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Valorisation of plastic waste: Waste-to-Chemicals processes vs. co-combustion in cement kilns

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ABSTRACT: This work compares two options for the valorisation of non-recyclable plastic waste: gasification-based Waste-to-Chemicals (WtC) processes geared toward the production of hydrogen or methanol vs. co-combustion in the cement industry. In both cases the use of waste as fuel displaces the consumption of fossil sources that would be used to produce chemicals (hydrogen / methanol) or cement. The comparison adopts an LCA inspired approach and focuses on energy consumption and CO_2 emissions. The performances of two WtC technologies close to commercial readiness have been estimated based on available data and detailed process simulation, whereas data on cement production have been provided by the Italian association of cement producers. Results demonstrate that the use of waste in the considered WtC processes is less effective in terms of energy savings and CO_2 emissions than the use of waste for cement production. When waste is used as feedstock for hydrogen production through the Ebara-UBE gasification technology, about 14% more energy is needed and about 33% more fossil CO_2 is emitted with respect to waste co-combustion in cement kilns. When waste is used to produce methanol through the ENERKEM gasification technology, about 5% more energy is needed and 30% more fossil CO_2 is emitted with respect to waste co-combustion in cement kilns.

Keywords: plastic wastes, Waste-to-Chemicals, SRF, gasification, cement industry

1. INTRODUCTION

Plastic waste that cannot be mechanically recycled is partly disposed into landfills, partly sent to energy recovery in Municipal Solid Waste (MSW) incinerators and partly used to produce good quality SRF (Solid Recovered Fuel, in accordance with the EN ISO 21640 norm) to replace fossil fuels in cement kilns. Recently, the concept of “chemical recycling” or “Waste-to-Chemical” is gaining more and more interest because of its alleged potential of strengthening the materials cycle, i.e. using plastic waste as feedstock for the production of new plastic polymers. Currently, several new technologies based on waste pyrolysis are under development to reach such a target ((Brightmark, 2022), (Quantafuel, 2022), (Plastic Energy, 2022), (LyondellBasell, 2020), (Eni-Versalis, 2020)) with pilot and demonstration plants being built around the world. The latest developments focused on pyrolysis follows earlier efforts centered around gasification and the production of simple chemicals like hydrogen (JGC Group, 2020) or methanol / ethanol (Waldheim, 2018). For these less recent gasification-based technologies, some medium-large size plants have effectively been built with the goal of reaching industrial or semi-industrial operations.

However, no evidence of such an achievement has never been provided and several data for such technologies remain unconfirmed, as well as over-optimistic.

An industrial sector that nowadays adopts SRF enriched with non-recyclable plastic to substitute conventional fossil fuels is cement production. Following high temperature, high residence time of gases and oxidative conditions in the kiln, the combustion of waste in cement plants allows the destruction of organic compounds, with typically lower dioxins, furans and volatile organic compounds emissions than other methods of waste combustion (Cement Sustainability Initiative (CSI), 2014).

This work provides a quantitative, comparative evaluation between the following two routes for the use of SRF enriched with non-recyclable plastics[1].

A) Co-combustion of SRF for cement production.
B) Gasification of SRF in processes geared towards the production of either hydrogen or methanol.

In order to compare the two routes on equal terms, in addition to the fate of SRF one must consider also how hydrogen or methanol are produced. To this end, we consider the following two “Cases”.

A) “Case A (Conventional)”, which represents the technological route followed today: co-combustion of SRF in cement plants and production of hydrogen/methanol from natural gas.
B) “Case B (WtC)”, which is meant to represent the Waste-to-Chemical route which may be followed sometime in the future: cement plants fed solely with fossil fuels and SRF fed to gasification processes for the production of hydrogen/methanol.

Depending on the chemical considered (hydrogen or methanol) each Case breaks down into two “sub-cases”: one for the production of hydrogen, the other for the production of methanol. The comparison between sub-cases that produce the same chemical originates the following two scenarios.

