CEFS CLIMATE NEUTRALITY TOOLBOX

EXECUTIVE SUMMARY

Climate change is already impacting sugar beet cultivation, and by extension the competitiveness of European beet sugar production. Addressing the cause of climate change – greenhouse gas emissions – is more urgent than ever before. Adding to this is the ongoing energy crisis: reducing energy consumption and transitioning away from fossil fuels are now economically imperative.

CEFS members have already made ambitious commitments to reduce emissions by 2030. Realising these commitments will lead to a reduction of at least 30% by this date. Given that the industry has already cut emissions by 59% between 1990 and 2021, this sets the industry well on the way to climate neutrality.

But climate neutral sugar production cannot be achieved without the right tools and a supportive policy framework. The aim of this document is to support both operators and policymakers in these efforts: it will discuss how to decarbonise beet sugar production in Europe by 2050 and what policies are needed to get there.

The fact that there is no single sugar factory configuration makes it impossible to present a "roadmap" for the sector as a whole. However, beet sugar factories share common characteristics owing to the specificities of beet sugar production; most notably seasonality and rural location. This has an impact on factory design and consequences for decarbonisation. Most importantly, it makes full electrification difficult and expensive.

In order to reach climate neutrality sugar manufacturers will need to reduce energy consumption and increase efficiency via tools such as energy management and heat recovery. Process

electrification tools such as heat pumps could also play a role in certain circumstances. Specific technologies such as gas engines and turbines can support a shift in the balance of heat and electricity use towards the latter. Meanwhile, emissions could be directly reduced via lime kiln conversion and carbon capture and storage (the latter depending on whether the challenge of seasonality can be addressed).

The energy that cannot be saved must be made renewable. This means making use of sugar beet residues generated on-site – a readily-available source of renewable biomass fuel. It can also mean external biomass and biomethane where there is sufficient availability. On-site renewables and externally procured electricity and heat are already playing a supplementary role, and will continue to do so. Concerning renewable hydrogen, it remains to be seen how that market will develop.

The right policies will be essential if the sugar sector is to be able to decarbonise. This means sensible implementation of the RED III by Member States to ensure that sugar beet residues can be used for energetic self-use. It also means exempting the energetic self-use of biomass residues from the revised Energy Taxation Directive. Carbon removals legislation should encourage the use of bioenergy combined with carbon capture and storage/use (BECCS/U).

Meanwhile, financial support will be essential due to the specificities of sugar production: grants and loans under both EU programmes and Member State funds such as the national Recovery & Resilience Plans and State aid facilitated by the Temporary Crisis & Transition Framework. And, potentially, Carbon Contracts for Difference to reduce operating expenses for manufacturers.

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THE INDUSTRY HAS ALREADY CUT EMISSIONS BY 59% BETWEEN 1990 AND 2021

CONTENTS

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1. INTRODUCTION

Climate change is already here, and its effects are being felt by the EU beet sugar sector. Europe is warming at twice the rate of the earth as a whole. Lack of rain is impacting beet yields. Warmer winters are worsening pests and diseases that would normally be eradicated by the cold. Addressing the cause of climate change – greenhouse gas emissions – is more urgent than ever before.

Adding to this emergency is the ongoing energy crisis. The post-COVID rebound in demand, and more still Russia's aggressive invasion of Ukraine, have caused the cost of fuels, especially natural gas, to skyrocket. Reducing energy consumption and transitioning away from fossil fuels are now economically imperative.

The EU sugar industry has already reduced emissions substantially over the past decades. Emissions fell by 59% between 1990 and 2021. But more efforts are needed to reach climate neutrality by 2050. The aim of this document is to support both operators and policymakers in these efforts: it will discuss how to decarbonise beet sugar production in Europe by 2050 and what policies are needed to get there.

Beet sugar production is highly specific. It is seasonal and continuous owing to the nature of the agricultural raw material: sugar beet. The specificities of the sector have an impact on factory design and consequences for decarbonisation, particularly as regards the production of residues that can be used as a readily available source of renewable energy on-site.

There are a number of hotspots in the beet sugar production process. The biggest is the on-site production of heat and electricity. But there are others, including the drying of beet pulp for animal feed and the production of quicklime in the lime kiln. Addressing these hotspots will be essential to decarbonise the industry.

The fact that there is no single sugar factory configuration makes it impossible to present a "roadmap" for the sector as a whole. Instead, this document presents a toolbox that can be used by operators looking to reduce emissions. And by policymakers to understand the strengths and weaknesses of the different decarbonisation tools for our industry. The tools are grouped into two broad categories:

- **Renewable energy** covers to a large extent to renewable alternatives to fossil heat, including external biomass, biomethane from the grid, renewable and low-carbon hydrogen, and, most promisingly, sugar beet residues generated during the sugar production process. In addition, this section also covers to externally procured renewable electricity and heat and on-site renewables.
- **Other tools** cover heat recovery and process electrification, in addition to specific technologies such as gas engines and turbines, lime kiln conversion, and carbon capture and storage.

Each tool is evaluated on the basis of its emission reduction potential, availability (in the case of "renewable energy"), technology readiness level (in the case of "other tools"), capital expenditure, operating expenditure, and regulatory hurdles that might impede its uptake.

The policy framework needed to facilitate the decarbonisation of EU beet sugar manufacturing will be discussed in the following section. This includes specific legislation such as the Renewable Energy Directive but also provisions for financial support from both the EU and Member States.

To provide inspiration for EU sugar manufacturers, the report concludes with a series of examples from CEFS members where greenhouse gas emissions have been substantially reduced.

2. SPECIFICITIES OF SUGAR PRODUCTION

2.1. Seasonality

2.1.1. Sugar beets: a perishable agricultural raw material

Sugar beet processing is highly seasonal due to the natural cycle of beet cultivation. Energy is required to extract sugar from beets over a period of 90-150 days a year (the 'campaign'). In most parts of Europe the campaign runs during autumn and winter (mid-September until the end of February), with sowing taking place in the spring. It is impossible to store the beets for more than two and a half months, since the root (living matter) degrades considerably beyond this period.

During the campaign factories operate 24 hours a day, 7 days a week. In most EU Member States the campaign starts in September; it starts slightly earlier in Italy (August time); and in southern Spain it starts in the spring with sowing taking place in the autumn.

Because sugar factories must operate continuously at maximum capacity, they cannot reduce fuel and electricity consumption without a corresponding reduction in production and the risk of agricultural waste. Sudden interruptions to energy supplies risk temporary shutdowns, prolonging the campaign with an increase in beets that are difficult or impossible to process.

2.1.2. Impact of seasonality on factory design

Seasonality has led to investment in industrial facilities sized to operate 90-150 days a year. Beet sugar factories are equipped with high efficiency combined heat and power (CHP) installations of 50-300 MW, 3-4 times larger than similar factories working 365 days a year. They need sufficient capacity to manage the variations in the volume of beets for processing within 3-5 months that can result from changes in weather conditions from year to year. Because of the high capacity of sugar factories' energy-consuming stations, security of energy supply is key.

2.1.3. Consequences of seasonality

The financial and administrative consequences of seasonality are substantial. Because sugar factories' energy consuming stations are sized to operate 90-150 days a year, reducing emissions in these energy-consuming stations costs 3-4 times more than in non-seasonal industries. Sugar factories also have a longer lifetime of equipment than in industrial sectors operating all year round: because equipment only operates for 3-5 months a year, it has to be kept and maintained more years to come to the same lifetime than in the case of industrial units operating 365 days/ year. As a result, beet sugar manufacturers have very high capital intensity, similar to that of heavy industry.

Table 1: Financial impact of seasonality compared with installations operating all year round (example)

Type of industry	Investment	Annual production
Seasonal (110 j/an)	30	100
Non-seasonal (330 j/an)	10	100

2.2. Necessary proximity to beet fields

2.2.1. Location of beet processing units

All factories that process beet in the EU today produce sugar as their primary product. As sugar beets contain approximately 75% water, sugar production is characterised by a high raw material intensity. To save on transport costs, sugar factories aim to minimise the radius within which they source sugar beets. This distance is 40km on average in France and 50km in Germany. Many operators pay a premium for sugar beets cultivated close to the factory.

The necessary proximity to sugar beet fields means in most cases isolation from high-voltage electricity grids, which generally supply urban areas. This, combined with significant energy requirements, has driven the development of Combined Heat and Power (CHP) systems to produce steam for the heat required for the extraction of sugar and electricity to power mechanical and electrical processes. CHP systems are highly efficient with an overall energy efficiency of over 90%. Historically these systems are equipped with steam turbines that provide only the electricity needed for the production process without any excess for sales to the public grid.

2.2.2. Transformation of living raw material

Sugar factories work with a living agricultural raw material: sugar beets. Both the volume (availability) and quality (sugar content etc.) of sugar beets vary from one year to the next due to variable meteorological conditions (temperature, humidity). The quality of the sugar beets can also change during a campaign depending on the weather in winter (soil adherent, degradation, impacts of freezing, thawing, etc.). This leads to variations in the energy requirements of factories. Once harvested, the beet cannot be stored for long and must be processed as quickly as possible in the nearest unit.

Agro-meteorological hazards that can impact both the availability and quality of sugar beets are becoming more frequent and include in recent years:

- Intense summer droughts (NW Europe, 2019, 2020, 2022)
- Excessively wet spring (NW Europe, 2016)
- Late frosts just after sowing (France, 2021)

Climate change is expected to decrease the frequency of frosts but increase their intensity and length, which will impact sugar beet availability.

Meanwhile, warming winters are increasing the incidence of pests and diseases. Combined with the ban on the use of seeds treated with neo-nicotinoids, this caused a catastrophic fall in beet yields (and therefore sugar production) in France during the 2020/21 campaign.

Pests and diseases are getting increasingly more difficult to control as beet growers have access to a shrinking set of active substances. If beet growers are unable to cultivate, they will abandon beet growing altogether. This will undermine the viability of industrial sugar production since factories must run at their maximum or close to maximum capacity in order to produce efficiently. Lower beet production has pronounced effects on heat demand (sugar extraction) and greenhouse gas emissions. Both are to a large extent a function of the volume of beets processed. Absolute heat demand and greenhouse gas emissions fall when lower volumes of beets are processed, but in relative terms (e.g. per tonne of beet processed) these factors increase.

