electric heavy duty truck in the long run.[13]
- Fuel cell forklifts have significant advantages over other types of forklift; unlike traditional electric forklifts whose speed drops an average 14% in the second half of

[9] https://fuelcellsworks.com/news/in-2019-83-new-hydrogen-refuelling-stations-worldwide/
[10] https://hydrogencouncil.com/wp-content/uploads/2017/06/Hydrogen-Council-Vision-Document.pdf
[11] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf
[12] https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/finance/deloitte-cn-fueling-the-future-of-mobility-en-200101.pdf
[13] https://www.act-news.com/news/hydrogen-fuel-cell-vehicles/

an eight-hour-shift, fuel cell forklifts can achieve a steady pick rate.[14] Furthermore, given the fact that they have no polluting emissions, forklifts are suitable in enclosed warehouses for industry applications such as food and beverage.

- FCH Trains: Hydrogen trains could be used on routes which are difficult or uneconomic to electrify due to route length or lack of space in urban areas. A fuel cell powered train with roof-mounted hydrogen tanks and a range of 500 miles has begun testing in Germany and the UK.[15] Light rail also presents opportunities for hydrogen, with fuel cell-powered trams being developed and operated in China.
- Airplanes: Aviation is one of the hardest sectors to decarbonise, and reducing emissions from aircraft propulsion has seen little progress. Some hybrid electric concepts are being studied, though emission reductions will be limited. Biofuels could be suitable due to their higher energy density than hydrogen or batteries, but are not completely emission-free and could remain costly with limited availability. Hydrogen could be used as a propulsion fuel, but needs to be liquefied to supply the required range. Hence much work remains on developing options for low-emission aircraft propulsion.

Heat and industry

Until recently, most energy systems and building stock models did not consider hydrogen and fuel cell technologies for meeting decarbonisation targets. However, recent studies have identified hydrogen as having an important role in decarbonising heat. There are several H2FC technologies to deliver heating.

- Hydrogen boilers: Existing gas boilers and furnaces can run on hydrogen mixtures at low levels. A changeover to hydrogen would require wholesale refitting of either appliances or components within appliances. Such a wholesale refitting of appliances is not unprecedented: many countries have switched from town gas to natural gas in recent decades.
- Fuel cell CHP: Combined heat and power (CHP) systems co-produce electricity and heat at high efficiencies via engines or fuel cells and may use a variety of fuels. All

[14] https://fuelcellsworks.com/news/fuel-cell-fork-lift-trucks-drive-hydrogen-into-the-future/
[15] https://www.toi.no/getfile.php?mmfileid=52027

CHP technologies offer greater combined efficiency than the ‘traditional frontier’ of using average power stations and condensing gas boilers.[16] Given their higher power-to-heat ratio, fuel cells are deemed more appropriate for well-insulated buildings with lower heat loads. FC-CHPs are currently expensive, but costs have been reduced in the last six years and lifetimes have grown with increasing rollout in Japan and Europe. Existing CHP systems mostly operate on natural gas, but could switch to hydrogen with slight modifications.

- Industry: Hydrogen could replace natural gas as a fuel for providing heat and power in a variety of industries; burners and furnaces may need replacement, but would not require high purity. Hydrogen could also be implemented into high-temperature industries including steelmaking and cement, although commercialisation is not anticipated before 2030 due to low maturity, uncertain costs, the likelihood of needing fundamentally re-designed plant and the slow turnover of existing systems.

2.2.1.1 Deployment of hydrogen technologies in the Savinjsko-Šaleška region

The Savinjsko-Šaleška region aims to develop and deploy a replicable, balanced and integrated hydrogen economy by facilitating investment into market-ready hydrogen technologies. The goal is to make use of available local hydrogen sources and apply it in applications for reducing green-house gas emissions, starting with zero-emission public transport. Primarily, the investment project shall include the construction of a hydrogen fueling station, modernization of the current fleet of diesel-powered minibuses with fuel cell electric vehicles (FCEV) operating within the local public transport service and the upgrade of local hydrogen production facilitates.

The hydrogen fueling station will include re-fueling at both 350 bar and 700 bar. This will allow the operator to plan and guarantee demand for hydrogen based on regular and predictable requirements of the local public transport service, so that the operation of the station is continuous. On the other hand, the project is focused to support the European network of hydrogen fueling stations for personal vehicles, for which the 700 bar stage is required. The FCEV buses will be deployed in local and inter-urban public transport, substituting standard diesel buses in operation. The main areas considered alongside price will be operational availability and maintenance requirements.

[16] https://www.epa.gov/chp/what-chp

Hydrogen of high purity is being produced by the Šoštanj Thermal power plant. The production is relatively small scale, but in its current state would be sufficient to supply approximately 80% of the hydrogen requirements for local public transport. The hydrogen is produced by alkaline water electrolysis by an on-site hydrogen generator powered through a transformer, obtained gasses (H_2, O_2) are stored in pressurized containment vessels. The unit was established with a primary goal to supply the technical tasks of power plant maintenance with oxygen, thus while hydrogen is being used mainly for cooling of electrical generators of block 5, a substantial amount is vented to local surroundings. Current studies show that upgrading the production unit to service the requirements for public transport as envisaged by the project would not cause a considerable increase of primary fuel (lignite) use, and would have a positive impact on the operational stability of the power plant.

The strategic focus of the project is to provide hydrogen refueling capability to the Graz-Ljubljana-Zagreb corridor and expand the European network of refueling stations, by placing the station nearby the third national development axis (Fastlane on route F2-2 connecting the lower part of the Savinjska valley with Velenje and beyond to Koroška region, for which a national spatial plan has already been confirmed). The capability to refuel personal FCEVs will make the region, and Slovenia in general, more attractive to owners of such vehicles, predominately from western and Scandinavian countries. In addition, the City municipality of Velenje plans to make a substantial investment for supporting green local tourism in the following years particularly on the Velenje Lake, where the goal is to expand the zero-emission transport to water going vessels with a demonstrational hydrogen powered boat that will link the touristic activities and content associated to sustainable development.