1) Hydrogen Production Scenario (HPS), where we compare:
   A) production of cement with co-combustion of SRF + production of hydrogen from natural gas
   with
   B) production of cement with combustion of fossil fuels only + production of hydrogen from SRF via an EBARA-UBE gasifier.
2) Methanol Production Scenario (MPS), where we compare:
   A) production of cement with co-combustion of SRF + production of methanol from natural gas
   with
   B) production of cement with combustion of fossil fuels only + production of methanol from SRF via an ENERKEM gasifier.

For each scenario, mass/energy balances of Case A and B are set to generate the same outputs, i.e. same amount of cement and same amount of hydrogen/methanol. The corresponding energy inputs and fossil CO_2 emissions, evaluated by modelling the whole production process, provide a basis for establishing which route is preferable from an energy and environmental standpoint.

The plants based on SRF gasification (followed by hydrogen production or methanol synthesis) are simulated and evaluated with Aspen Plus® version 11. Data for modelling the Ebara-UBE and Enerkem gasification technologies are obtained from information publicly available.

2. METHODOLOGY

2.1 Situations to be compared

The alternative uses of SRF described above have been assessed by a methodology based on Life Cycle Assessment (LCA) principles. For each scenario, Case A and Case B are modelled and quantitively

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[1] For the sake of concision, in the following the term SRF signifies “SRF enriched with non-recyclable plastics” (unless denoted otherwise).

evaluated to generate the same useful outcomes: one ton of clinker and a certain amount of hydrogen or methanol, which is set to the same value for Case A and B. For such equal-outcome situations, the energy consumption and the fossil CO_2 emissions of Case A and B are used as indicators of their energy and environmental virtuousness. To warrant a coherent comparison, for each scenario we also assume that the same amount of SRF is fed to the cement plant (Case A) and to the Waste-to-Chemical plant (Case B).

In Case A (the conventional route) we further assume that SRF is co-combusted with pet coke, providing 50% of the total thermal input to the cement plant, while the chemical product is produced from natural gas: steam reforming followed by shift and Pressure Swing Absorption (PSA) for hydrogen; steam reforming followed by shift and catalytic synthesis for methanol.

In Case B (the WtC route) we assume that the cement plant is fed solely with pet coke, while the gasifier serving the production of hydrogen or methanol is fed solely with SRF (in the same amount considered in Case A). The cement plant fed with 100% pet coke is assumed to be the "reference" cement plant described in the following paragraph.

2.2 Reference cement plant

The reference cement plant representing the current Best Available Technique (BAT) for situations with 100% fossil fuel feed has been defined through a review of the technical literature and iterative consultations with AITEC (*Associazione Italiana Tecnico Economica del Cemento*), which led to the features summarized in Table 1.The production of 32.7 kg/s of clinker corresponds to about 900.000 tons/yr, while the specific energy consumption of 3.245 GJ_{LHV} per ton of clinker and CO_2 emissions of 0.822 $kgCO_2$/kgClinker are representative of state-of-the-art Italian plants.

Table 1. Main mass flows and specific indicators of the reference cement plant.

	Reference cement plant		
Pet coke LHV		34.17	MJ/kg
Clinker production		32.7	kg/s
Flue gas flow rate		62.2	kg/s
Fuel flow rate		3.1	kg/s
	Specific indicators		
Specific fuel consumption		0.095	kgFuel/kgClinker
Specific CO_2 emissions		0.822	$kgCO_2$/kgClinker
	Pet coke	0.297	$kgCO_2$/kgClinker
	Calcination	0.525	$kgCO_2$/kgClinker
Specific thermal duty		3.245	GJ_{LHV}/tClinker

2.3 Reference Solid Recovered Fuel (SRF)

The SRF considered in the study is representative of co-combustion feeds adopted in Italian cement plants. Based on biomass, non-biomass, ash and moisture content, as well as LHV, we've inferred the elemental composition in Table 2 according to accepted correlations (FDBR, 2013) and the experience developed in tests and studies carried out by LEAP. Assuming a mass carbon content of 56.65% for the dry biomass portion (Fellner et al., 2007), the SRF carbon content can be split between a biogenic and fossil fraction; likewise for the corresponding CO_2 emissions, which turn out to be about 39% biogenic, the remaining 61% fossil.