3. THE SUGAR PRODUCTION PROCESS

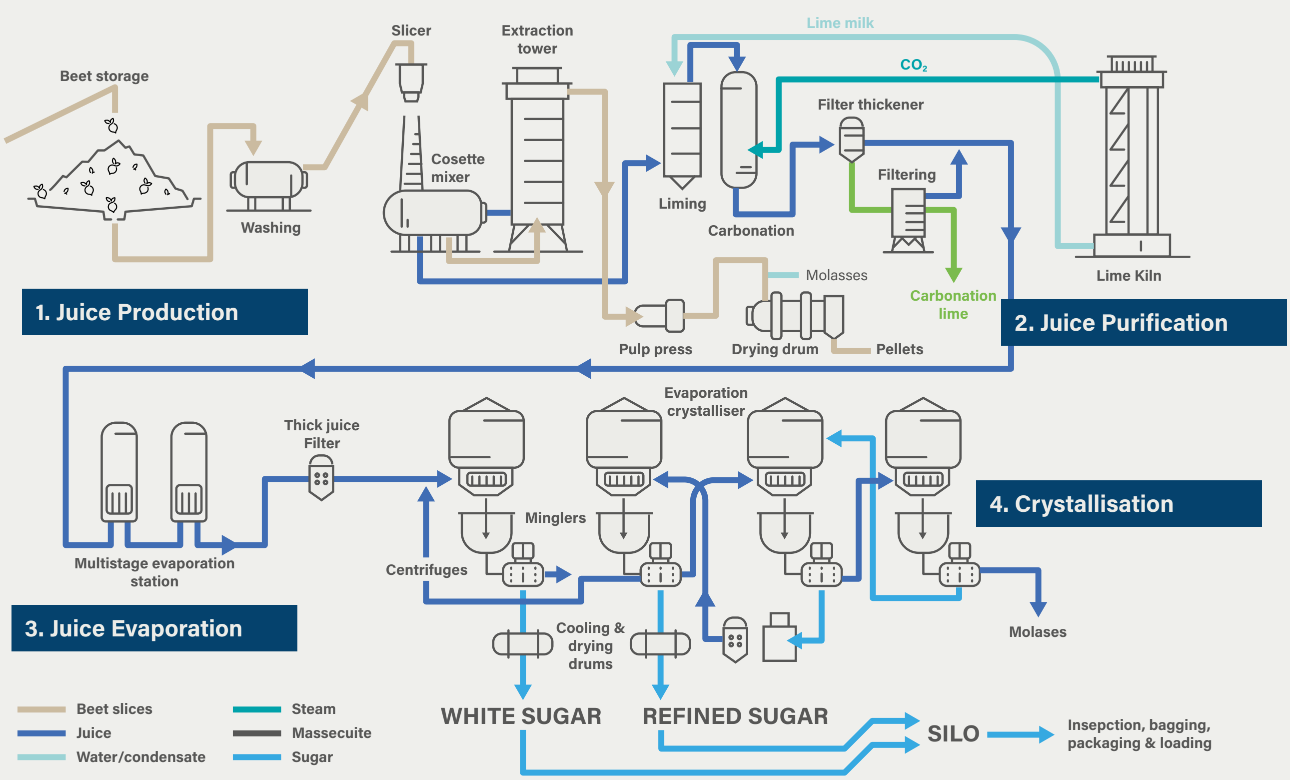
3.1. Basics

The sugar production process follows the same succession of steps for both sugar beet and sugar cane. Throughout the world, all sugar factories, from the oldest to the most recent, use the same process, which will probably continue for the foreseeable decades (2030-2050): no "industrial revolution" is foreseen to extract sucrose from sugar beet and sugar cane.

The sugar production method consists of extracting and preserving the sucrose in a state that allows for its storage and its transport. After washing the sugar beet to separate the soil and adhering plant matter or after crushing the cane stems, four major steps take place to separate the sucrose molecule from all the other components of the plant:

1. Extraction by diffusion in hot water, the sugar being mixed with many dissolved or suspended substances (impurities from the plant) in a raw juice.
2. Calco-carbonic purification by adding quicklime and CO_2 to the raw juice to precipitate the impurities extracted, followed by filtrations and obtaining a clear juice.
3. Multiple effect evaporation: stepwise concentration of the clear juice by evaporating the water using heat to obtain a dense syrup.
4. Crystallisation by boiling under vacuum, then separation of the crystals from the remaining liquid (molasses) via centrifugation before drying.

Figure 1: The beet sugar production process



3.2. Residues/products

All factories that process beet in the EU today produce sugar as their primary product. Many factories also produce bioethanol or non-fuel alcohol as a primary product, especially in France.

However, sugar factories also produce other products, such as dried or pelleted animal feed, biogas, bioplastics, and betaine. The production of these various co-products can have a substantial impact on the energy consumption and emissions of a beet sugar factory (e.g. high-temperature drying of beet pulp for animal feed).

Currently most of the beet pulp is used for animal feed, mainly for dairy cows. But beet pulp can also be used to provide energy to fuel factory processes. The relative proportions of beet pulp going to animal feed and energy will depend primarily on market demand, energy prices, and (potentially) access to energy supplies. Certification of bioenergy installations by accredited bodies will ensure that only residues are used for such purposes.

Other co-products such as carbolime (from the sugar production process) and vinasses (from bioethanol fermentation), by substituting other more emitting agricultural additives and fertilisers, indirectly reduce agricultural greenhouse gas emissions upstream.

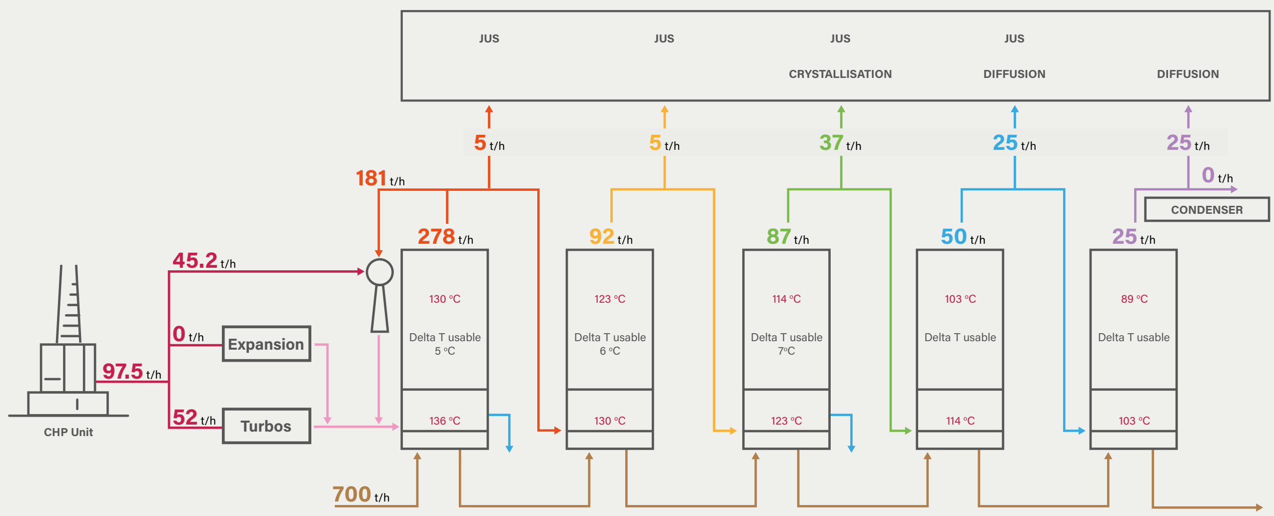
3.3. Sugar factory configurations

Due to their geographical location and the high energy requirements of the process, the sugar sector has developed over time a complex energy scheme making it possible to effectively ensure the thermal balance between the need for heat and electricity. This scheme is based on the implementation of techniques found within the Best Available Techniques Reference Document for the Food, Drink and Milk Industries (FDM BREF), the main ones being, in terms of energy:

- multiple effect evaporation and recycling, which allow the same kWh of steam to be used five or six (even up to nine) times;
- cogeneration of heat and electricity in CHP installations; and
- fatal heat recovery.

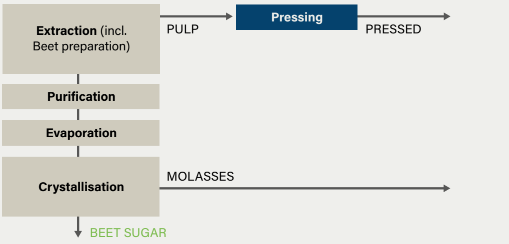
Due to the cogeneration of heat and electricity, a reduction in heat needs associated with increasing efficiency will lead to an electricity deficit and increased reliance on electricity imported from the grid.

Figure 2: Example of a thermal diagram of a sugar factory – cogeneration and multiple effect evaporation

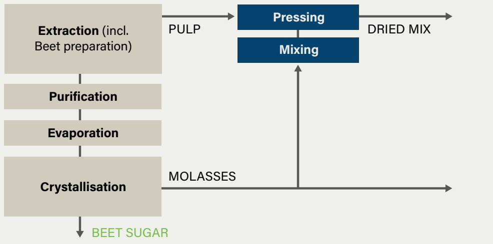


There is no "typical" sugar factory configuration. Factories are configured differently according to the products they produce, which is itself a function of the technology chosen to fulfil market demand.