By creating stable demand from reliable consumers operating on the regional level (operators of local and interurban public transport services), hydrogen will also be made available for consumers with personal fuel cell electric vehicles. The long-term ambition of the project is to support further investment into hydrogen technologies, with hydrogen as an energy vector being at the cornerstone of the energy transition of the Šaleška Valley, that aims to substitute the gradual shut-down of the lignite thermal power plant Šoštanj (providing from one third to one half of the national electrical energy supply) with an ever-increasing share of renewable energy sources in the energy mix. The long-term outlook of the project is to transform a region deeply characterized by decades of energy production by fossil fuels to a ‘Hydrogen valley’, utilizing vast potentials of locally available renewable energy in a system focused on grid stability and pollution reduction.

2.2.2 Waste-to-energy

Not all waste streams can be diverted to such end and final wastes are always produced. Furthermore, even though some materials can have an increased lifetime, they generally end up degraded and in a state where their reutilization is impossible. Finally, some wastes, especially if they are made of mixed materials, are so that their recycling is costly or is associated with a quite high energy demand or pollutant production and therefore is unrealistic.

Where waste-to-energy processes are opted for, there is a need to ensure that the most efficient techniques are used: this maximises their contribution to the EU’s climate and energy objectives. It is estimated that if proven techniques and supporting measures are properly implemented, the amount of energy recovered from waste could rise by 29% to 872 PJ/year, using exactly the same amount of waste as feedstock.[17] This shows the potential for energy efficiency improvements. The EC Communication “The role of waste-to-energy in the circular economy”[18] suggests, based on previous knowledge, that the best proven techniques to increase energy efficiency for the four waste-to-energy processes are:

- co-incineration in combustion plants: gasification of solid recovered fuel[19] (SRF) and co-incineration of the resulting syngas in the combustion plant to replace fossil fuels in the production of electricity and heat;
- co-incineration in cement and lime production: conversion of waste heat to power in cement kilns;
- waste incineration in dedicated facilities, such as the use of super heaters; harnessing the energy contained in flue gas; the use of heat pumps; supplying chilled water for district cooling networks; and distributing heat from waste through low temperature district heat networks.

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17 https://publications.jrc.ec.europa.eu/repository/bitstream/JRC104013/wte%20report%20full%2020161212.pdf

18 https://ec.europa.eu/environment/waste/waste-to-energy.pdf

19 SRF (solid recovered fuel) is generated from waste that is separated at source and then mechanically sorted and crushed. As a result, they are cleaner, have a higher value and are also suitable for use in thermal power plants.

- anaerobic digestion: upgrading of the biogas into bio-methane for further distribution and use (e.g. injection into the gas grid and transport fuel).

Regarding the decarbonisation of power plants, waste-to-energy through co-combustion is an option of great interest. The combustion of fuel derived from municipal solid waste is a promising cheap retrofitting technique for coal power plants, having the added benefit of reducing the volume of waste disposal in landfills. Co-combustion of waste-derived fuel (WDF) and coal, rather than switching to WDF combustion alone in dedicated power plants, allows power plant operators to be flexible toward variations in the WDF supply. Substituting part of the coal feed by processed high calorific value waste could reduce the NOx, SO2, and CO2 emissions of coal power plants. However, the alkaline content of WDF and its potentially harmful interactions with the coal ash, as well as adverse effects from the presence of chlorine in the waste, are important drawbacks to waste-derived fuel use in large-scale power plants.

Currently, coal combustion accounts for around 40% of the world's electricity generation even though coal combustion is a major source of NOx and SO2 emissions. These emissions are precursors for acid rain, and therefore sensible environmental policy suggests that they be curtailed. Cheap retrofitting techniques are needed to permit existing infrastructure to continue to operate without contributing to the incidence of acid rain.

Since municipal solid waste (MSW) generally has negligible sulphur content and lower nitrogen content than coal, substituting part of the coal with waste-derived fuel might be beneficial to the environmental performance of coal power plants. Furthermore, since the coal power plants electric efficiency is usually 10-20% superior to that of incinerators, burning MSW in coal power plants can lead to higher waste utilization efficiency than in dedicated incineration plants. Also, MSW contains a renewable fraction and can therefore help to reduce the amount of fossil CO2 generated by coal power plants. This is somewhat mitigated by the higher chlorine and alkaline content of WDF compared with coal, which may contribute to corrosion and ash deposition issues.

Synergetic effects between the coal and the waste, such as oxidation of mercury by HCl facilitating its capture in the particulate control device, are promising outlooks. Furthermore, in a world looking toward green energy production, reduction of the amount of coal used to produce energy through co-combustion of cheap partly renewable material that are the waste is of critical interest. Waste-derived fuels can be combined with additives dedicated to the capture of targeted pollutants, improving even further the environmental performance of coal power plants.

2.2.2.1 Waste incineration in Šoštanj Thermal Power Plant

As elsewhere in the world, the amount of waste is growing steadily in Slovenia. According to the statistical office Si-stat, more than 5 million tons were generated in 2015, and in 2018 almost 8.4 million tons of hazardous and non-hazardous waste. In 2015, there were 4.2 million tons, and three years later, almost 7.4 million tons. Slovenia only recycles about 40% of them. Also, about 1.1 million tons of waste are imported and about as much is exported. As a result, landfills with leachate and gases poison the soil, pollute the water and the quality of air. Uncontrolled waste disposal and illegal dumpsites accumulate hazardous chemicals in nature and increase health risks.