Table 2. SRF composition on D.A.F. (Dry Ash Free), dry and A.R. (As Received) basis.

	D.A.F.	**DRY**	**A.R.**
LHV [MJ/kg]	29.61	26.21	23.53
C content, % by mass	64.03%	57.56%	52.17%
H content, % by mass	8.94%	8.04%	7.28%
N content, % by mass	2.33%	2.10%	1.90%
O content, % by mass	23.00%	20.67%	18.73%
S content, % by mass	0.40%	0.36%	0.33%
Cl content, % by mass	1.30%	1.17%	1.06%
Ash content, % by mass	-	10.10%	9.15%
Moisture content, % by mass	-	-	9.38%

2.4 Conventional route (Cases A): SRF co-combustion in cement plant

For the co-combustion of SRF and pet coke considered in Cases A, where each feed provides 50% of total thermal input, we’ve assumed that the cement plant is operated so to maintain the same flue gas flow rate of the reference cement plant adopted for Cases B. Under such conditions, which correspond to common practice, the specific thermal duty of the cement plant increases due to either the lower LHV of SFR (with respect to pet coke) and off-design operation. The increase is evaluated by a correlation between specific thermal duty and SRF thermal substitution rate (which in our case is 50%). The correlation follows from numerical models developed by AITEC members for actual cements plants. Specific CO_2 emissions from raw meal calcination are assumed equal to those of the reference cement plant. Table 3 compares the most significant indicators of the reference cement plant with those of the plant with SRF co-combustion providing 50% of thermal input. SRF co-combustion increases total specific CO_2 emissions, mainly due to higher specific thermal duty. However, part of such emissions is biogenic, so that specific fossil CO_2 emissions actually decrease.

2.5 Conventional route (Cases A): production of hydrogen and methanol

Performances and CO_2 emissions of conventional plants for the production of hydrogen and methanol via steam reforming of natural gas have been taken from the technical literature. Table 4 reports the distinctive features and the parameters adopted to estimate overall energy consumption and CO_2 emissions.

Table 3. Performance indicators of the reference cement plant fed solely with pet coke vs. the corresponding indicators of the cement plant with SRF co-combustion providing 50% of thermal input.

		Reference cement plant	**SRF co-combustion**	
Fuel MIX LHV		34.17	27.87	MJ/kg
Flue gas flow rate		62.2	62.2	kg/s
		Specific indicators		
Specific fuel consumption		0.095	0.125	kgFuel/kgClinker
	SRF	-	0.074	kgSRF/kgClinker
	Pet coke	0.095	0.051	kgPetcoke/kgClinker
Specific CO_2 emissions		0.822	0.826	$kgCO_2/kgClinker$
	SRF	-	0.142	$kgCO_2/kgClinker$
	Pet coke	0.297	0.160	$kgCO_2/kgClinker$
	Calcination	0.525	0.525	$kgCO_2/kgClinker$
Specific fossil CO_2 emissions		0.822	0.771	$kgCO_2/kgClinker$
Specific thermal duty		3.245	3.482	$GJ_{LHV}/tClinker$
	SRF	-	1.741	$GJ_{LHV}/tClinker$
	Pet coke	3.245	1.741	$GJ_{LHV}/tClinker$

Table 4. Main parameters used to estimate energy consumption and CO_2 emissions for the production of hydrogen and methanol from natural gas steam reforming.