FACTORY SETUP 1



FACTORY SETUP 2



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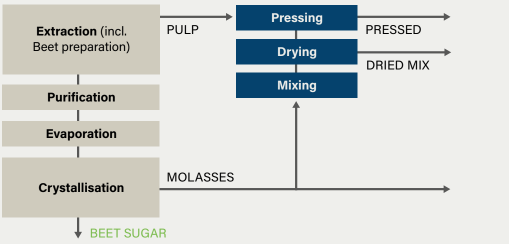

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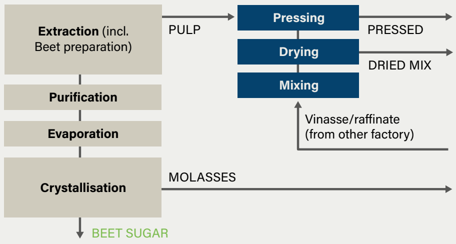

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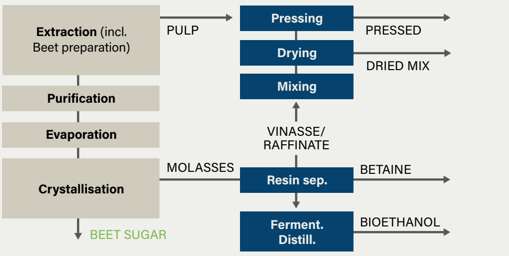

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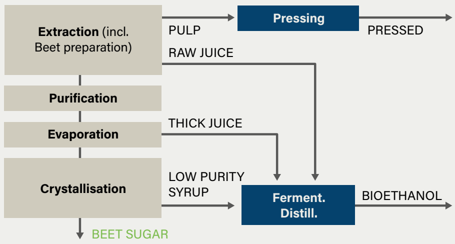

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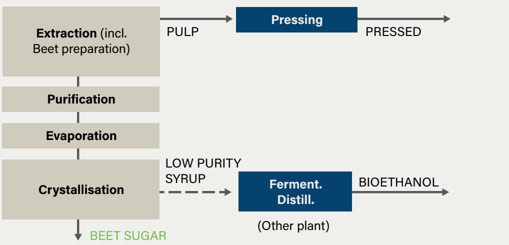

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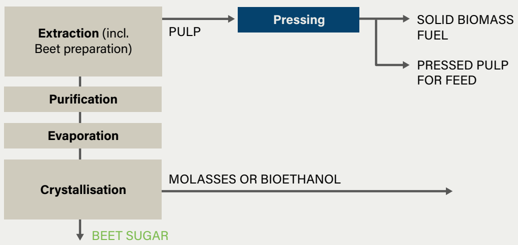
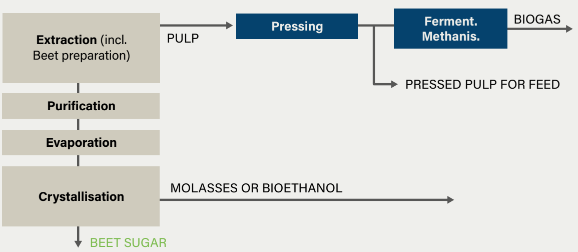


FACTORY SETUP 9



4. GREENHOUSE GAS EMISSIONS FROM THE EU BEET SUGAR SECTOR

Sugar production is highly energy-intensive. Heat must be used to evaporate water at temperatures ranging between 15 and 150oC (but generally min. 60oC due to vacuum cost constraints). This has resulted in traditionally high energy usage and CO_2 emissions.

Nevertheless, EU27 sugar industry emissions fell fairly steadily over the period 2017-2021, both in absolute (total) and relative (per tonne of beet processed) terms. See figure 3.

Figure 3: CO_2 emissions from the EU (27) beet sugar sector, 2017-2021, expressed in absolute (million tonnes of CO_2) and per kilogramme of beet (Kg CO_2/tb). Sources: ETS for emissions; CEFS for paid beet.[1]

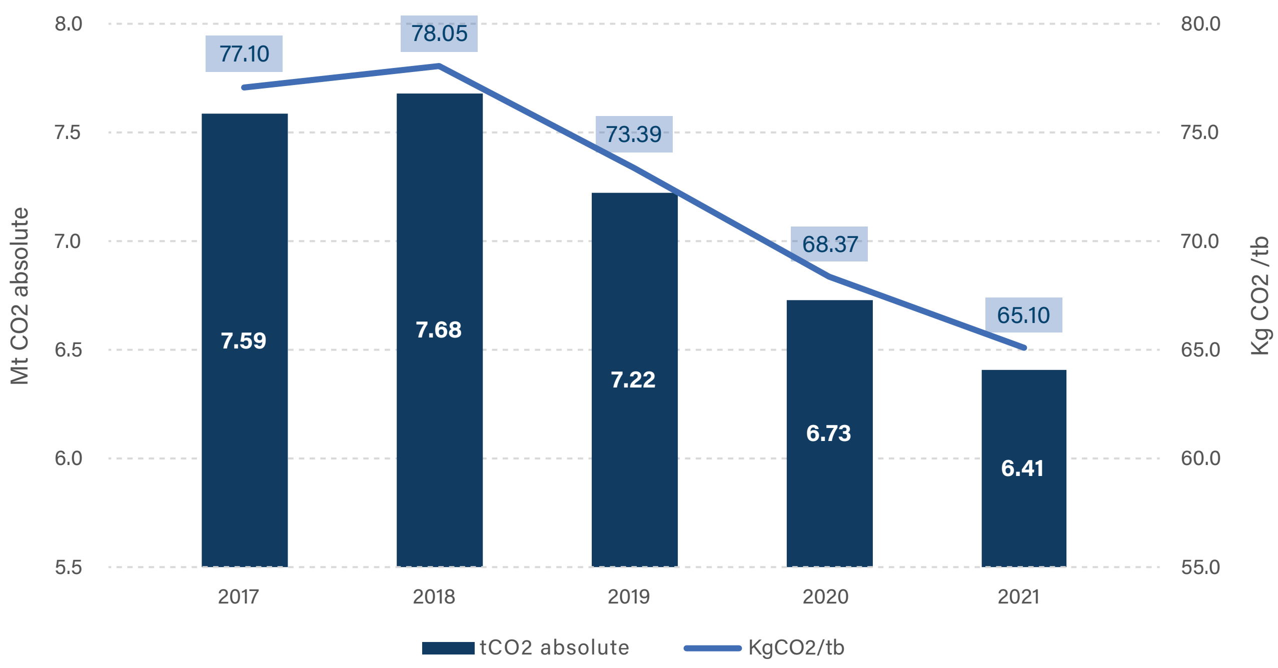
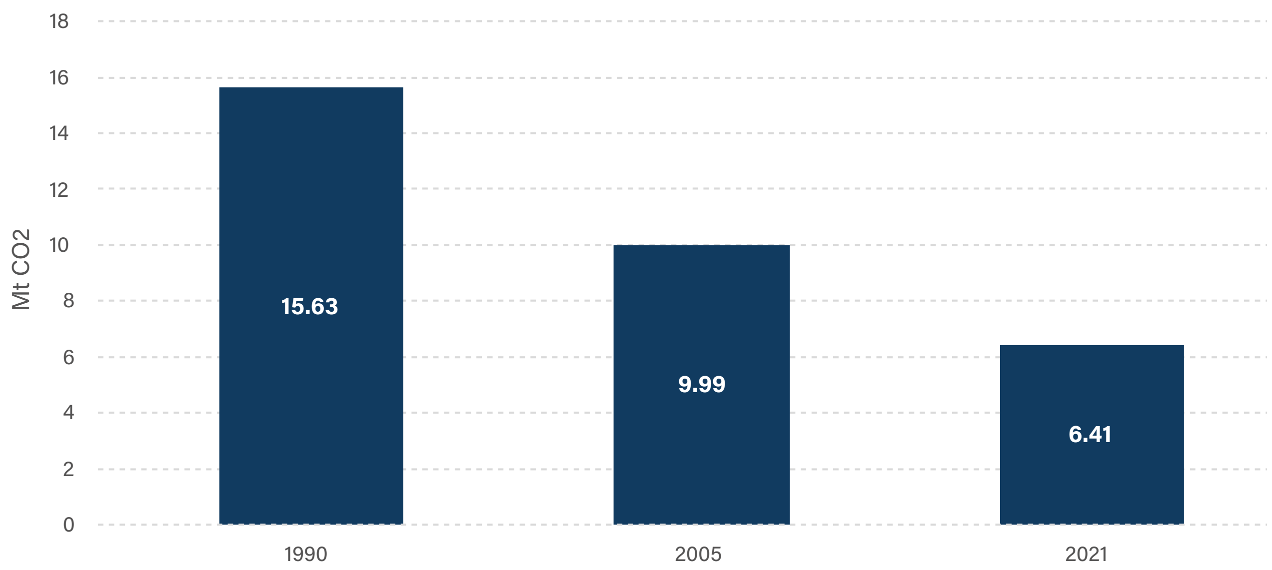


Figure 3 presents the emissions data for the sugar production facilities as notified to the ETS registry. There are therefore two important caveats. First, not all emissions are the direct result of sugar production, since a number of sugar production facilities also produce bioethanol from sugar beet. Emissions from the production of bioethanol cannot be separated from the overall numbers. Second, some sugar factories have co-refining facilities to refine imported raw cane sugar into white sugar. As for bioethanol emissions, emissions from co-refining activities cannot be separated from the overall numbers.

1. Emissions per tonne of beet expressed as an EU average weighted by national paid beet volumes as a proportion of total EU paid beet volumes.

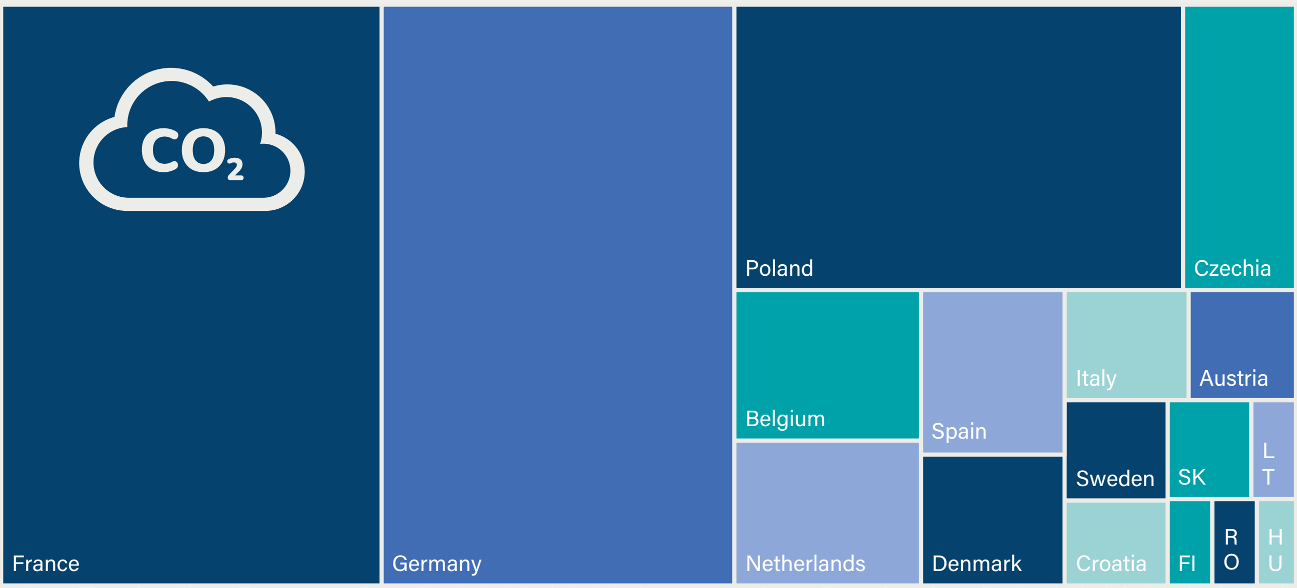
The decrease in emissions since 2017 reflects a historical trend; between 1990 and 2021 emissions fell 59%. This fall can be explained by the closure of a large number of sugar production facilities (mostly during the 2006-2009 reform) in combination with a switch to natural gas from more emitting fuels such as coal and fuel oil. See figure 4.

