Synergies socio-economic impact assessment

Industrial Symbiosis potential and impacts

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SCALER

SCALING EUROPEAN RESOURCES WITH INDUSTRIAL SYMBIOSIS

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Contents

Executive summary

This deliverable presents a screening socio-economic assessment results of the 100 synergy types which were selected in Deliverable 3.1 for assessing the potential of industrial symbiosis in Europe. The shortlist is considered representative of the diversity of synergies that may be encountered within a European context.

This deliverable is part of a series of deliverables composed by the initial list of synergies type (identified in T3.2 and presented in D3.1), a technology assessment and identification (identified in T3.3 and D3.2), a screening life cycle analysis of the 100 synergy types (identified in T3.4 and D3.3) and then final industrial symbiosis potential assessment (T3.6 and D3.5).

Of the 81 synergy types that could be modelled, estimated 33 500 M€ added value thorough Europe, 7 000 M€ VAT, 350 000 direct jobs creation and 100 000M€ of environmental impacts savings are expected.

A second more sensitive assessment considering the 15 most profitable synergy types' implementation level lead to refine the results and characterise the remaining industrial symbiosis potential: 2 500 M€/y added value, 6 000 M€/y of labour share, 130 000 direct jobs created and between 66 000 and 400 000 indirect jobs.

Other indicators confirm the socio-economic benefits. These results clearly show the potential of industrial symbiosis in Europe from a socio-economic point of view, in particular regarding the added value generated and jobs creation. Industrial symbiosis is thus a key driver to leverage the circular economy in Europe.

In case of non-profitable synergy (economically), the use of avoided environmental economic values allows to turn the synergy viable. This argument can motivate especially local authorities to support the synergies implementation (e.g. for example with subsidies that will be profitable in the long term).

Data quality and availability was identified as one of the main challenges of this work. Despite an in-depth and extensive search for data, some synergies could not be evaluated due to a lack of data specifically needed from a socio-economic assessment perspective. Primary industrial data are required to confidently model an accurate socio-economic assessment. Although the scope of this work does not encompass modelling to this level of detail, secondary data allowed us to perform a screening level socio-economic assessment, with a certain degree of uncertainty. Some other limitations of the methodology are explained.

T3.5 outcomes and activities carried out during this step will feed the reflexion for the statistical analysis and the final Industrial symbiosis European potential assessment (T3.6 and the associated D3.5).

These work and deliverable constitute a relevant and innovative step forward to assess the socio-economic impact of a 100 synergy types sample. The main advantage of this work is to make synergies implementation comparison easier and to quantify economic benefits and associated jobs creation order of magnitude.

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Tables

Abbreviations

IS: Industrial symbiosis

SPIRE: European association for Sustainable Process Industry through Resource and Energy Efficiency

IMA: International Mineralogical Association

ORC: Organic Ranking Cycle

ADT: Air Dry Tonne

EAF: Electrical Arc Furnaces

EAFD: Electrical Arc Furnace Dusts

COG: Coke Oven Gas

BOF: Basic Oxygen Furnace

BOFG: Basic Oxygen Furnace Gas

BF: Blast Furnace

BFG: Blast Furnace Gas

DPM: Deodorized and sanitized Poultry Manure

ATS: Ammonium Thiosulfate

S: Sector

P: Process

SS: Subsector

LHV: Lower Heating Value

BREF: Best Available Techniques Reference Document

LCP: Large Combustion Plant

LCA: Life cycle analysis

CAPEX: CAPital EXPenditure

OPEX: OPerational EXPenditure

LHV: Lower Heating Value

LCA: Life cycle assessment

TDB: Technology database

WWTP: Wastewater Treatment Plant

BaU: Business as Usual

1. Introduction

The SCALER project vision is to successfully scale up the delivery of value embedded in European physical resources (materials, water and energy) through efficient and quick implementation of industrial symbiosis (IS) across the whole European territory. It will provide mechanisms to promote a wider implementation of IS in the European process industry by developing action plans and adapted solutions to industrial stakeholders and communities.

WP3 aims at assessing the European IS potential. After the three first steps; identify 100 promising synergy types (T3.2), assess them technically and identify relevant technologies for the implementation (T3.3) and model the life cycle analysis of the 100 synergy types (T3.4), this deliverable (**D3.4**) introduces the outcome of the 100 synergy types socio-economic assessment (T3.5). For each of them, a dedicated analysis is proposed providing information on the value added generated by the synergy, all associated tax benefits, the potential job creation, wastes management costs avoided and an economic analysis of environmental and social impacts.