Energy efficiency of steam reforming for H_2 production	0.750	GJ H_2/GJ Natural Gas	(Consonni & Viganò, 2005)
Specific fossil CO_2 emissions of steam reforming for H_2 production	8.90	kg CO_2/kg H_2	(Sun et al., 2019)
Net specific electric consumption of steam reforming for H_2 production	0.000	MWhel/t H_2	(Consonni & Viganò, 2005)
Energy efficiency of steam reforming for MeOH production	0.660	GJ MeOH/GJ Natural Gas	(Collodi et al., 2017)
Specific fossil CO_2 emissions of steam reforming for MeOH production	0.327	kg CO_2/kg MeOH	-
Net specific electric consumption of steam reforming for MeOH production	0.087	MWhel/t MeOH	-

2.6 WtC route (Cases B)

Data required for modelling and predicting the performances of the WtC routes are taken from publicly available information on the Ebara-UBE and ENERKEM gasification technologies, as well as from technical literature. Where data could not be found, process details have been defined based on the authors' experience on energy conversion and chemical synthesis plants, as well as the history of tests and studies carried out by LEAP. Once the plant configuration and basic specifications have been defined, an Aspen Plus version 11 model has been built to calculate mass / energy balances and the relevant performance indicators needed for the comparative analysis: specific electric consumption, energy efficiency, CO_2 emissions, etc.

2.6.1 Production of hydrogen

We've assumed that hydrogen production is based on the Ebara-UBE technology, which comprises a two-stage oxygen-blown gasification process with pressurized reactors at 10 bar, 800°C (first stage) and about 1350°C (second stage). SRF is introduced into the first reactor via a lock-hopper. Oxygen and saturated steam at 25 bar are used as gasification agents. The second gasification stage incorporates a water quench to remove the slag and cool the syngas to a temperature compatible with the Direct Contact Cooler (DCC) placed downstream, which further floods the syngas with water to completely remove acid gases, first of all hydrochloric acid. The cooled gas exiting the DCC at about 45°C is then compressed to about 20 bar, saturated with steam at 25 bar and sent to a two-stage Water Gas Shift (WGS), with the first stage at 350°C and the second at 200°C (Chein & Yu, 2017); such WGS significantly increases the hydrogen yield of the process. A heat exchanger network in the (exothermic) WGS section and heat extraction from the gasifier allow generating the saturated steam needed by process. Shifted gas is cooled to 35°C and sent to Pressure Swing Adsorption (PSA) to generate high purity hydrogen, which is compressed to 60 bar for final delivery. Based on earlier work (Consonni & Viganò, 2005), it is assumed that 88% of the hydrogen in the gas entering the PSA can be recovered.

2.6.2 Production of methanol

Methanol production is assumed to be based on the ENERKEM technology, which also comprises a two-stage, oxygen-blown gasifier. Operating pressure in this case is 5 bar, with the first stage at about 700°C, the second at about 1200°C. Also in this case SRF is introduced into the first reactor via a lock-hopper, oxygen and saturated steam at 25 bar are used as gasification agents and the second stage incorporates a water quench system to remove entrained ashes and cool the syngas. Quenched syngas at about 150°C is further cooled to about 45°C in a water DCC, compressed to 20 bar, mixed with 25 bar steam and sent to a single-stage WGS reactor at 350°C. CO conversion is controlled in the WGS reactor to obtain a molar module most appropriate to methanol synthesis. The molar module is defined as:

$$Module = \frac{mol_{H_2} - mol_{CO_2}}{mol_{CO} + mol_{CO_2}}$$

and the range of values most desirable for methanol synthesis is between 2 and 2.2, mol_{H2}, mol_{CO} and mol_{CO2} are mols of hydrogen, carbon monoxide and carbon dioxide in the unit mass/volume of syngas, respectively. Shifted gas is compressed to about 38 bar and cooled to make it ready for Acid Gas Removal (AGR), which removes carbon dioxide (thereby achieving the required syngas module) and sulphur compounds (H_2S and COS) by chemical absorption. The AGR process considered here is Rectisol®, with removal efficiencies taken from (Gatti et al., 2014). The syngas exiting the Rectisol® system is further compressed to 60 bar, the operative pressure of the methanol synthesis reactor, and heated to 270°C through a heat exchanger network fed by the WGS section. Such gas at 60 bar and 270°C is mixed with the recycle coming from the first stage of the flash process placed downstream of the methanol synthesis reactor, thereby reaching the proper inlet temperature of the methanol synthesis reactor of 210°C. The methanol reactor is a water-cooled packed bed multi-tubular reactor with catalyst packed in the tubes operating at 60 bar, about 250°C. At the reactor exit, the product is cooled and depressurized in a two-stage flash (Ghosh et al., 2019), ensuring the separation of the gas from the liquid phase. The liquid stream comprising methanol and water and is fed to a single stage distillation column to produce high-purity methanol. Part of the purge gas generated in the two flash stages is recycled (see above), the remaining fraction sent to a burner together with the gaseous stream coming from the distillation column. The use of a burner allows generating part of the saturated steam needed by the gasifier, the WGS and the AGR system (solvent regeneration). The remaining part of the needed steam is generated by recovering heat from the WGS section.

2.6.3 Assumptions and models adopted for Aspen Plus simulations

Physical properties of process flows have been evaluated by the Peng–Robinson equation with Boston–Mathias (PR-MB) modifications. Properties of SRF and ash (enthalpy, thermal capacity and density) have been evaluated by the HCOALGEN and DCOALGEN models implemented in Aspen Plus. Ashes are considered as inert. Other assumptions adopted for the simulation of the various blocks of the WtC processes are reported in Table .

Table 5. Main models used in Aspen Plus.

Section	Aspen model	Brief description
Gasification	RYield+RGibbs	RYield for the SRF conversion into conventional components Equilibrium RGibbs model for the simulation of the gasifiers
Water quench + DCC	Cooler+Flash+Sep	Syngas cooled down to 45°C, flashed and all HCl removed
WGS reactors	RGibbs	Only possible products of the reaction: H_2, CO, CO_2, H_2O
PSA system	Sep	H_2 separation from the syngas with 88% of efficiency
AGR system	Sep	Removal efficiency of 98% of CO_2 and of 99.99% of COS and H_2S
MeOH reactor	RPlug	Quasi-isothermal steam-raising fixed bed reactor operating at 250°C and 60 bar
Distillation column	Radfrac	42 stages. Feed introduced at stage 27
Boiler	RStoich	Boiler to produce a part of steam for the whole process from the purge gases of the distillation column and of the flash stages

2.7 Building the cases to be compared

As already mentioned, the goal of the analysis developed here is comparing the following two situations.

Case A, which represents the conventional route where pet coke and SRF are used for the production of clinker, while natural gas is used for the production of chemicals.

Case B, which represents the alternative route where SRF is used to produce chemicals and the production of clinker relies only on pet coke.

The four steps described below clarify how we build the cases to be compared. The procedure is the same for the Hydrogen Production Scenario (HPS) and the Methanol Production Scenario (MPS).

STEP 1. In order to represent cement production for Case A, consider a cement plant producing 1 ton of clinker with co-combustion of SRF and pet coke, each providing 50% of thermal input. Under these conditions (Tab. 3) total thermal duty is 3.482 GJ_{LHV}, where 1.741 GJ_{LHV} are provided by 0.051 tons of pet coke and 1.741 GJ_{LHV} are provided by 0.074 tons of SRF.

STEP 2. In order to represent cement production for case B, consider the reference cement plant (Tab. 1) producing 1 ton of clinker, with a pet coke consumption of 3.245 GJ_{LHV} and 0.297 tons of fossil CO_2 emissions.

STEP 3. Assume that the same amount of SRF co-combusted in the cement plant of Case A is used as input of a WtC plant producing hydrogen or methanol. Such WtC plant contributes to Case B together with the reference cement plant defined in STEP 2. Based on the specific consumption and specific CO_2 emissions calculated through the Aspen model of the WtC plant, we calculate chemical production (i.e. amount of hydrogen or methanol), electric consumption and CO_2 emissions associated to the assumed SRF feed.