Figure 4: CO_2 emissions from the EU (27) beet sugar sector in 1990, 2005 and 2021, sans UK. Sources: CEFS for 1990, 2005 due to absence/unreliability of ETS data; EU ETS for 2021.[2]



France and Germany account for the biggest share of emissions within the EU, followed by Poland. These are the EU's biggest sugar manufacturers. France's position as biggest emitter, in spite of it having almost completely converted to natural gas, can be explained by the fact that many French sugar factories have bioethanol distilleries attached.

Figure 5: CO_2 emissions per EU Member State, three year average 2019-2021. Source: EU ETS.



2. Unfortunately paid beet data for all of the Member States concerned is not available for 1990 and 2005. Therefore, emissions intensity in Kg CO_2 per tonne of beet cannot be calculated for these years.

The EU sugar industry should deliver a reduction of absolute emissions of at least 30% by 2030.

This is based on the targets adopted by CEFS member companies.

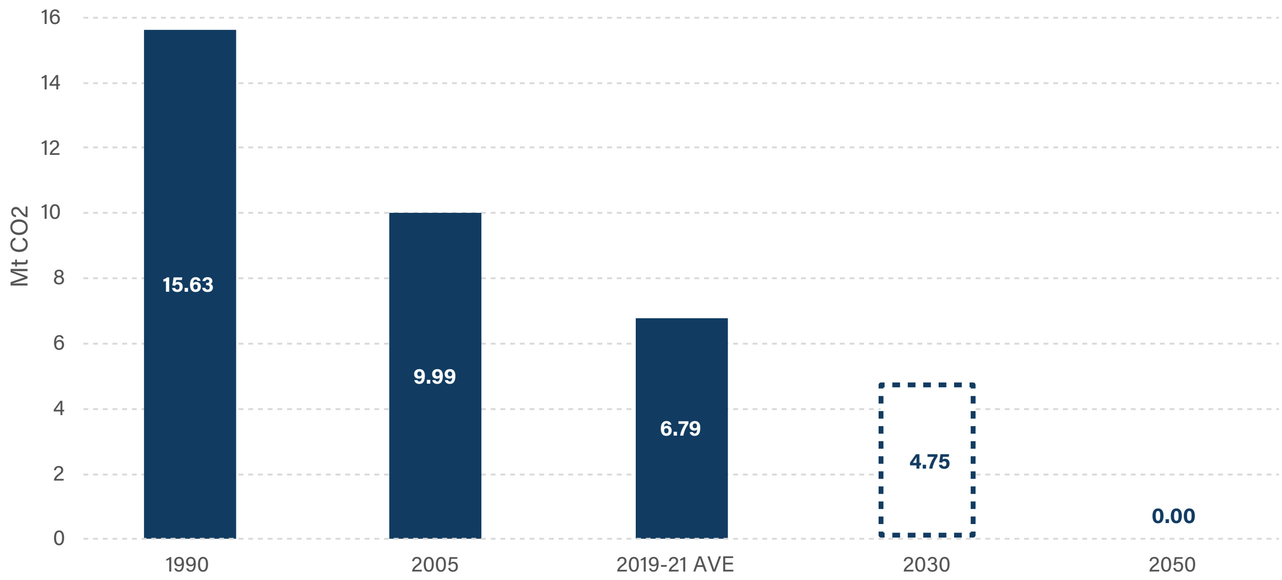
Progress towards this target will be monitored using data from the EU ETS registry.

-30% BY 2030

EXPECTED REDUCTION IN TOTAL CO_2 EMISSIONS

(REF 2019-2021 AVE)

Figure 6: Possible trajectory of EU sugar industry emissions, 1990-2050



3. Hrvatska industrija šećera d.d.

5. EMISSIONS HOT SPOTS

5.1. Production of heat and electricity

The provision of heat (in the form of steam) and electricity is by far the most important greenhouse gas emitter in the beet sugar production process. Nevertheless, most EU beet sugar factories are equipped with cogeneration units that provide both heat and electricity at much higher efficiencies (c. 90%) than power-only electricity generation combined with a heat-only boiler.

Currently almost all beet sugar factories rely on fossil fuels as their primary energy source. Natural gas is the most used energy source in the sector, followed by coal. Oil and, increasingly, biogas and biomethane are also used in CHP systems.

The selection of the energy source (e.g. natural gas, coal, oil, biomethane, biomass) and the corresponding CHP technology are key when it comes to reducing greenhouse gas emissions from sugar production.

5.2. Drying of beet pulp

The drying of beet pulp is common practice when there is a limited local market for fresh (pressed) pulp for animal feed. Unlike pressed pulp, dried pulp can be stored and transported long distances thanks to its much higher dry matter content. Dried pulp can be used to produce animal feed within the factory confines (e.g. by mixing with molasses and pelleted) or it can be sold on to specialised feed producers.

High-temperature drum dryers (HTD) have been traditionally used to dry beet pulp, after a pulp press has first mechanically removed the water. The temperature in the HTD can range between 500°C and 750° C and the exhaust heat can exceed 100°C.[4] For this reason, drying beet pulp is highly energy-intensive; using a high-temperature dryer can consume 100 kWh of gas per tonne of beet, which translates into 607 GJ (1,600-1,900 kWh) of gas to produce a tonne of dried beet pulp.[5] Pulp drying can account for up to 50% of factory energy demand and 25-30% of emissions when the all of the beet pulp generated in the factory is dried in an HTD. Because of this, it is more energy efficient to use the beet pulp for bioenergy or directly as pressed pulp for the local animal feed market. The decision concerning which part of the pressed pulp is allocated to which end product (biogas/bioenergy, dried animal feed, pressed pulp), depends on the demand for pressed pulp, demand for dried pulp, cost of energy, factory equipment and capacity, and efficiency of equipment.

5.3. Lime kiln

On-site lime kilns convert limestone to quicklime and carbon dioxide, which are used as precipitants for the first stage of juice purification.

The lime kiln uses coke or natural gas to heat limestone to very high temperatures (900-1,250°C) to produce quicklime (CaO) and CO_2.[6] After the quicklime has been added to the raw juice, CO_2 is injected to precipitate impurities that can then be filtered off. In most installations coke is used in the lime kiln as this solid fuel has the lowest specific consumption value. Moreover, coke firing allows for a particularly high yield of CO_2 in the lime kiln gas. In the sugar industry coke is therefore a dual use energy product: it provides the heat required for thermal scission in addition to the input CO_2.

The lime kiln can account for up to 5% of factory energy demand and up to 10% of emissions.

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4. Merino, Alves, Acebes and Prada. 2017. Modeling and simulation of a beet pulp dryer for a training simulator. Drying Technology 35(14).
5. Arne Sloth Jensen and Bernard Morin. 2015. Energy and the environment in beet sugar production. Bartens.
6. Agrana. Undated. Lime kilns and sugar manufacturing.

5.4. Other emissions sources

5.4.1. Beet transport

Beets must be transported from the field to the factory, in addition to within the factory confines.

Both operations represent a relatively small share of emissions (especially transport within the factory). Nevertheless, given that operators control these processes, the ways in which emissions resulting from beet transport can be reduced are presented later in this document.

5.4.2. Agricultural emissions

The cultivation of sugar beets is a substantial source of greenhouse gas emissions. These emissions mainly result from fertiliser production and use and field work (notably fuel used in agricultural machinery). However, the cultivation of sugar beets is characterised by lower emissions than cane due to lower GHG emissions resulting from the use of fertilisers and non-existent land-use change effects.[7]

Agricultural emissions are beyond the scope of this document. Therefore, the following sections will not delve into ways to reduce emissions during the agricultural stage. Nevertheless, in 2023 CEFS plans to publish a roadmap on how to reduce GHG emissions in the whole sector as part of the EU Beet Sugar Sustainability Partnership.

THE CULTIVATION OF SUGAR BEETS IS A SUBSTANTIAL SOURCE OF GREENHOUSE GAS EMISSIONS

7. Suiker Unie. 2020. "Comparative Life Cycle Assessment of beet sugar, cane sugar and corn glucose syrup."

6. RENEWABLE ENERGY

6.1. Context and pathways

Getting to climate neutrality by 2050 will mean transitioning away from fossil fuels.

A number of operators have already phased out the use of coal in the boiler house. This includes several French sugar manufacturers (Cristal Union, Lesaffre, Ouvré Fils), in addition to Cosun Beet Company, Iscal Sugar, and Azucarera . Several other operators plan to phase out coal by 2030, including Nordzucker and Pfeifer & Langen. Südzucker group plans to phase out coal by 2032 at the latest.

If the EU sugar sector is to decarbonise competitively, renewable energies must be available and affordable. Several options have been identified and will be considered in turn. These are:

- the use of external (forest) biomass;
- the use of biomethane purchased from the gas grid;
- the energetic self-use of biomass residues from sugar beet processing (sugar beet pulp, biomass fraction of wastewater, other residues); and
- renewable electricity and heat (externally procured and on-site).