This screening socio-economic assessment will provide inputs for detailed analysis in the T3.6 and the final IS potential evaluation.

The deliverable is organised as such:

- 1rst Section introduces the Scope & Objective;
- 2nd Section details the whole methodology used for the socio-economic assessment of the100 synergy types;
- 3rd Section introduces the results (overall results and individual synergies analysis)
- 4th Section is the conclusion and perspectives for the last step of WP3 (T3.6)
- References are given in the 5th Section.

2. Scope & Objective

WP3 aims at quantifying the potential of industrial symbiosis in Europe. The specific objectives of the work package are to:

- Map industrial sites, identify new locations, estimate the potential reduction of operational / logistics costs from a wide implementation of IS in Europe.
- Provide an input / output flows database to enable an automatic identification of physical resource synergies
- Develop a database of technical solutions enabling the implementation of the synergy types and estimate the related investment needs and related costs.
- Assess and quantify environmental and socio-economic impacts of a synergy type implementation.

The aim of this deliverable is **to perform a screening socio-economic assessment of a synergy type implementation.** More specifically, the objective is to:

- Quantify the economic impacts/benefits of the shortlisted 100 synergies types implementation
- Benchmark the identified synergies against a defined business as usual scenario
- Provide data and inputs for the final European IS potential assessment (Task 3.6)

This deliverable builds upon the output from D3.1 "Short list of the 100 most promising synergies", D3.2 and the associated technology database developed, T3.3 and associated LCA and will provide inputs for the deliverable 3.5.

It is not the aim of this task to provide a detailed socio-economic assessment for each of the 100 synergy types. A more detailed analysis on each synergy will be provided on the final deliverable of the WP3, which will include geolocated data to make the analysis more sensitive.

The objective of this task is to develop a methodology to compare socio-economic impacts of the 100 and obtain an order of magnitude of the socio-economic benefit of an IS large scale implementation in EU.

3. Methodology

3.1 Socio-economic assessment approach

For each synergy type, the objective is to compare a baseline scenario with a synergy scenario.

The business as usual scenario involves:

- An emitting industry
- A waste management company (and associated transport)
- A raw material provider for the receiving industry
- A receiving industry

On the other hand, the synergy scenario involves:

- An emitter industry
- A transportation mode or process that can be done by the emitter and/or receiver industry or a third company
- A procedure and eventual technology in case of an indirect synergy
- A waste management company in case of residual final waste stream
- A receiving industry

The two situations are presented in Figure 1 and Figure 2.

Figure 1: Business as usual scenario (Source: Strane)

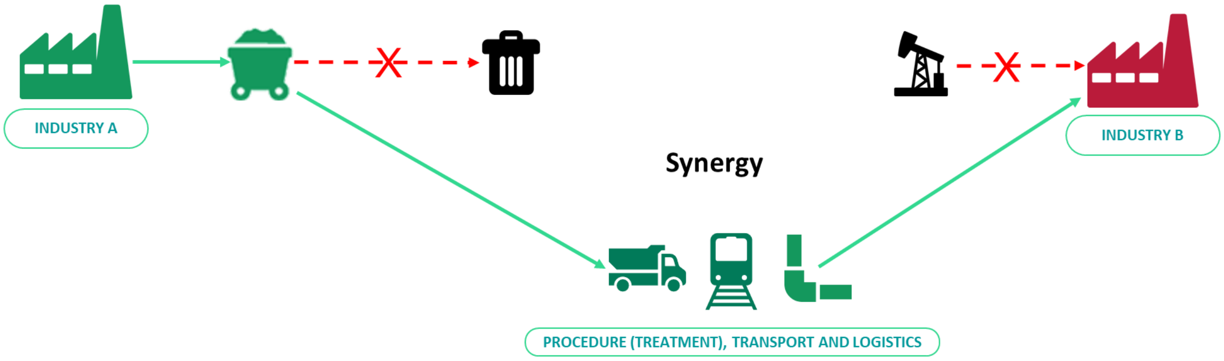

Figure 2: Synergy case scenario (Source: Strane)

3.1.1 Ideal theoretical approach

In an ideal theoretical approach, many values (economic, environmental, social, brand image, etc.) must be assessed to have a systemic approach and identify benefits and losses for each stakeholder. In the business as usual scenario, values assessed are presented in Figure 3:

- Emitting industry: landfilling costs, and/or incineration costs
- Waste management industries: avoided fuel use for energy production, waste management revenues. It is assumed (expected some specific cases) that landfilled waste do not have any intrinsic values.
- Raw material supplier: raw material sales revenues, energy sales revenues
- Receiving industry: raw material and fuel costs

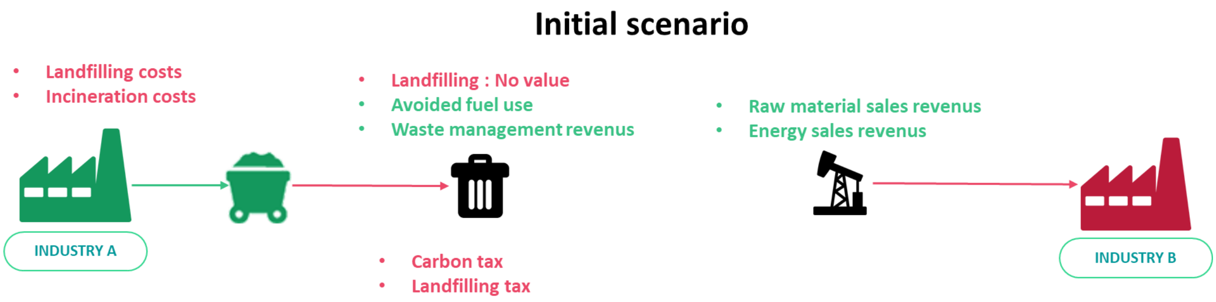

Figure 3: Business as usual scenario values to assess (Source: Strane)

In the synergy case, additional values assessed are:

- Resource: intrinsic value increase due to the synergy implementation
- Emitting industry: avoided landfilling costs or incineration costs, job creation, residual wastes management costs. Additional social values that could be assessed are brand perception and innovation capacity.
- Waste management company: revenues losses, residual wastes management revenues
- Raw material provider: Business losses
- Territory: environmental and social impact economic equivalence, taxes (carbon tax, landfilling taxes), territorial development, health and safety evolution

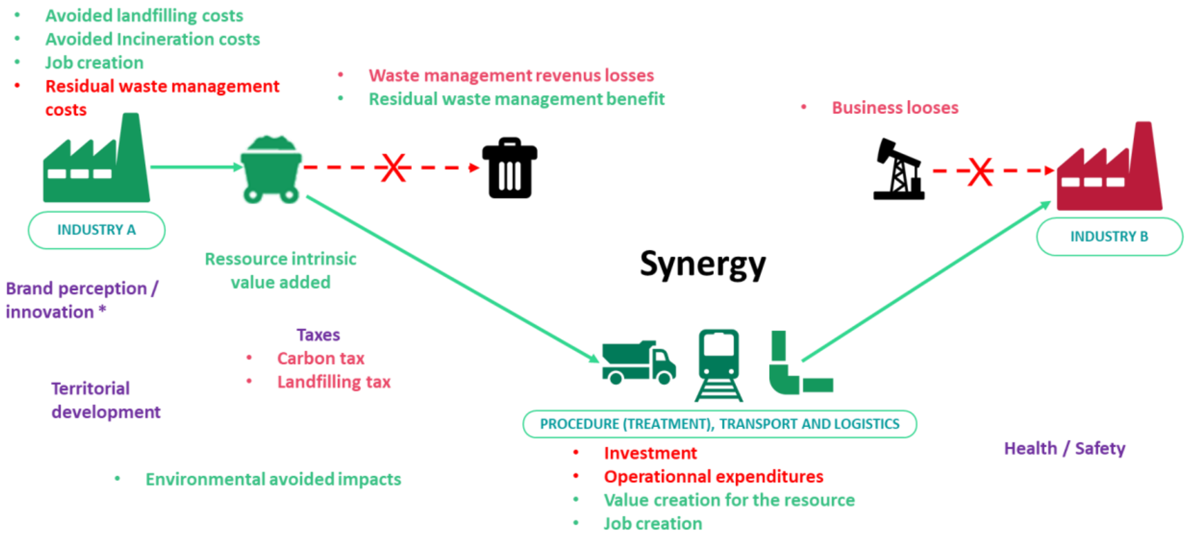

Figure 4: Synergy scenario values to assess (Source: Strane)

3.1.2 System boundaries

Given the quality and availability of data gathered during the first tasks of the SCALER project (wide ranges, data not available, generic data and not real industrial data), it was not possible to make a full ideal socio-economic assessment approach for the T3.5. The elements included in the system boundaries were:

- the waste stream and elements of interest
- the emitter industry
- the transportation company
- the waste management company

3.1.3 Approach retained in the scope of SCALER

The approach retained for SCALER project is based on the intrinsic value acquired with the synergy. Values assessed are presented in Figure 5: Values assessment in SCALER socio-economic assessment (Source: Strane).