STEP 4. Consider the production of the same amount of chemical calculated at STEP 3 by means of a conventional process fed with natural gas. Such conventional, natural gas-fed plant contributes to Case A together with the cement plant defined in STEP 1. The amount of natural gas required by such plant and its CO_2 emissions are estimated from the conversion efficiencies and the specific emissions in Tab. 4.

The execution of STEPS 1 to 4 generates two situations (Cases A and B) which share the same SRF input, the same production of clinker (1 ton) and the same chemical production (hydrogen or methanol). Energy and fossil CO_2 emissions of such two situations are taken as indicators of the energy and environmental virtuousness of each route.

2.8 Evaluation of fossil CO_2 emissions

For hydrogen production, total CO_2 emissions are simply determined by the amount of carbon entering the system of interest, which all goes to atmosphere as CO_2. The split between biogenic and fossil emissions equals the split between biogenic and fossil carbon in the feedstock (either natural gas or SRF).

For methanol production, we assume that all the carbon in the methanol is fossil – as it is certainly the case when the feedstock is natural gas – while the carbon emitted to atmosphere is the sum of the remaining fossil carbon and biogenic carbon that has entered the system of interest with the feedstock. Based on this assumption, we calculate the split between biogenic and fossil CO_2 emissions in the Methanol Production Scenario.

As for the CO_2 emissions associated to electricity production, they are evaluated according to the assumptions in Table 6.

Table 6. Assumptions adopted to evaluate CO_2 emissions associated to electricity production.

Specific electric consumption of the cement plant (reference or co-combustion)	30.88	kWhel/t Clinker	-
Indirect CO_2 emissions from electric consumption	268.6	kg CO_2/MWhel	(ISPRA, 2020)

3. RESULTS AND DISCUSSION

Table summarizes the main results of the simulations of the two WtC processes. Specific fossil CO_2 emissions include the indirect emissions deriving from electric consumption.

Table 7. Main results of the two WtC processes simulations.

WtC process	Energy efficiency	Specific electric consumption	Specific fossil CO_2 emissions
H_2 production	0.379 GJ H_2/GJ SRF	6.375 MWhel/t H_2	16.45 kg CO_2/kg H_2
MeOH production	0.481 GJ MeOH/GJ SRF	1.056 MWhel/t MeOH	0.952 kg CO_2/kg MeOH

Figure 1 and Figure 2 report in graphical form the Hydrogen Production Scenario (HPS) and the Methanol Production Scenario (MPS), respectively, while Table 8 summarises the most relevant results. CO_2 emissions do not include the amount generated by calcination and by electric consumption in cement plants because such processes are assumed to be the same in Case A and B, and therefore they do not affect the outcome of our comparison.

Cases B require an energy input higher than that of Cases A: +14% in the HPS, + 5% in the MPS. This is mainly because the energy efficiency of WtC technologies is significantly lower than that of conventional technologies. This follows from the much lower quality of SRF with respect to natural gas, which inevitably translates into large losses for its conversion into high-quality chemicals.

A similar situation holds for fossil CO_2 emissions, which are significantly higher in Cases B: + 33% in the HPS, +30% in the MPS. In addition to lower energy efficiency, the reason why the WtC route entails higher CO_2 emissions lies in the displacement of natural gas used for chemical production in favour of carbon-intensive fossil fuel used for cement production. As shown in the figures and the table, in Case B natural gas consumption disappears, because chemicals are produced from SRF, while fossil fuel consumption strongly increases, because the sole energy input of cement production is pet coke.