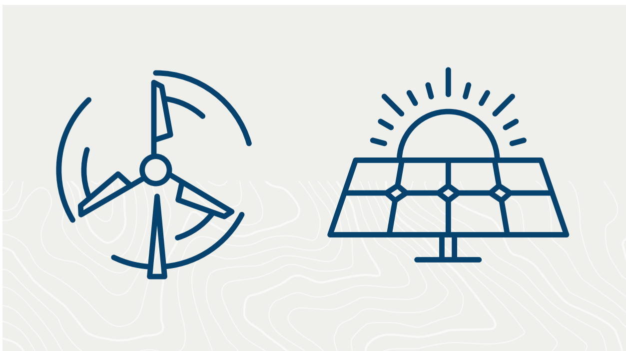
Each of these avenues, with their advantages and disadvantages, will partially contribute to decarbonisation by 2030. They all require significant investment, and therefore a substantial level of aid, as well as a reassuring and appropriate regulatory framework.

In this section (‘renewable energy’) and the next (‘other tools’), the tools will be assessed on a qualitative basis resulting from discussions between CEFS member experts. The criteria applied are the following:

1. Emissions reduction potential: how big a contribution to emissions reduction can the tool make?
2. Availability: this mainly relates to renewable energy, since most other tools rely on electricity.
3. Technology Readiness Level (TRL): how mature is the technology? This relates to other tools.
4. Capital Expenditure (CAPEX): how expensive is the initial investment?
5. Operational Expenditure (OPEX): how expensive is the tool to run on a day-to-day basis?
6. Regulatory hurdles: is the tool supported or hindered by EU/national policies?

For each criterion the score will be evaluated as low, medium or high. For the first three criteria a “high” evaluation score is preferable; for the last three criteria a “low” evaluation is preferable.

As stated above, TRL is not considered a relevant criteria for renewable energy; nor is availability considered a relevant criterion for “other tools”.



6.2. External biomass

External biomass such as wood chips could be used as an alternative fuel source in pulp dryers, particularly for existing drying installations. This solution has been used by the fodder drying sector in France, which benefited from OPEX aid from ADEME.[8]

External biomass could also be used in the main sugar factory boilers. However, in most cases the local availability of external biomass is insufficient to meet the main boilers' very high energy needs. In addition, more investment is required to convert a main sugar factory boiler to biomass than a drying installation. Finally, the high transport intensity of biomass can make it prohibitively expensive to transport it over long distances to the factory gate. Transport by barge can reduce costs, but this is only possible when rivers or canal infrastructure allow it.

Solid and liquid biomass have never been used in lime kilns, as the high temperatures needed (>1100° C) cannot be reached using such fuels.

Table 4: Evaluating external biomass

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	Variable	-	Low/medium	Medium/high	Medium

6.3. Biomethane purchased on the gas grid

In theory, sugar manufacturers could decarbonise by purchasing biomethane from the local gas grid. This biomethane must be certified renewable with Guarantees of Origin (GOs), which would allow to reduce the purchase of emissions allowances under the EU Emissions Trading System.

The major disadvantage of this option is that in many areas the market does not currently offer sufficient volumes of biomethane. However, this is not the case in all Member States. The OPEX of using externally procured biomethane would depend on the price for the biomass converted to biomethane, the market price for natural gas, and the CO_2 emissions allowance cost.

In some Member States operators are facing regulatory uncertainty regarding the treatment of externally procured biomethane by future carbon taxes.

Some of the pulp and herbs from the beet washing stage are sent to methanisation units outside the sugar factories. These materials are in high demand because of their excellent methanogenic power, as they improve the performance of the units that include them in their feedstock.

Table 5: Evaluating biomethane purchased on the gas grid

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	Variable	-	Low	Medium/high	Medium

8. SNFS roadmap

6.4. Renewable and low-carbon hydrogen

Hydrogen could be used as an alternative to natural gas to generate heat within the sugar factory. In order to contribute to decarbonisation, the hydrogen must be renewable or at least low-carbon.

The use of hydrogen in generic industrial boilers would require a retrofit of the burner to accommodate the properties of hydrogen gas (e.g. velocity and flame heating properties).[9] In this way, hydrogen could be co-fired with natural gas. Hydrogen could also be used as a single source of fuel in oxyfuel burners, whereby pure oxygen rather than air is used as the oxidising agent. This could increase the combustion efficiency by 15% compared to conventional natural gas boilers (to reach 90%). The use of pure oxygen would also virtually eliminate NOx emissions.[10]

The availability and cost of low-carbon and renewable hydrogen remain limiting factors in the uptake of hydrogen as a renewable/low-carbon fuel. Currently over 95% of hydrogen is produced from natural gas without carbon capture and storage (CCS).[11] This is unlikely to change substantially in the near future. In addition, the production costs of renewable hydrogen are high due to the heavy electricity requirements and the cost of electrolysers. The market price of renewable hydrogen will be further inflated by high demand from sectors that have no alternative solution to decarbonise (e.g. fertilisers, chemicals, steel). Finally, getting the hydrogen to the factories is a further challenge: due to the high energy requirements of the sugar production process only a pipeline could deliver the volumes needed, which would require substantial investment.

Table 6: Evaluating renewable and low-carbon hydrogen

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	Low	-	Low	High	Medium/high

6.5. Energetic self-use of residues from biomass processing

The EU beet sugar sector generates effluents and residues with considerable energy potential that can contribute to decarbonisation:

- Residues such as beet pulp, tops, tails and leaves that today have non-energy uses but are essential for the decarbonisation of the sector.
- Process effluents (i.e. the biomass fraction of wastewater).

These solutions enable sugar sites to maintain part of their energy self-production, including electricity, which would limit their exposure to the extreme variability of energy prices and avoid overloading public electricity networks in rural areas where many sugar factories are located.

In order to be considered renewable, energy produced from such residues must meet specific sustainability criteria set out in the Renewable Energy Directive II (RED II) and, in future, the RED III.

Cane sugar producers already benefit from the energetic use of fibrous cane residues (bagasse). These producers are the main competitors of the EU beet sugar industry and benefit from grow-ing access to the EU sugar market due to concessions made in the EU's bilateral trade negotia-tions. Cane sugar producers' use of bagasse for energy means they are not impacted by increas-es in fossil energy costs. In order to compete effectively, EU beet sugar manufacturers need an equivalent solution.

As mentioned above, the allocation of pressed pulp to different markets (biogas/bioenergy, dried animal feed, pressed pulp), depends on the demand for pressed pulp, demand for dried pulp, cost of energy, factory equipment and capacity, and efficiency of equipment. To keep the share of beet pulp in the animal feed market at current levels, animal feed prices will need to rise substantially to offset the rise in energy costs.

9. E4tech et al. 2015. Scenarios for deployment of hydrogen in contributing to meeting carbon budgets and the 2050 target.
10. *Ibid.*
11. Robert Rapier. 2020. LIFE CYCLE EMISSIONS OF HYDROGEN. The Fourth Generation. Retrieved on 6 December 2022 from https://4thgeneration.energy/life-cycles-emissions-of-hydrogen/

6.5.1. Anaerobic digestion of the biomass fraction of wastewater

Anaerobic digesters connected to wastewater treatment plants generate biogas from the fermentation of the biomass fraction of process wastewater. Most sites with an on-site wastewater treatment plant have an anaerobic digester for the wastewater in operation today.

Biogas can be blended with natural gas in the CHP, the maximum ratio depending on boiler design, air flow, and natural gas flow . If upgraded into biomethane, there is no limit to the volume that can be used in a natural gas CHP.

Anaerobic digesters for wastewater can produce sufficient biogas to meet up to 5-10% of the energy needs of a beet sugar factory.

Biogas produced in this way is recognised as an advanced biofuel under Annex IX to the RED II and future RED III. But it must sill demonstrate GHG savings in order to be considered sustainable (and therefore renewable).

Table 7: Evaluating anaerobic digestion of the biomass fraction of wastewater

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
Medium	Medium	-	Medium	Low	Low

6.5.2. Methanisation of beet pulp and other residues

The methanisation of beet pulp and other residues has already been implemented in Europe both to provide energy for factory processes and to supply external users, particularly in the Netherlands, Germany, Poland and Hungary. Beet pulp alone has an energy potential comparable to that of cane bagasse: it can provide enough energy to meet the needs of an energy efficient sugar factory without annex production like distilleries or sugar conversion. The methanisation of beet pulp and other residues could therefore make a central contribution to the decarbonisation of the beet sugar industry in Europe.

Several aspects must be considered for the development of the methanisation of beet pulp and other residues:

- Investment costs and seasonality: the profitability of a biogas plant is linked to the duration of its operation. It is compromised if the latter is limited to the campaign (3-5 months), with the technical risks linked in particular to the start-up phases (several weeks) to achieve its optimum performance.
- Biological processes are sensitive to many factors, including weather, availability and quality of residues, which can make the volume of biogas produced very variable.
- Management of digestates leftover from the methanisation process: their production in winter, when their spreading is prohibited (regulation on fertiliser use), makes it necessary to store them with regulatory constraints to be assessed.
- Regulatory framework for the use of pulps: the uncertainty concerning the arbitration between the uses of pulps (i.e. animal feed or energy).

Spreading the production of biogas/biomethane over the whole year is possible but involves injecting the surplus into the public gas grid between campaigns and withdrawing gas from the grid during the campaign. The use of Guarantees of Origin (GOs) will be necessary to ensure that the surrender or purchase of emissions allowances is not required to cover the tailpipe emissions of the gas purchased.

In the case of a sugar factory-distillery whose combustion facilities operate all year round, the situation is simplified because the biogas generated can be entirely consumed without the need to inject it into the public network. However, the investment required for this remains high, in particular for the year-round storage of the pulp intended for the digester. This case also generates the same regulatory issues regarding the sustainability and management of digestates.

Table 8: Evaluating the methanisation of pulps and other residues

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	High	-	Medium/High	Low/Medium	Medium

6.5.3. Beet pulp combustion

Solid beet pulp can also be combusted directly in a biomass boiler after pressing. As for methanisation, the direct use of beet pulp in this way also involves very substantial investments. The most mature solution available would be the use of a biomass boiler in combination with a steam dryer or low temperature dryer (LTD) integrated into the energy scheme of the sugar process.

In comparison with methanisation, pulp combustion is more compatible with the seasonality of sugar production. In addition, transitory periods (start-ups and stops) are reduced and easier to manage with appropriate storage of dry pulp and flexible production make it possible to dispense with natural gas as a backup.