By converting non-hazardous waste into solid SRF fuel, the Šoštanj Thermal Power Plant can co-incinerate much of the otherwise unusable waste. According to the studies performed by the plant, around 160,000 tons of SRF per year can be added to lignite in both units at the Šoštanj Thermal Power Plant. That is, up to six percent SRF fuel or up to ten percent energy value based on the amount of lignite. Since SRF fuel has a calorific value between 14 and 20 MJ / kg and lignite between 9 and 11 MJ / kg, the addition of alternative fuels will improve the efficiency of electricity and heat production for heating the Šaleška valley. With high temperature and flue gas cleaning, emissions into the environment per unit of electricity produced will also be lower. Thus, for the same amount of electricity produced per year, the plant will emit 156,000 tons less CO2 into the air. All other parameters will also remain within the limit values.

For the needs of co-incineration, the plant will set up a facility in its vicinity, arranged in such a way that it will emit unpleasant odors and the fuel will not be able to be carried by the wind. According to the set timetable, the plant will start trial operation of co-incineration at the end of 2021, and regular operation in 2022.

2.2.2.2 Waste gasification

Despite policy actions to curb waste generation, the waste quantity generated is still growing due to population increase and lifestyle changes. The global quantities of wastes that could be treated by thermal methods amount to the order of 3 billion tonnes annually. Some of this is already processed in incinerators but still a dominant fraction is disposed of in landfills. Even so, in terms of the energy content and also the GHG emissions, waste overall contributes a small fraction (3-4%) of the global energy usage and GHG emissions.

Nevertheless, is it still a significant energy potential to valorise and the management of this quantity in itself is a challenge.

The state-of-the-art thermal treatment technology is waste incineration with energy recovery. The use of waste gasification technologies, in particular, has the potential to increase the efficiency of power. Besides, waste gasification can also be used not only for energy recovery but also to produce fuels, i.e. material recovery. Both these options are however linked to that the product gas from the gasifier is subjected to a more or less extensive cleaning in several stages before it is combusted or used for synthesis of fuels.

Gasification is the conversion by partial oxidation (i.e. more oxidizing agent than for pyrolysis but less than for complete combustion) at elevated temperature of a carbonaceous feedstock such as biomass or coal into a gaseous energy carrier. Gasification takes place in two main stages. First, the biomass is partially burned to form producer gas and charcoal. In the second stage, the carbon dioxide and water produced in the first stage are chemically reduced by the charcoal, forming carbon monoxide and hydrogen. Gasification requires temperatures of around 800°C or more to minimize the residues of tars and high hydrocarbons in the product gas. This gas, commonly called "producer gas", contains hydrogen (18-20%), carbon monoxide (18-20%), carbon dioxide (8-10%) , methane (2-3%), trace amounts of higher hydrocarbons such as ethane and ethene, water, nitrogen (if air is used as the oxidising agent) and various contaminants such as small char particles, ash, tars and oils.

Products of gasification can be used for heat and power generation, separately or together with other applications, as well as for the production of chemicals and transportation fuels. The producer gas is mostly intended for immediate use on site and the gasification unit is an integral part of the heat or power generating plant. In the small unit size, the gas is mostly used in a combustion engine and in the larger units in a gas turbine or combine cycle plant. The various gasification applications for power and or heat are shown in the figure below, in terms of their market potential and overall technology reliability.

However, due to the presence of contaminants in wastes, notably chlorine, corrosion issues limit the feasible steam superheat temperatures, while the scale of operation is smaller than for other solid-firing thermal power plants with more sophisticated steam cycles. Therefore, the efficiency of the power of waste incinerators is significantly lower than in thermal power plants using other fuels. Waste gasification technologies must achieve a high level of contaminant removal to meet ever-more stringent statutory limiting emission values.

3 ORGANISATIONAL DETAILS

3.1 Participants

The DeCarb Application Form foresees that two representatives from partners' organisations, accompanied by one regional stakeholder or external expert, can attend the study visit, to be held in Velenje, Slovenia. The target audience includes all those individuals that can be impacted by the project outcomes and are interested in using project outputs and results to support policy measures on decarbonisation.

The Application Form provides a list of key regional stakeholders per project partners. Nevertheless, this is only an indicative pool of regional stakeholders identified at an initial stage; the project development phase. As the project progresses, project partners are expected to expand their network of contacts, through targeted communication actions and networking, reaching and liaising with new stakeholders and interested institutions from across Europe such as environmental agencies, regional development agencies, higher education institutes, and research centres, chambers of commerce, professional associations and public authorities. In any case, DeCarb partners are advised to invite any other organisation or body involved in the decision making process and/or interested in triggering policy development and behavioural changes towards decarbonisation.

3.2 Structure

There are several different methods and techniques from which KSSENA can choose from to engage participants in study visit activities and proceedings. To facilitate knowledge sharing and capacity building, the study visit could be structured to deliver the following sessions: a) field visits, b) round table discussions (panels), c) interactive exercises, and d) oral presentations.

a) Visits in selected sites can be an excellent way to see how things work in practice, recognise achievements and shortcomings, gain insights from actual implementation and find inspiring ideas that can be applied in own context, to address similar needs and common challenges. Field visits, if properly planned and implemented, can be proved rich learning experiences for participants, paving also the way for collaborative and coordinated actions.

b) Roundtable discussions represent a flexible form of discussion employed at workshops and conferences to facilitate participants' interaction and exchange of ideas. A small number of participants are seated around a table to discuss in-depth a particular topic of interest, seeking to resolve issues of disagreement; extract useful conclusions, and decide and plan future actions. The roundtable discussion format allows participants to interact with each other, promoting networking and equal participation/contribution, and allowing for faster decisions.