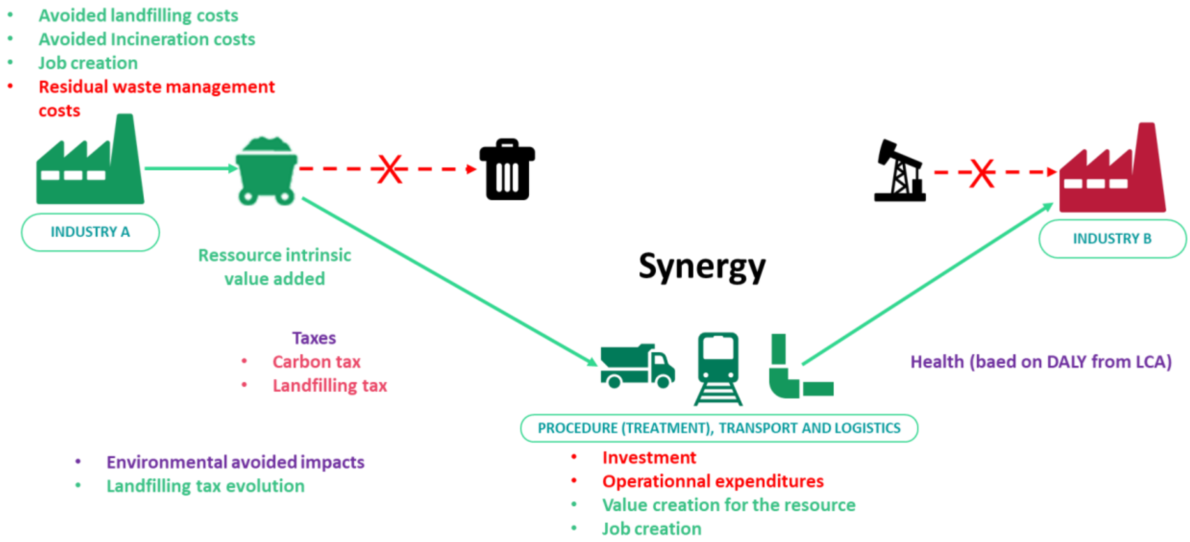

Figure 5: Values assessment in SCALER socio-economic assessment (Source: Strane)

Due to the variety, quality and availability of data, it was not possible to use a theoretical approach with mathematical models. The high level of uncertainty was too high to use such a model.

As an example, a formula has been identified to estimate the job creation in chemical plants:

Equation 1: Number of jobs equation (Source: Strane)

$$Number\ of\ Jobs = \sum_i \frac{L_i}{W_i}\left(\frac{(Fixed\ Capital\ Investment)}{(Lifetime)} + 0.11 \cdot Operating\ Cost\right)$$

This equation is coming from reverse-engineering the cost-estimation for labour in chemical plants [1]. The Li parameters are defined in Table 1: Li parameters.

Table 1: Li parameters

Component	Factor (% of fixed capital investment), 100·L_i [10]
Engineering & supervision	7.3
Construction expense	9.2
Contractor's fee	1.8

The 'Wi' parameters are the cost for employing 'regular' employees and supervisors/engineers.

Unfortunately, this equation was not applicable at all in SCALER’s scope due to the quality, variety, and availability of data. Fixed Capital Investment, Operating costs were not available for most of the synergies. Furthermore, the technologies ‘Lifetime was available only for one synergy over 100.

Finally, it was impossible to use that type of approach. The final selected methodology is based on a statistical approach and the use of data gathered by several European study entities (Eurostat, etc.)

Some social indicators were not calculated since no reliable methodology was found.

The brand perception is extremely difficult to assess quantitatively. Strane internal PhD, carried out within the EPOS project, concluded that the topic is controversial, and no dedicated methodology was found.
The Marketing & Innovation benefits of implementing synergies is difficult to assess and not relevant in the SCALER study. Indeed, all synergies will have a similar marketing and innovation benefit.

3.2 Methodology used

3.2.1 Economic value assessment

The economic assessment considers pure economic values created or destroyed by a synergy project.

Several typologies of economic values are evaluated: **new revenues, costs avoided, costs created, and revenues avoided**.