Aspects to be considered:

- Significant investment: the boilers must be changed for use with solid biomass. In addition, the steam dryer or low-temperature dryer requires changing the energy schema of the factory.
- Ash management (regulatory framework, outlets).
- Regulatory framework for the use of pulps: the uncertainty concerning the arbitration between the uses of pulps (i.e. animal feed or energy).

Table 9: Evaluating pulp combustion

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	High	-	Medium	Medium	Medium

6.5.4. Other energetic self-use of biomass residues

Methanisation of vinasses (if produced): Currently valued as fertiliser (potash), their methanisation is theoretically possible. However, there are still technological uncertainties; an anaerobic digestion project has been implemented on one site without success.

In addition to anaerobic digestion, hydrothermal gasification may be a solution for the future to recover energy from these fermentation residues while maintaining their agronomic potential. This solution is only applicable where a high capacity ethanol distillery is attached to the sugar factory. It is also unlikely to be available until 2030-40.

6.6. Renewable electricity and heat

6.6.1. Externally procured renewable electricity

Operators in the sugar industry may conclude contracts with external suppliers of renewable electricity.

A Power Purchase Agreement (PPA) is an agreement between an electricity generator and a user to provide a set volume of electricity for a pre-defined price over a period of time. PPAs with renewable electricity generators can effectively decarbonise indirect (scope 2) emissions resulting from the purchase of electricity from the grid.

Due to the low marginal cost of renewable electricity generation, multi-year PPAs can deliver savings to operators, in addition to long-term visibility regarding electricity costs.

Table 10: Evaluating externally procured renewable electricity

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	Variable	-	Low	Variable, depending on availability, national taxes, tariffs and levies	Low

6.6.2. Externally procured renewable heat

Operators in the sugar industry may also conclude contracts for the external supply of renewable heat. This could take the form of steam transmitted via pipeline from local renewable power generation facilities.

The availability of externally procured renewable heat is generally low, with the possible exception of the Nordic countries where there is a greater incidence of district heating systems running on biomass and geothermal energy.

Table 11: Evaluating externally procured renewable heat

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	Variable, but generally low	-	Low	Variable	Low

6.6.3. On-site renewables

The use of on-site (or near-site) renewables can supplement sugar factories' electricity supply. Many sugar manufacturers have already installed on-site solar panels and wind turbines. Given its intermittency, renewable electricity generated on-site cannot be used as the primary source of electricity for the factory during the campaign. Instead, it is more appropriate for processes that do not require a constant source of electricity. This includes methanisers and certain administrative buildings others?

Table 12: Evaluating on-site renewables

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
Medium	High	-	Medium	Low	Low

MANY SUGAR MANUFACTURERS HAVE ALREADY INSTALLED ON-SITE SOLAR PANELS AND WIND TURBINES

Cosun Beet Company

7. OTHER TOOLS TO REDUCE EMISSIONS IN THE EU BEET SUGAR SECTOR

Other tools are available to reduce emissions resulting from beet sugar production, including heat recovery, process electrification, lime kiln conversion, and carbon capture and storage.

Reducing specific energy consumption comes with its own challenges. As most sugar factories using steam turbines to cover the demand on electricity, a drastic reduction in heat demand would lead to a shortage of power generation. As a consequence the CHP has to be re-designed to generate a higher output of electricity by a lower fuel use (e.g. via installation of gas engines/turbines).

These tools are discussed in turn.

7.1. Energy management

Most sugar factories have already implemented an energy management system and a steady improvement in specific energy consumption can be achieved. Energy management system requirements are covered by the ISO 50001 Energy Management, which provides a framework of requirements for organisations to:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure the results
- Review how well the policy works
- Continually improve energy management.

7.2. Heat recovery

Recovery of low-grade heat can deliver energy savings. This can be done via an increase in the surface area of the heat exchangers (enlargement of existing exchangers, installation of additional evaporation effects) and associated measures such as additional cold spots. However, such operations require substantial investments and maximising efficiency requires increasingly heavy investments for increasingly weak progress as the thermodynamic limit is reached. The high energy integration of a sugar factory, with multiple points of heat recovery, means increasing the surface area of heat exchangers can potentially require a complex and expensive reconstruction of the production process.

Other solutions include heat recovery for pulp drying and less impactful solutions such as recovery of carbonatation vapours. These technologies all include a part of electrification and therefore the sector will need to make more use of the electricity network in the long term. efficient systems of recovery of fatal energy, cold point in diffusion, improvement of the performance of exchangers, etc.

Südzucker

7.2.1. Low temperature drying

Low temperature dryers allow for direct (pre)drying of beet pulp using waste heat. About 30 % of the energy used for pulp drying can be saved by using the vapours from the high-temperature dryer in a preliminary step, low-temperature drying (LTD).

High-temperature drying is energy-intensive (cf. section 5.2). But an LTD/HTD combination is a solution as it can be combined with all types of dryers if sufficient "waste heat" is available (cf. section 7.2.3).

Table 13: Evaluating low-temperature drying

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
Medium	-	High	Medium	Low	Low

7.2.2. Steam drying

Steam drying is using primary steam at pressures between 20 and 30 bar and re-uses the residual steam from the beet pulp for the juice evaporation. This increases energy recovery and delivers substantial primary energy savings over high-temperature drum drying (although power requirements are increased).

As the demand of electricity is increasing the CHP design must fit to install this technology.

Table 14: Evaluating steam drying

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	-	High	High	Low	Low

7.2.3. Solar drying of beet pulp

Using the heat of the sun instead of a dryer to dry sugar beet pulp is an effective way to reduce energy consumption. In Spain implementation of this solution mitigates c. 12,500-13,000 tonnes of CO_2 per annum depending on the production site.

This solution is naturally climate dependent and is currently unviable in Central and Northern Europe.

Table 15: Evaluating solar drying of beet pulp

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	-	High	Low	Low	Low

7.3. Process electrification

Electrifying part of the sugar production process would reduce heat demand in exchange for higher electricity demand. Electrification results in zero process emissions and zero indirect emissions when renewable electricity is used.

Several techniques are available, albeit at varying levels of technological readiness. These include mechanical vapour recompression (MVR), high temperature heat pumps (HTHP), and electric boilers.

So far those techniques are not established in the beet sugar production and would demand a complete re-design of the processes.

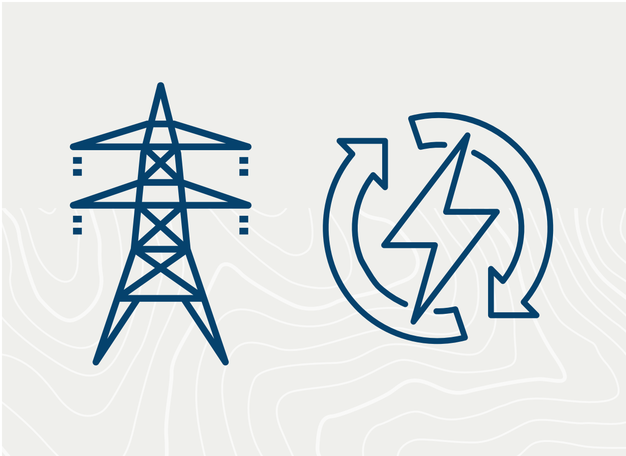
Partial electrification of sugar manufacturing by 2030 will require a review of how sugar factories are connected to the electricity network. In cases of greatly increased electricity demand, this will mean switching from the distribution grid to the transmission grid.

Complete electrification will not be possible by 2030 because:

- The necessary technologies are not mature (this goes for HTHP). Or economically viable (complete reconfiguration of factory heat schema required).
- Access to the transmission grid for sugar manufacturers remains limited. Bottlenecks in the development of the electricity grid mean long waiting times of up to 10 years. In addition, the seasonality of the sector means that investments by grid operators will take 3-4 times longer to amortise than if they were connecting a year-round user. This will lead to higher costs for both parties.
- Lack of visibility on electricity costs and their evolution. Electricity has long been more expensive than natural gas. The variability of sugar beet harvests makes it difficult to anticipate needs. In addition, transmission fees are higher for seasonal industries such as sugar.

In addition, investment aid funds to drive the uptake of MVR, e.g. Innovation Fund and creation of additional funds for the implementation of electrification.

ELECTRIFYING PART OF THE SUGAR PRODUCTION PROCESS WOULD REDUCE HEAT DEMAND IN EXCHANGE FOR HIGHER ELECTRICITY DEMAND



7.3.1. Mechanical Vapour Recompression (MVR)

MVR can deliver substantial reductions in process requirements, at the expense of increased electricity demand. MVR is an open heat pump system in which vapour is mechanically compressed using electric compressors and then reused as a heat source (when pressure increases, heat also increases). The compressed steam can be used again for evaporation, so that a saving of fresh process steam is achieved. For every for every megawatt of mechanical steam compressors installed in an evaporation and/or crystallisation station, multiple megawatts of thermal energy can used. This is known as the coefficient of performance (COP). To make this techniques economical viable the COP must overcome the price factor between gas and electricity prices at the location of the factory.

Installing a new MVR unit involves a substantial capital investment. But it can also deliver significant (up to 75%) OPEX savings when compared to Thermal Vapour Recompression (TVR), whereby heat is recovered via condensation. MVR can deliver a reduction of heat demand in the order of 5-10%.[12]

MVR is a mature technique (TRL 9) and already used in sugar factories or distilleries. It could electrify part of the process if the thermal diagrams and the local networks allow it. The sector widely uses TVR and it is uncertain that the gain provided by the MVR is sufficient to justify the investments.

Table 16: Evaluating Mechanical Vapour Recompression

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
Low/medium	-	High	Medium	Variable, depending on local electricity prices	Low

7.3.2. High-temperature heat pumps (HTHP)

Heat pumps take energy from the air, ground and water and turn it into heat or cool air using refrigerants. They run exclusively on electricity.

High-temperature heat pumps can have a high energy efficiency (COP of 3 or potentially more), which would reduce specific energy consumption and mitigate the operating expenditure associated with increased purchases of electricity from the grid (in comparison, for example, with electric boilers).