c) Interactive exercises can be defined as a structured set of facilitated activities for groups of participants to stimulate creativity and knowledge sharing through collaborative working. The purpose of interactive exercises is to facilitate the demonstration and application of skills and techniques, which will enable participants to find new ideas regarding potential policy measures on decarbonisation. Project partners and key regional stakeholders will explore procedures that encourage involvement and cooperation, promoting knowledge sharing and capacity building, leading to useful outcomes for participants with diverse experience but also with common needs and shareable solutions.

d) Oral presentations are brief discussions of a defined topic delivered to a group of listeners to impart knowledge and stimulate debate. There are four different types of oral presentations: a) the informative presentations, seeking to convey information and promote understanding of an idea or concept, b) the demonstrative presentations, showing the process of how to accomplish a task or activity, c) the persuasive presentations, which aim to influence a change in the belief, attitude, or behaviour, stimulating the uptake of actions, and d) the motivational or inspirational presentations that are designed to create an emotional connection between the topic and listeners, while encouraging the latter to go after their objectives.

3.3 Proposed sites

The following sites are proposed to ensure that the visit will facilitate reflection, discussion, and ideas around applicable cleaner coal technologies.

- **Šoštanj Thermal Power Plant**

  The Šoštanj Thermal Power Plant produces about one-third of all electricity in Slovenia. It operates a 600 MW supercritical, lignite-fired steam turbine power plant and associated cooling tower, stack, flue gas desulphurisation, wastewater treatment and control systems, and connection to an existing substation.

The power plant, with an overall efficiency of 46%, operates in cogeneration mode (supplying heat to the local district heating system) and largely replaced the previous lignite-fired generating capacity operating at low conversion efficiencies (26-33%). The power plant has been designed to be carbon capture ready as there is ample space for the installation of CO_2 flue gas cleaning equipment in the future and the parent company has considered the possibility of long-term CO_2 storage.

- **Coal Mining Museum**

  Modern Velenje in large part owes its existence to its coal mine, which has been continually operating since the 19th century and still produces some 4 million tons of coal annually - which is used at the nearby Šoštanj power plant to produce roughly 1/3 of Slovenia's energy needs. The mine is inherently intertwined with many aspects of the city's history, culture, and economy. To bring the long and storied history of Slovenian coal mining to a wider public audience, the museum includes a multimedia presentation, followed by a trip 160m below the earth's surface for a hands-on demonstration of what it's like to work in the mine.

- **Lake Velenje**

  Lake Velenje was formed as a consequebce of coal mining activities in the area through ground subsidence and is today one of the deepest lakes in the country. It has been utilized to develop touristic content primarily wih regards to the Velenje beach which has been very successful in drawing visitors from all of Europe.

- **Velenje castle**

  Velenje Castle is one of the few well-preserved castles in the region, housing a museum of art and culture. The museum located within the castle premises has a diverse collection, including a model of a coal pit, and many mining-related artifacts. The Coal Mining Museum is also located in the vicinity of the castle.

- **Inter-business educational centre - MIC**

  The Inter-Entrepreneurial Education Center (MIC) is a hub for the interdisciplinary development, exchange of experiences, and the flow of information around technological developments in the energy sector.

- **SAŠA business incubator**

  SAŠA incubator is a regional business incubator that covers the Savinjsko-Šaleška subregion and provides a supportive environment for the development of entrepreneurship and inovation. By promoting and providing expert services for the emergence and development of innovative companies the incubator provides an important support structure for individuals and young companies with innovative entrepreneurial ideas. The key goal of the SASA incubator is to build an effective regional entrepreneurial ecosystem through the integration and cooperation of key stakeholders in the region.

3.4 Topics for discussion

This section provides a very first suggestion on the topics to be presented and discussed during the study visit, based on the thematic background on technologies presented in section 2 of this input paper. This list is provisional, subject to changes or updates (if necessary) with respect to availability, capacity, permits and declared interest from participating stakeholders.

Three distinct topics have been identified for the visit; each is divided into specific discussion points. Guest speakers are expected to build upon the findings of the research conducted for the input paper by extending the scope of analysis and providing new perspectives for the topics under examination.

1) **Feasible technological strategic development pathways**. Participants can focus on the following discussion points:
    - **Waste management (inceneration and gasification):** How viable is the deployment of waste management technologies for energy production in DeCarb regions? What are the main environmental benefits and key performance indicators? What is the potential of the technology implementation to support innovation and economic development in knowledge intensive industries?
    - **Hydrogen and fuel cell technologies:** How viable is the deployment hydrogen technologies in DeCarb regions? What are the main environmental benefits and key performance indicators? What is the potential of the technology

implementation to support innovation and economic development in knowledge intensive industries?

- **Carbon Capture and Storage**: How viable would be the employment of CCS in DeCarb regions? How ready are –in terms of infrastructure, social acceptance, and financial incentives– the DeCarb regions to adopt such carbon capture solutions?
- **Carbon Capture Utilisation**: How viable would be the employment of CCU in DeCarb regions? What would be the utilisation pathway with the most economic potential in each DeCarb region?
- **Storage versus Utilisation**: What carbon capture route is more appropriate for the long-term mitigation of climate change and the most feasible economically?