New revenues are generated by being aware that underutilised resources might have hidden economic values. Resource economic value depends on its uses and more precisely the type of substituted resource. For example, coke can be used as a combustible in several energy intensive industry and as a raw material for its intrinsic properties in the steel sector.

For the former, its value will be indexed on other solid fuels depending on its quality (e.g. coal, biomass, tyres, etc.) while for the latter, the value will be based on coke market prices or production costs. These economic values can significantly change.

For resources used as fuels, they must be compared to conventional fuels with the same state of matter (solid, liquid, gaseous and electricity) and for the same amount of energy produced by combustion (based on LHV). It must be noted that boiler efficiency might decrease with alternative fuels and should be considered when calculating the equivalent substituted energy amount. Some equivalent fuels of reference are provided in Table 2.

Table 2: Alternative reference fuels prices and LHV

Fuel of reference	Coal	Heavy fuel	Natural Gas	Electricity
Price (€/t)	70[1]	580[2]	18,1 (€/MWh)[3]	0,11 (€/kWh)[4]
PCI (GJ/t) [5]	27-32	39-40	39	

[1] https://commoprices.com/fr/c/Energie/Houille/Charbon/WRB-COAL_COL?currency=EUR (consulted the 2019/03/21)

[2] http://www.prix-carburants.developpement-durable.gouv.fr/petrole/se_resul_fr.php (consulted the 2019/03/21)

[3] https://commoprices.com/fr/c/Energie/Gaz/Gaz-naturel/WRB-NGAS_EUR?currency=EUR&unit=20 (consulted the 2019/03/21)

[4] https://commoprices.com/fr/c/Indices-Macro%C3%A9conomiques/Energie/Prix-de-l_%C3%A9lectricit%C3%A9/ELEC-FR#CP (consulted the 2018/08/30)

[5] https://www.picbleu.fr/page/tableau-comparatif-pouvoir-calorique-inferieur-pci-des-energies (consulted the 2019/03/21)

For material valorisation, resource economic value is defined by comparing with prices of available resources on the market. In cases where flows are mixed, the total value of the flow is the sum of individual elements value from the mix. It is assumed here that technical solutions exist to treat any mixed flow and split it into individual fractions. Table 3 provides some market prices of material examples.

Table 3: Examples of material prices

Raw material	Industrial water	Sulphur crystal	Tar	Coke breeze	Scrap
Market prices (€/t)	0,5[6]	123[7]	210[8]	131[9]	200[10]

It is important to note that this methodology leads to assess the maximal value recoverable in the resources and probably overestimate the flow valorisation. Fairer values might be defined by the guide user or through co-assessment discussions between involved actors, considering quality and availability among other criteria. Decreased rates might be applied (from a few percent up to 80%) and in some cases resources might finally have negative economic values (i.e. provider pays to send its resource).

Costs avoided can emerge from different sources. Business as usual costs might be related to:

- **Public bodies** (e.g. EU-ETS with a CO2 ton cost of about 21,4 €/t[11] in March 2019, while it was about 5€/t between 2013 and mid-2017);
- **Private entities** for several types of disposal or depollution treatments (e.g. landfill taxes in EU vary from a few euros to more than 150 €/t depending on the region)
- **Internal costs** if part of the waste management is done by the organisation.

These costs are highly dependent on the business, context and resource nature. By implementing synergies, these avoided costs generate positive values for organisations.

Additional costs are automatically generated with a synergy creation and **must be (roughly) assessed**. Depending on the case, they can be insignificant or require significant investments. For example, transport costs vary depending on transport mode (e.g. freight, river, truck, pipeline transport) and resource nature (e.g. state of matter, corrosiveness, hazardousness, etc.). As an example, pipelines require around 1 M€/km CAPEX and 40 k€/km/y OPEX.

Treatment procedures and associated technologies might be required for the synergy implementation. These costs can be externalised, through subcontracting services (OPEX), or internalised with infrastructures investments and day-to-day operation (CAPEX and OPEX). Available data was gathered during the T3.3 in the technology database.