HTHP technology is not yet industrially mature. In addition, the installation of a high-temperature heat pump would require a substantial reconfiguration of the production process. These two factors mean that the installation of a HTHP requires a high capital expenditure (CAPEX).[13]

The Horizon Europe SPIRIT project is supporting the demonstration of a full-scale (0.7 – 4 MW) high-temperature (140°C -160°C) heat pump at Raffinerie Tirlemontoise's factory in Tienen, Belgium.[14] Prices of HTHP are expected to fall with market penetration and standardisation but the outlook remains uncertain.[15] However, more research is needed into the potential of high-temperature heat pumps. EU and Member State funding will be crucial to bring this forward. The SPIRIT project is expected to conclude by 2030.

The operating expenditure associated with a HTHP will depend heavily on the cost of electricity.

12. Cameron, Lopez and Jule. July 2021. Decarbonisation road map for the European food and drink manufacturing sector. Report commissioned by FoodDrinkEurope.
13. Defauw, De Jaeger, Martin and Pestiaux. October 2022. Opportunities to get EU industry off natural gas quickly Cost analysis of alternatives to natural gas in food, chemical and glass industries. CLIMACT.
14. European Heat Pumps Association. 16 September 2022. 'Game changing': SPIRIT project targets climate-friendly industrial heating. Retrieved on 29 November 2022 from https://www.ehpa.org/2022/09/16/ehpa_news/game-changing-spirit-project-targets-climate-friendly-industrial-heating/
15. Defauw, De Jaeger, Martin and Pestiaux. October 2022. Opportunities to get EU industry off natural gas quickly Cost analysis of alternatives to natural gas in food, chemical and glass industries. CLIMACT.

Table 17: Evaluating high-temperature heat pumps

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	-	Medium	High	Variable, depending on local electricity prices	Low

7.3.3. Electric boilers[16]

Electric boilers convert electricity into heat to produce steam. Several types of industrial boiler systems are available. The two most common are:

- Electric boiler, which uses a heating element that acts as a resistance
- Electrode boiler, which uses the properties of the water itself to carry electric current

Electrode boilers (3-70 MWe) have higher thermal capacities than electrode boilers (<5 MWe).[17] Electrode boilers can produce saturated steam with temperatures of up to 350C at 70 bar pressure.

Electric boilers have several advantages. They are almost 100% efficient and relatively robust. Importantly, their installation would not require a complete reconfiguration of factory processes, resulting in lower capital expenditure than e.g. industrial high-temperature heat pumps.[18]

Nevertheless, the grid infrastructure must be able to deliver the needed power without shortages or outages and the electricity purchase prices must be well below current levels for this option to be economically viable. Since the early 2000s electricity in most Member States has traded at around 2.5x the price of gas (wholesale), but in certain Member States such as Germany it has traded at a multiple of 6-8x.[19] According to the German sugar association, electricity prices of €50/MWh could make this option attractive to operators.[20] Whether such prices are realistic is up for debate: France's transmission system operator RTE projects electricity prices at €110/MWh in 2050.[21]

Table 18: Evaluating electric boilers

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	-	High	Low	Variable, depending on local electricity prices, but higher than heat pumps due to lower COP	Low

16. K. Rademaker, M. Marsidi. 2019. DECARBONISATION OPTIONS FOR THE DUTCH SUGAR INDUSTRY. PBL Netherlands Environmental Assessment Agency.
17. *Ibid.*
18. Berenschot, Energy Matters, CE Delft and Industrial Energy Experts. 2017. Electrification in the Dutch process industry. Commissioned by: Netherlands Enterprise Agency (RVO).
19. Schellen & Couplet. November 2022. Significant energy savings in the beet sugar industry to reach the decarbonization goals. Sugar Industry. DOI: 10.36961/si29263.
20. Geres, Mühlpointner & Weigert. 1 December 2020. Roadmap treibhausgasneutrale Zuckerindustrie in Deutschland Pfade zur Klimaneutralität 2050. Eine Studie für den Verein der Zuckerindustrie e.V. (VdZ). P. 9.
21. RTE. 16 February 2022. Futurs énergétiques 2050 : les scénarios de mix de production à l'étude permettant d'atteindre la neutralité carbone à l'horizon 2050. Retrieved on 28 March 2022 from https://www.rte-france.com/analyses-tendances-et-prospectives/bilan-previsionnel-2050-futurs-energetiques

7.4. Gas engines and turbines[22]

Gas engines and turbines are not a standalone measure but can be installed in a CHP system in parallel with process electrification to compensate for a fall in heat consumption and production and corresponding fall in electricity generation. This is because gas engines and turbines produce more electricity in relation to heat than conventional CHP gas boilers with steam turbines.

Gas engines can replace conventional gas boilers in the CHP. Or they can be installed alongside the existing boilers in hybrid format. Gas engines can run on natural gas, self-produced biogas or biomethane.

They can be installed in a modular manner, allowing for stepwise investments. In addition, the efficiency of gas engines is almost constant independent of load, meaning they are compatible with a progressive reduction in energy use. The main disadvantage of gas engines lies in their lower availability rate compared to other types of cogeneration.

Gas engines and gas turbines differ in that the latter are less flexible and modular than gas engines (higher CAPEX). In addition, gas turbines cannot run on self-produced biogas (it must first be upgraded to biomethane).

Table 19: Evaluating gas engines and turbines

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
Low/medium (when installed in combination with process electrification)	-	High	Medium	Medium	Low

7.5. Lime kiln conversion

Lime kilns are usually operated with hard coal coke or anthracite. However, individual plants have converted the furnaces so that they can be operated with natural gas, including one in Germany.

Although the use of natural gas (or biomethane) requires around 20% more fuel (2.2-2.7 GJ of gas per tonne of limestone), a reduction in emissions of 25-30% can still be delivered.[23] If renewable biogas were used, the lime kiln would be carbon-neutral.

Gas fired lime kilns use smaller limestones (45-60mm), which are typically cheaper than those used in coke-fired kilns.[24] In addition, users of gas fired lime kilns report lower wear of the kiln refractory, which would extend the lifetime of the asset.[25] Although gas firing produces a lower CO_2 concentration in the kiln gas, the amount remains sufficient for juice purification.

Table 20: Evaluating lime kiln conversion

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
Medium	-	High	Medium	Variable, depending on natural gas prices	Low

22. Schellen & Couplet. November 2022. Significant energy savings in the beet sugar industry to reach the decarbonization goals. Sugar Industry. DOI: 10.36961/si29263.
23. Arndt. 2019. Lime kiln conversion from coke to natural gas operation – an option in direction of sustainable energy. Sugar Industry. DOI: 10.36961/si24555.
24. *Ibid.*
25. *Ibid.*

An alternative to lime kiln conversion would be the direct procurement of quicklime and CO_2 from external suppliers. This would require zero CAPEX. OPEX would become dependent on the respective market prices of quicklime and CO_2. In this case sufficient supply of CO_2 for the carbonation step is a challenge. However, CO_2 from internal sources (e.g. boiler, digester) could be an alternative/ supplementary source.

Table 21: Evaluating external procurement of quicklime and CO_2

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
Medium	-	High	Low	Variable, depending on prices of quicklime and CO_2	Low

A final alternative could be to do away with the use of quicklime in the purification process altogether. Lime-free technologies such as membrane filtration and chromatographic separation have been discussed in this regard,[26] but they remain untested at industrial scale.

Table 22: Evaluating lime-free technologies

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
Medium	-	Low/ medium	High	Low	Low

7.6. Carbon capture and storage

Carbon capture and storage (CCS) or carbon capture and use (CCU) is attracting attention as a solution for highly-emitting industries. The use of CCS/CCU could be combined with the use of renewable self-produced energy from beet residues (bioenergy + CCS/U). In this way the sugar production process could in theory be carbon negative.

The implementation of CCS/U depends strongly on a positive cost/benefit analysis: do the ETS emissions allowances saved by reducing CO_2 emissions (and in the case of CCU: the value of the CO_2 captured) justify the upfront investment and operating expenditure of the system?

CCS/U may not be economically attractive for sugar factories due to the relatively low annual emissions, which are in part due to the seasonality of sugar production (cf. section 2.1).[27] Sugar factories that have bioethanol distillery attached could be better candidates for CCS/U, since these operate year-round. The long payback time for seasonal production facilities could be mitigated

26. De Bruijn. 2021. The beet sugar factory of the future. Sugar Industry 146(7). DOI: 10.36961/si27255.

27. Rademaker and Marsidi. 2019. DECARBONISATION OPTIONS FOR THE DUTCH SUGAR INDUSTRY. PBL Netherlands Environmental Assessment Agency.

by compensation for carbon captured during the combustion of sustainable solid or gaseous biomass fuels, e.g. under the legislation on the certification of carbon removals that is currently under discussion.

The use of CO_2 from biodigesters is already under consideration, e.g. by Cosun Beet Company.[28] This option becomes more attractive given the ongoing CO_2 shortage in the EU, which has pushed up prices.

Table 23: Evaluating carbon Capture and storage (CCS)

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
High	-	Medium	High	High	Medium

7.7. Beet transport

Going beyond the factory, beet transport is another area where emissions can be reduced.

Two relatively simple fixes are already readily available:

- The first is to use biogenic fuels such as renewable biodiesel, bioethanol or biomethane in the trucks delivering the sugar beets to the factory. ED95 delivers emission reductions of >50% in comparison to diesel.[29] According to the Renewable Energy Directive (RED III), bioethanol and biogas for transport must deliver emissions reductions of 65% vs fossil transport fuel.[30] Many sugar manufacturers already provide biogenic fuels to drivers in order to reduce the emissions of this stage.
- Another way to reduce beet transport emissions is to transport more beets in every consignment. Increasing the maximum weight limits of trucks from 40 to 48t reduces fuel use by 5-10% on average, and with it transport emissions by the same percentage. In most Member States it is still not permitted to transport more than 40t of beet per consignment.[31] It is important to note that vehicle upgrades are required to make it safe and feasible to transport 48t of beet in a single load.

Table 24: Evaluating beet transport solutions

Emissions reduction potential	Availability	TRL	CAPEX	OPEX	Regulatory hurdles
Low	-	High	Low	Low	Medium

28. *Ibid.*
29. SNPAA. Undated. L'ED 95. Retrieved on 2 February 2023 from https://www.alcool-bioethanol.net/led-95/
30. DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. 11 December 2018. L 328/82. Art. 29(10)(c).
31. OECD. 2019. PERMISSIBLE MAXIMUM WEIGHTS OF LORRIES IN EUROPE (in tonnes). Retrieved on 26 May 2023 from https://www.itf-oecd.org/sites/default/files/docs/weights-2019.pdf

8. FRAMEWORK CONDITIONS

8.1. EU policies

With the European Green Deal a number of EU policies are set to impact the decarbonisation pathways available to EU sugar industry operators.