2) **Policy framework**. Participants can focus on the following discussion points:
   - **EU climate mitigation policy goals**: Are 2030 and 2050 objectives realistic? Are the proposed technological pathways and the policy in which they are supported sufficiently effective to achieve long-term greenhouse gas emission reductions?
   - **The Carbon Capture and Storage Directive and Renewable Energy Directive - RED II amendment (ILUC)**: Is the existing policy framework adequate for addressing the issues of widespread technological uptake. Is it sufficient to drive the decarbonization and particularly phasing-out process of coal?
   - **The EU Emissions Trading System**: Is ETS enough for incentivising the use of clean technologies in the European CO_2 and energy market? Are the funds appropriately allocated towards supporting investment into clean technologies? What are the national/regional experiences?
   - **Policy gaps**: What challenges in cleaner coal technology employment remain unaddressed under the current EU policy framework? Will the upcoming Innovation Fund incentivise regions and key players to act?
   - **Clean coal technologies and the EU Green Deal**: What is the impact of the Green Deal to the advancement of clean coal technologies such as CCUS?
3) **Needs and barriers of clean coal technolgoeis.** Participants can focus on the following discussion points:
   - **Needs and barriers**: What needs to change on a policy, technological, economic, and social level so that clean coal technologies such as CCS and

CCU become mainstream options for climate change mitigation? What are the most pronounced barriers that hinder their employment?

3.5 Agenda

The following is an indicative agenda for the study visit.

Digital study visit of the Savinjsko-Šaleška coal region in transition

EVENT AGENDA

Venue and date: Online meeting

November, 2020

09.00 - 09.15	**Log in to Microsoft Teams**
	Establishment of connections and preparation of audio-visual settings *(KSSENA)*
09.30 - 09.50	**Welcome and introduction**
	Promotional video Velenje Formal welcome *(KSSENA)* Official welcome and opening statement *(MOV)* Presentation of the Savinjsko-Šaleška/Zasavska coal region in transition *(RA SAŠA)* Introduction to the study visit, agenda overview *(KSSENA)*
09.50 - 11.30	**1st Thematic session - Energy production**
09.50 - 10.20	**Coal Mine Velenje**
	Presentation of the organization and overview of potentials for innovative energy technology use cases *(PV Velenje)* Video 1 (Coal Mine Velenje)

10.20 - 11.10	**Thermopower plant Šoštanj**
	Presentation of the organization HSE and TEŠ *(HSE)* Video 2 (Presentation of TEŠ unit 6) Presentation of the SOEN project *(TEŠ)* Presentation of the hydrogen deployment project *(KSSENA)* Video 3 (Presentation of the hydrogen production site) Q&A session *(TEŠ, KSSENA)*
11.10 - 11.20	**Inter-business educational centre (MIC)**
	Video 4 (Presentation of the test site for energetics) *(FE)*
11.20 - 11.30	**Coffee break**
11.30 - 12.30	**2nd Thematic session - Development potentials**
11.30 - 11.45	**Velenje lake**
	Video 4 (Presentation of the features available/in development, Event site, Velenje beach) Presentation of the development of tourism in the municipality *(MOV)* Video 5 (Virtual drive together with presentation of the Lokalc public transport service) *(KSSENA)*
11.45 - 12:00	**Vila Bianca and Velenje castle**
	Video 6 (Virtual walk from Vila Bianca to Velenje Castle with presentation of the energy renovation in the Municipality and cultural heritage) *(KSSENA)* Video 7 (Virtual Jump) *(KSSENA)*
12.00 - 12.15	**SAŠA inkubator**
	Presentation of the organization and incubated companies *(SAŠA INKUBATOR)*
12.20 - 12.25	**Coal mining museum and the old power plant**
	Promotional video *(Muzej PV Velenje)*
12.30	**Wrap up and conclusion of the study visit**

3.6 Summary report guidelines

To conclude DeCarb activity 3.4, KSSENA will deliver a summary report. The report will present the outcomes of the visit and will be used by project partners as the main input for diffusing the lessons learned within their organisations and to promote storytelling. Summary reports are short written communication documents, which aim to convey information related to the discussions and activities carried out during study visit proceedings. The summary report should include the following aspects:

- Document the interventions of participants and the overall discussion within each session.
- Draw conclusions from the roundtable discussions and the debates in each session of the workshop.
- Briefly present policy recommendations for the development of action plans based on the interventions of the participants and the conclusions drawn from the discussion.
- Present an evaluation of the workshop based on the comments and feedback from participants.
- Present the metrics of the workshop (number of registered participants, type of participants, duration).

The following guidelines have been developed to provide assistance and guidance to KSSENA on how to summarise and present the main conclusions drawn from the visit; the summary report should be drafted as follows:

1) Develop short summaries for each session of the workshop. The summaries should include a) the context and objectives of the session, b) key argumentation from the interventions of participants, and c) conclusions and findings extracted from the overall discussion.

2) Review the evaluation forms and present the main conclusions. The author should summarise the key pitches and ideas as drawn from the forms completed by study visit participants. It is highly recommended that any idea (i.e. policy advice) that could contribute to the improvement of regional policies in the field should be integrated

3) Juxtapose the key arguments/conclusions drawn with any relevant results and findings from DeCarb thematic studies and guides on similar policy aspects. Identify convergences and divergences between findings.

4) Provide guidelines (in the form of policy recommendations) on how to utilise the key conclusions drawn to design policy measures and action plans to promote the adoption of policy measures that lead to EU region's decarbonisation. The guidelines on how to integrate the lessons learnt in the DeCarb action plans, as well as any policy advice that may be derived from the analysis of evaluation forms, should be described in a way that is simple, brief, and easy to follow.

5) Draft the summary report. The workshop summary report should be drafted clearly and concisely, focusing on the conclusions drawn from knowledge sharing and consultation processes that took place during the workshop sessions. To meet its purpose, the summary report should include the following:

    a. Overview and statistics, i.e. the number of participants and the type of organisations represented.

    b. Short description of the sites visited and the reasons for their selection.

    c. Summary of the main observations and lessons learnt from field visits and the key discussion points and conclusions from topics discussed.

    d. Brief presentation of policy recommendations for the development of action plans, based on the interventions of the participants and the conclusions drawn.

    e. The evaluation of the visit, based on participants' feedback.