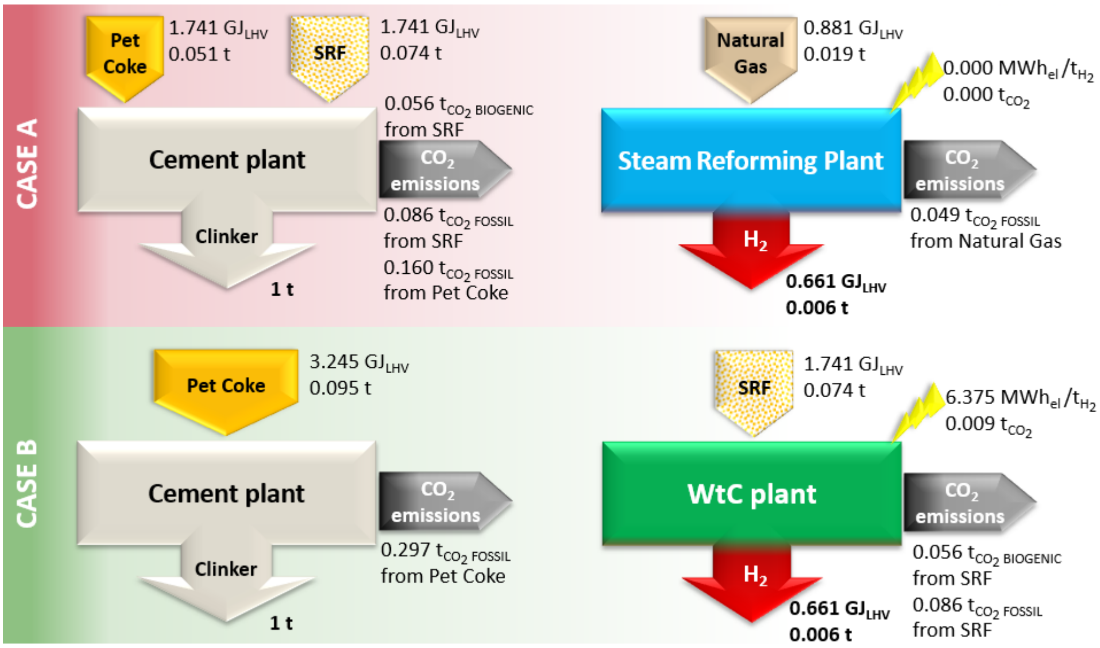

Figure 1. Hydrogen Production Scenario. CO_2 emissions do not include the emissions from calcination and electrical consumption in the cement plant, which are assumed to be the same for Case A and B.