Three are discussed here: the revised Renewable Energy Directive, the Energy Taxation Directive, and the Certification of Carbon Removals Regulation.

8.1.1. Renewable Energy Directive

The Renewable Energy Directive (RED) sets minimum criteria for biomass fuels for heating to be considered “sustainable”. The RED sustainability criteria have implications for the free allocation of EU emissions allowances under the Emissions Trading System (ETS), since in the future only the use of sustainable biomass (i.e. biomass that complies with the sustainability criteria) will be considered renewable. The renewable status of sustainable biomass means it is considered to be zero emission, meaning no emissions allowances need to be surrendered/purchased to cover its use.

The third Renewable Energy Directive (RED III) will strengthen the existing RED sustainability criteria, by moving forward the time by which new installations must comply with the highest (-80%) GHG emissions savings threshold and applying this threshold to existing installations after a defined grace period. Under these conditions it will become more difficult to use beet pulp for energetic use within the confines of the sugar factory.

When implementing the RED III, Member States should recognise the status of beet pulp as a residue when used for energy. This is essential to ensure that energy produced from beet pulp is able to meet the stricter sustainability criteria under the RED III.

8.1.2. Energy Taxation Directive

The Energy Taxation Directive (ETD) sets minimum tax rates for various energy carriers. Currently, it does not cover biomass fuels.

In July 2021 the European Commission proposed to revise the existing ETD to incentivise the use of electricity over fossil fuels. The proposal was also extended to biomass fuels, such as sustainable biogas.

Unfortunately, the Commission proposes to set the minimum tax rates for such fuels at the same rate as natural gas from 2033. This would provide no incentive to develop the production and use of sustainable biogas and solid biomass. Instead, it would result in an increased financial burden for sugar manufacturers.

8.1.3. Certification of carbon removals

The European Commission has proposed a new Regulation on the Certification of Carbon Removals. It aims to set harmonised rules for the awarding and recognition of such certificates to operators that remove carbon from the atmosphere and store it over the long-term. Such legislation could support the development of: (i) solid/gaseous biomass fuel use plus carbon capture and storage (BECCS); and (ii) solid/gaseous biomass fuel use plus carbon capture and long-term use (BECCU).

8.2. Electricity prices

Electricity prices have a significant influence on the feasibility of decarbonisation measures associated with an increase in electricity consumption, such as process electrification.

Electricity prices can be brought down by reducing the costs of the highest cost marginal electricity producers, currently power-only electricity generators running on natural gas. This can be done by reducing demand for gas across the economy, for example by accelerating the electrification of domestic heating and cooling and developing additional renewable energy capacity.

Reducing taxes, tariffs and levies (e.g. grid usage fees, renewable energy surcharges) is another straightforward way to bring electricity prices down, although this could result in reduced funding for transmission system operators and Governments to support renewable energy build-out.

A common price of power for European industry deserves serious consideration. This could be set at a level that guarantees the competitiveness of European operators while levelling the playing field on the EU internal market.

8.3. Direct financial support

Direct financial support will be essential to support the decarbonisation of sugar manufacturing in the EU.

8.3.1. Grants

The ETS Modernisation Fund is a source of support for the newer Central & Eastern European Member States.

The Temporary Crisis Framework allows Member States to support investments that do one or both of the following:) reduce greenhouse gas emissions by at least 40%; reduce by energy consumption by at least 20%. The aid can be granted in the form of direct grants, repayable advances, loans, guarantees or tax advantages and the aid intensity must not exceed 40% of the eligible costs.

8.3.2. Carbon Contracts for Difference (CCfDs)

Carbon Contracts for Difference would support investments in decarbonisation by bridging the gap between the current carbon price and the carbon price required for the investment to pay off. In its decarbonisation roadmap for the German sugar sector, FutureCamp considers that a carbon price of €160/EUA represents the tipping point for investments in biogas production.[32]

WITH THE EUROPEAN GREEN DEAL A NUMBER OF EU POLICIES ARE SET TO IMPACT THE DECARBONISATION PATHWAYS AVAILABLE TO EU SUGAR INDUSTRY OPERATORS

32. *Geres, Mühlpointner & Weigert. 1 December 2020. Roadmap treibhausgasneutrale Zuckerindustrie in Deutschland Pfade zur Klimaneutralität 2050. Eine Studie für den Verein der Zuckerindustrie e.V. (VdZ).*

9. MEMBER EXAMPLES

EU beet sugar manufacturers are investing heavily in technologies to reduce greenhouse gas emissions.

Below is a selection.

Methanisation of beet residues at Kaposvár[33]

The Agrana subsidiary Magyar Cukor Zrt. operates Hungary's largest biogas plant at its sugar factory at Kaposvár. The plant is able to provide 83% of the primary energy needs of the sugar factory from the methanisation of beet residues during the sugar beet campaign. A connection with the natural gas grid ensures that biomethane can be injected to and withdrawn from the grid as needed.

Acor biomass cogeneration plant[34]

Spanish sugar cooperative Acor has signed a contract with the energy company ENSO to build a €70m biomass cogeneration facility at its factory in Olmedo. The facility will produce renewable steam and electricity using locally-sourced agricultural and forest biomass.

The project will generate 346,000 t of steam and over 45,000 MWh of electricity annually, using around 90,000 t of biomass per year. It will prevent the emission of more than 60,000 t of CO_2 into the atmosphere and reduce factory greenhouse gas emissions by 80%. Construction will start in the first half of 2023.

The Junta de Castilla y León is supporting the investment via the public company SOMACYL.

Reducing pulp drying emissions at Cristal Union[35]

In Bazancourt Cristal Union has invested €4m to replace the energy supply of its pulp dryers with woody biomass and create a storage platform ensuring a continuous supply of the fuel. The initiative saves 65,000 tonnes of CO_2 per year. It was undertaken with the help €1.5 million provided by the French Recovery & Resilience Plan.

In Sainte-Emilie, a substantial investment of €25 million, including €6.9 million in State aid, is dedicated to a new unit for indirect drying of beet pulp that will be operational in September 2023. This will make it possible to use the residual heat of the plant and will lead to the cessation of the use of coal. A 90% reduction in CO_2 emissions from drying is expected, as well as a reduction in dust and sulfur emissions.

Green gas at Cosun Beet Company[36]

Cosun Beet Company ferments beet residues such as beet pulp, beet tips, foliage and molasses in anaerobic digesters to produce biogas. 25 million cubic metres of green gas are injected into the national gas transmission network annually, enough for 20,000 households a year. Of the 25 million cubic metres, about 8 million are used instead of natural gas in Cosun Beet Company's own factories. This cuts their natural gas consumption by about 10% a year. Cosun Beet Company is one of the biggest producers of green gas in the Netherlands.

Ortöfta steam pipeline[37]

In 2022 Nordic Sugar opened an airborne steam pipeline to transport unused steam from Kraftringen's fossil-free Combined Heat & Power plant in Örtofta to Nordic Sugar's factory in the same city.

The pipeline involved an investment of around SEK 80 million (€7.8m). The fossil-free steam covers around 25% of Nordic Sugar's total energy needs at the Örtofta factory, which corresponds to the annual heating needs of around 4,000 houses.

Reducing gas consumption at Tereos[38]

In March 2021 Tereos and SUEZ announced a partnership project to reduce gas consumption at the Origny-Sainte-Benoite sugar plant in France. This project is based on SUEZ supplying renewable energy and energy recovered as steam, which is produced from solid recovered fuels (SRF). This boiler will cover almost 40% of the plant's energy needs.

Tienen extraction tower[39]

At Raffinerie Tirlemontoise's factory in Tienen a high-capacity extraction tower will replace two diffusers. The extraction tower is expected to reduce annual CO_2 emissions by 5,744 t (in addition to water consumption by 150,000 m^3). The project was supported by a €1m subsidy from the Flemish Government. The extraction tower should start operations in the 2023/24 production campaign.

Energy savings at Agrana Czechia[40]

Agrana invested CZK 10.8m in a new centrifuge station at its Hrušovany nad Jevišovkou factory to improve investments in energy efficiency. Two intermediate product continuous centrifuges were subsequently installed at Agrana's sister factory at Opava (CZ) in advance of the 2021/22 campaign. The total costs of the centrifuge station investments was CZK 21.3m (€800,000 in 2020 prices).

Both projects were co-financed by the EU Regional Development Fund at a rate of 30%.

Iscal wind turbine

Iscal is investing €11m for the installation of a wind turbine and its integration into the electrical production network of the company's Fontenoy factory. The 3.7MWh wind turbine is expected to enter into operation in 2024.

Renewable electricity at Krajowa Grupa Spożywcza S.A. (KGS)

Since 2022 the electricity used by Poland's KGS to produce sugar is purchased from 100% renewable sources backed by guarantees of origin.

Azucarera: solar drying of beet pulp[41]

Spanish beet sugar manufacturer Azucarera has implemented sun-drying of sugar beet at all production plants in Azucarera, with the exception of Miranda de Ebro in northern Spain where weather conditions are not suitable. Previously pulp was dried using gas-fuelled dryers.

Sun-drying allows a considerable reduction of CO_2 emissions. The mitigated CO_2 is estimated at around 12,500-13,000 tonnes a year depending on the factory location. Energy costs are also minimised, as fossil fuels are replaced with energy from the sun. Investment costs are low to non-existent. Some additional labour is required to spread the pulp for drying.

Saint Louis Sucre beet transport by rail[42]

French sugar manufacturer Saint Louis Sucre transports beets by rail to reduce emissions and transport costs. The geographical location of the Saint Louis Sucre sugar factories, in the centre of one of the most fertile areas of Europe, also guarantees a controlled transport distance for sugar beets.

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CEFS

Comité Européen
des Fabricants de Sucre

Avenue de Tervuren 268,
B-1150, Brussels, Belgium

cefs@cefs.org
Tel: +32 2 762 0760
Fax: +32 2 771 0026

www.cefs.org
www.sugardialogue.eu

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