ANNEX A: FEEDBACK FORM

Evaluation Form				
DeCarb A3.4 - "Study visits on the potential of "cleaner coal" and Carbon Capture and Storage technologies"				
Organised by Energy Agency of Savinjska, Šaleska and Koroška Region (KSSENA)				
Name:				
Organisation:				
Please answer the following questions, relevant to different aspects of the public consultation meeting, by rating on a 1 to 5 scale.				
How would you rate the exchange of study visit's overall organisation?				
1	2	3	4	5
☐	☐	☐	☐	☐
Do you think that the time allocated to each topic was sufficient?				
1	2	3	4	5
☐	☐	☐	☐	☐
How would you rate the quality of the presented topics?				
1	2	3	4	5
☐	☐	☐	☐	☐
How would you rate the quality of the discussion during the study visit?				
1	2	3	4	5
☐	☐	☐	☐	☐
How relevant to your organisation's operations were the topics addressed?				
1	2	3	4	5
☐	☐	☐	☐	☐
The study visit will lead to improvements in the proposed policies				
1	2	3	4	5
☐	☐	☐	☐	☐
The study visit, as a whole, has been appropriate and productive.				
1	2	3	4	5
☐	☐	☐	☐	☐

Are there any issues related to the topics of the study visit that have not been addressed? Please briefly describe them.
Click here to enter text.
Do you have any suggestions for the organisation of future study visits?
Click here to enter text.

ANNEX B: ORGANISATION OF A VIRTUAL MEETING

Virtual events offer a viable alternative in cases where physical attendance is not an option, such as the current Covid-19 outbreak. This appendix provides guidelines for the organisation of a virtual study visit, as a viable alternative, seeking to guarantee the project's seamless implementation and continuity.

Maintaining the schedule is essential for virtual events, as delays can be much more irritating than face-to-face events. Thus, the organisers should make sure that the study visit will start and end on time. Also, breaks should be scheduled every 45-60 minutes, to maintain the attendees' attention; virtual events require rigid scheduling. Taking into consideration the limitations associated with virtual communication in comparison to physical communication and live events, the virtual events are expected to have a decreased duration, not exceeding 5 hours, to remain productive and efficient.

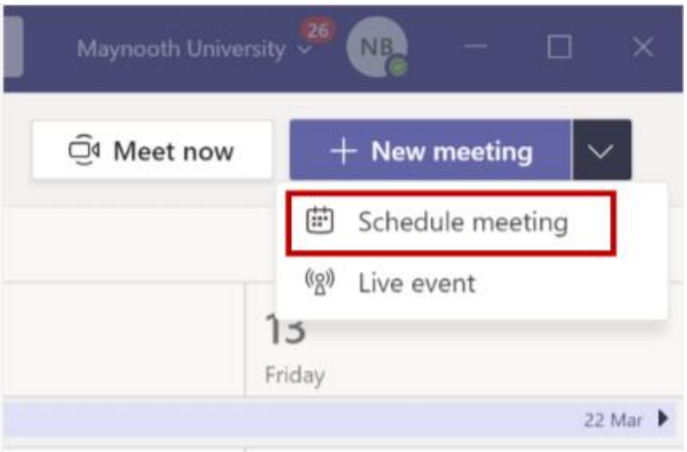
There is a wide selection of virtual conferencing tools available, both fee and paid, offering the technical possibilities to support the purposes of the study visit, such as Google Meet, Zoom and Microsoft Teams.

The hosting organisation (KSSENA) has decided to hold the meeting in the Microsoft Teams platform.

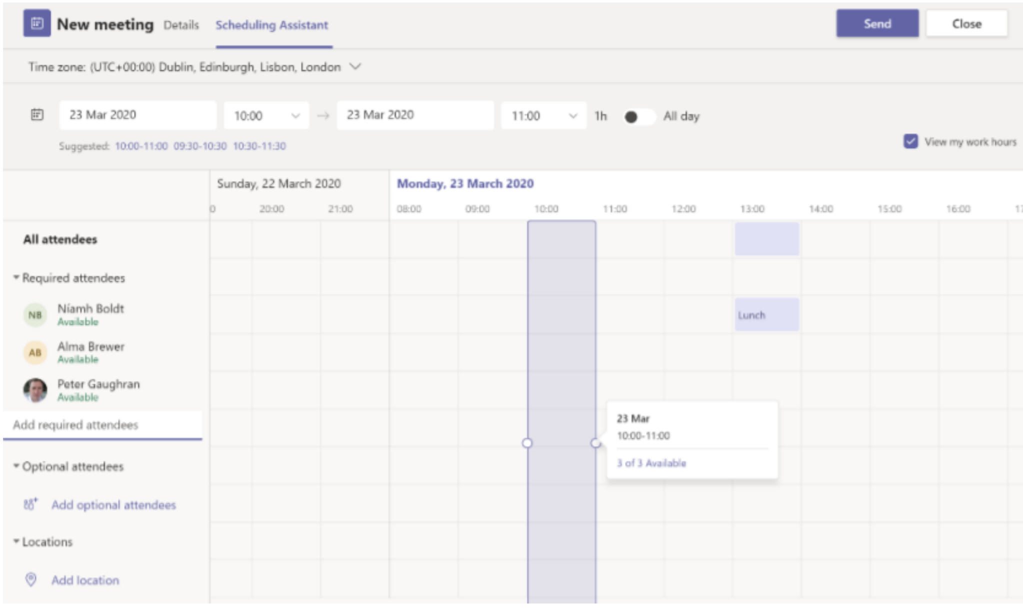
1. How to schedule a meeting in Microsoft Teams