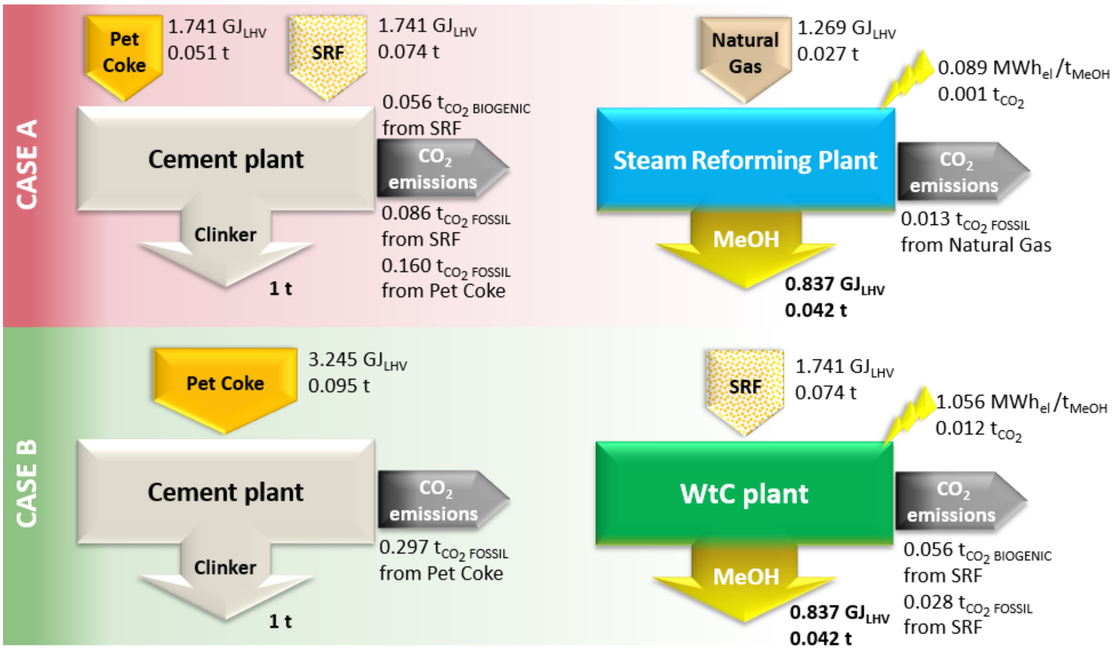

Figure 2. Methanol Production Scenario. CO_2 emissions do not include the emissions from calcination and electrical consumption in the cement plant, which are assumed to be the same for Case A and B.

Table 8. Main results of the comparative analysis.

Scenario and case		Energy input [GJ$_{LHV}$]			Electric energy input [GJ$_{EL}$]	Fossil CO_2 emissions [ton]	Final products
		Pet coke	SRF	Natural Gas			
Hydrogen	CASE A	1.741	1.741	0.881	0.111	0.295	1 ton of clinker and 0.006 ton of H_2
	CASE B	3.245	1.741	-	0.237	0.392	
Methanol	CASE A	1.741	1.741	1.269	0.125	0.259	1 ton of clinker and 0.042 ton of MeOH
	CASE B	3.245	1.741	-	0.271	0.337	

4. CONCLUSIONS

The framework and the analysis developed in this work give quantitative indications on whether feeding SRF to Waste-to-Chemical plants gives energy or environmental advantages with the respect to the consolidated co-combustion of SRF in cement plants.

Results show that the WtC route of SRF entails higher primary energy consumption (+14% for hydrogen production, +5% for methanol production) and higher fossil CO_2 emissions (+33% for hydrogen production, +30% for methanol production).

The main reason why the WtC route requires more energy lies in the much lower quality of SRF with respect to natural gas, which inevitably translates into large losses for its conversion into high-quality chemicals. In addition to lower energy efficiency, the reason why WtC entails higher fossil CO_2 emissions lies in the displacement of natural gas used for chemical production with higher carbon-intensive fossil fuel consumption for cement production.

In addition to higher energy consumption and higher fossil CO_2 emissions, the WtC route of SRF would be hampered by a further circumstance. The use of SRF in WtC plants crucially requires enrichment with non-recyclable plastics, which are needed to bring the quality of SRF up to the level required by the WtC process. Should WtC become the preferential destination of SRF, less non-recyclable plastics would be available to re-qualify low-quality non-recyclable waste, which therefore may no longer be used for energy recovery. In other words, the use of large quantities of non-recyclable plastics for the production of high-quality SRF may prevent the recovery of other low-quality, non-recyclable waste, thereby reducing the virtuousness of the waste management systems.

For the reasons above, the use of SRF in WtC plants doesn't seem to offer neither energy nor environmental advantages with respect to co-combustion in cement plants, and any incentive directed toward the production of chemicals from SRF should be carefully assessed in a LCA perspective.

5. ACRONYMS

AGR	Acid Gas Removal
AITEC	*Associazione Italiana Tecnico Economica del Cemento*
A.R.	As Received
BAT	Best Available Techniques
Clk,	Clinker
D.A.F.	Dry Ash Free
DCC	Direct Contact Cooler
HPS	Hydrogen Production Scenario
LCA	Life Cycle Assessment
LEAP	*Laboratorio Energia e Ambiente Piacenza*
LHV	Lower Heating Value
MeOH	Methanol
MPS	Methanol Production Scenario
MSW	Municipal Solid Waste
NG	Natural Gas
Pet.	Pet Coke
PSA	Pressure Swing Adsorption
SRF	Solid Recovered Fuel
WGS	Water Gas Shift
WtC	Waste to Chemicals

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