An online meeting can be scheduled any time before the meeting is due to take place. A reminder can be sent out to attendees at any time by opening your calendar, selecting the event, getting the attendee link and sharing this with the current or additional attendee/s. The link can be shared by posting to a channel in the relevant team, emailing orother. To schedule an online meeting:

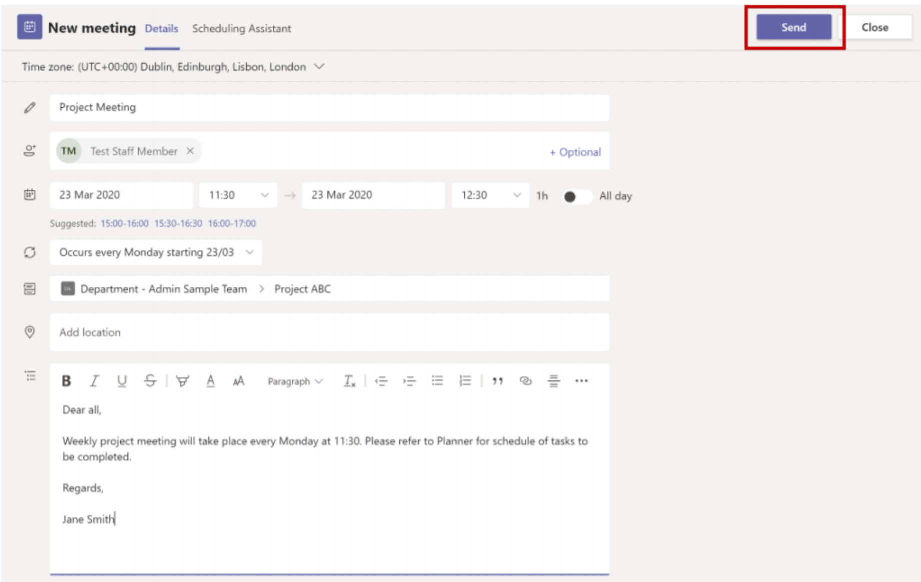
i. Open Microsoft Teams desktop app. If you do not yet have Microsoft Teams installed on your machine, navigate to the following link and download the relevant app for your operating system: https://teams.microsoft.com/downloads#allDevicesSection
ii. Select *Calendar* from the navigation panel on the left
iii. Select *Schedule Meeting* from the New Meeting drop-down menu.



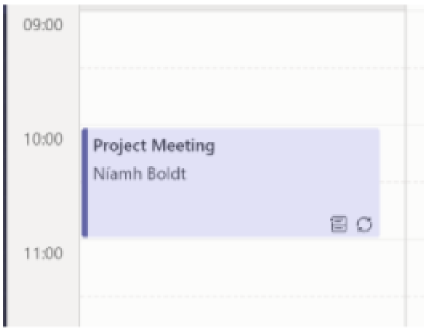
iv. If the meeting will be scheduled according to attendee's availability, select *Scheduling Assistant* to select a time to suit all or most attendees. Once an appropriate time is selected, click *Details* to complete the *New Meeting* request and then *Send* the invite.



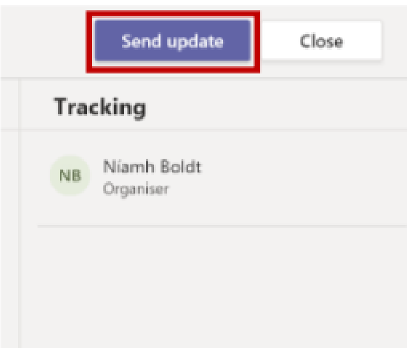
v. If the meeting is due to take place at a set date and time, complete the *New Meeting Details* as required and click *Send*. Note: Scheduling Assistant would not be required in this case.



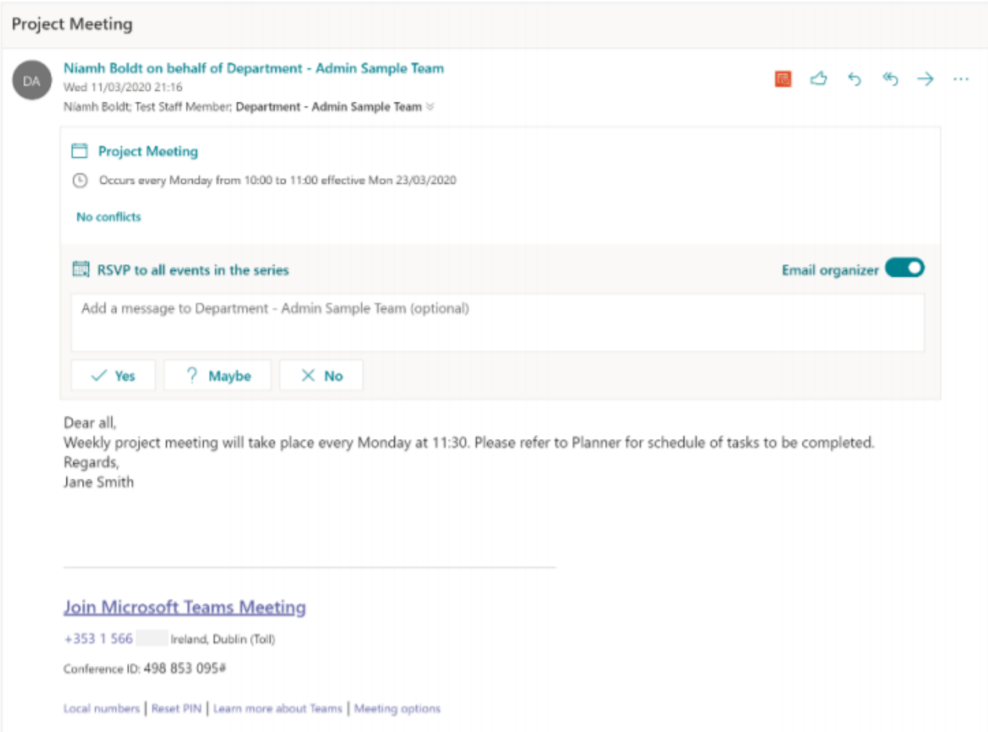
vi. The meeting has now been scheduled. This will appear in your *Calendar* in Microsoft Teams and Outlook. To edit this meeting at any time, open your *Calendar* and select the meeting request.



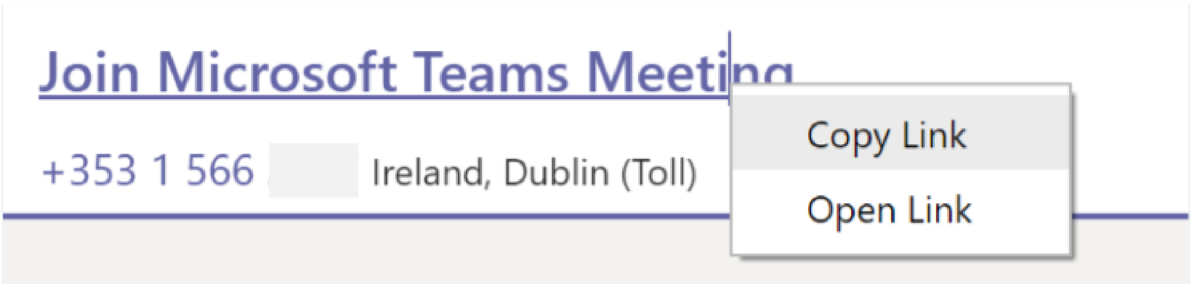
vii. To edit this scheduled meeting at any time, open your *Calendar* via Microsoft Teams and select the meeting entry. Edit the meeting event as required and click *Send update*.



viii. All invited attendees will receive an email similar to that shown below. Attendees will be required to RSVP to the meeting.



ix. A weblink to the online meeting, along with the direct dial information can be copied and shared with existing or new attendees, if required. To do this, right click on the *Join Microsoft Teams Meeting* at the bottom of the *Meeting Details* and click *Copy Link*.



2. How to join a Microsoft Teams meeting as a participant

Option A: Join a Teams meeting from the Microsoft Teams application.

i. From your **Calendar**, select **Join** on an in-progress meeting.
ii. Choose the audio and video settings you want.
iii. Select **Join now**.

Option B: Join a Teams meeting on the web

i. In your email invite, select **Join Microsoft Teams Meeting**. You can also use a dial-in number and conference ID from the email to call in.
ii. **Choose to join on the web**: Join a Teams meeting on the web.
iii. Type in your name.
iv. Choose the audio and video settings you want.
v. Select **Join now**.
vi. Depending on meeting settings, you'll get in right away, or go to a lobby where someone in the meeting can admit you.

ANNEX C: INVITATION

Energy Agency of Savinjska, Šaleska and Koroška (KSSENA) on behalf of the DeCarb transnational project invites you to the:

Thematic study visit

on the potentials of applying 'cleaner coal' technologies in the energy transition of the Savinjsko-Šaleška coal intensive region

Date: 11.11. 2020

Time: 09.30

Venue: Digital on-line event

The extensive use of coal for fuel in most parts of the world still produces about 15 billion tonnes of carbon dioxide each year. While supercritical coal-fired power plants even without CSS applications can drastically reduce emissions relative to energy output, their continued operation will prohibit any chance of achieving the emission reduction targets set forth by the international community. Some clean coal technologies offer notable potential in terms of reducing emissions but come about with both a substantial energy as well as price-increase penalty. The main challenge is therefore to structure the energy transition in a way that will not critically overburden the regional and national economy with unsustainable cost for energy, but rather to mobilize existing potentials in other sectors in order to take part of the stress associated with the phasing out of coal.

The Energy agency of Savinjska, Šaleška and Koroška region with the support of their national stakeholder and the transnational partner consortium of the DeCarb project will organize the thematic study visit that will provide insight into the current situation, ongoing projects and strategic development targets related to the energy transition of the Savinjsko-Šaleška coal region in transition.

ABOUT THE PROJECT

DeCarb (Supporting the clean energy transition of coal-intensive EU regions) aims to foster exchange of experiences and facilitate knowledge transfer between regions that have already succeeded in the 'green energy' transformation and the ones seeking advice on how to decarbonise their energy industry. It brings together 9 partner organizations from Germany, Denmark, Poland, Spain, Hungary, Bulgaria, Romania, Greece and Slovenia. It seeks to increase the capacity public administrations to effectively support new growth trajectories and promote energy security, to unlock and facilitate investment into energy infrastructure re-trainings and repurposing of degraded areas in addition to aiming for increased awareness and consensus building among the energy sector, the workforce, and citizens with the main goal to jointly support measures for the clean energy transition. DeCarb is co-funded by the European Regional Development Fund through the Interreg Europe transnational programme.

ABOUT THE EVENT

Due to traveling and other limitations because of COVID-19 the event will be organized as a thematical online video conference on MS Teams. Participants will be asked to register at least 3 days prior to the event and will receive the connection link to the e-mail address they provide. The event will be followed up by an organization of a conventional study visit in spring or summer 2021 provided that the situation with respect to the pandemic will permit.

For additional information please contact us at:

E: info@kssena.velenje.eu

T: 386 (0)3 8961 520

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