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[6] Industrial partner

[7] https://minerals.usgs.gov/minerals/pubs/commodity/sulfur/mcs-2016-sulfu.pdf (consulted the 2019/03/21)

[8] http://www.crugroup.com/about-cru/cruinsight/The_changing_coal_tar_supply_demand_dynamics (consulted in 03/2017)

[9] http://www.eia.gov/coal/production/quarterly/pdf/t25p01p1.pdf (consulted the 2019/03/21)

[10] http://www.eurofer.org/Facts%26Figures/Scrap%20price%20index.fhtml (consulted the 2019/03/21)

[11] https://sandbag.org.uk/carbon-price-viewer/ (consulted the 2019/03/21)

The last economic value to be considered is **foregone income**. This negative type of value generally appears when extending the analysis scope to peripheral and external stakeholders. Their assessment is **optional** if the value assessment focus is on central actors, but it is recommended for systemic and complete assessments. In this socio-economic study's scope, the negative type of value was not assessed.

The global viability can easily be checked according to the sign of the above-mentioned values sum:

$$\sum(new\ revenues + avoided\ costs - additional\ costs - foregone\ impacts) > 0$$

3.2.2 Exploitation of previous WP3 work

a. Technologies database exploitation T3.3 & D3.2

Data identified and gathered in the technology database were used for the socio-economic assessment:

- **Technology description:** this information was used to understand the treatment procedure involved and support decision if the technology involved is widely used or not.
- **Viability resume and GO / NOGO technical decision**: this comments and decision were used to understand if the technology is commercially available and used at an industrial scale and finally if the synergy could be implemented or not. In the case of an unavailable technology, the synergy was still modelled to quantity the benefit to make research effort on implementing such a technology.
- **Yield**: the yield was used to estimate the productivity and number of equipment required thorough Europe and to compare the capacity treatment with the final amount of waste volume.
- **Recovery rate**: the recovery rate was used to quantify the final recovered flow.
- **Key costs and transportation mode.**
- **CAPEX**: Capital expenditure data were used to quantify the total investment effort required in EU to implement the synergy type.
- **OPEX**: OPEX were considered as a cost source in the calculation of the value added.
- Heat demand, electricity demand and water demand were used in case of lack of OPEX data to quantify costs associated to heat, electricity and water use.
- **CO^2 emissions of the procedure** were considered in carbon tax calculation. In D3.3 This information has not been included in the calculation of the LCA climate change indicator.

b. LCA results exploitation T3.4 & D3.3

Environmental values are necessary to consider in an IS project to (1) validate the environmental positive performance of a synergy and (2) mobilise non-central stakeholders impacted by these values and who might unlock decisions only based on economics. On the one hand, industries are facing environmental regulations, pressure from the society to reduce their footprint and to better consider their societal responsibility. In addition, environmental performance can be traduced as a new form of competitive advantage. Thus, these actors need tools to guide them in assessing environmental impacts of their new projects, and in that case synergies. On the other hand, such information is of high interest for public authorities, at different scales, and citizens for whom synergies might create or destroy value and should be involved or at least considered in the decision-making.

The value analysis was made through a Life Cycle Assessment (LCA) performed by Quantis in T3.4. A functional unit was defined in order to enable comparison between several synergies and scenarios. Thanks to this step, the consortium compared the environmental performance of the synergy scenarios and the reference scenario to produce the same amount of goods and make the analysis more accurate. If LCA results show that a synergy scenario has less environmental impact than the business as usual, it can be considered that the synergy will create environmental value. If not, the synergy destroys value.

The LCA analysis was performed with the software SimaPro. Reference and alternative synergy scenarios defined in step 3 were modelled, using the collected data (in line with the hypothesis used in the economic assessment.

Endpoints (or damage)) in aggregation of the midpoints and indicate concretely where environmental effects occur and to what extent. They are expressed in DALY (Disability Adjusted Life years) for human health, PDF.m².y (Potentially Disappeared Fraction of species in a certain area during one year) for ecosystem quality, MJ (required energy for the extraction of the same amount of material in the future) for resources depletion and t CO2 equivalent for global warming.

Damage economic values are defined by the StepWise2006 [21] methodology as such: QALY (Quality Adjusted Life Year) corresponds to the average economic production per capita in one year (74 000€), BAHY (Biodiversity Adjusted Hectare Year) is based on ecosystem services evaluation, and the two latter represent the actual cost of 1 MJ or 1 t CO2 for the economic productivity.

Links between indicators at different aggregation level and values are given in Table 4.

LCA remains a science based on a certain amount of hypothesis and uncertainties. In the case of monetarisation methods, they are highly debated by experts and are based on a utilitarian vision of nature assuming a perfect substitution of economic and natural capitals. While highly controversial, it has the main benefit to facilitate the internalisation of non-economic values in synergy business models.

Table 4: Economic value for LCA endpoints indicators (Source: Strane)

Midpoints	Endpoints	Weighting factors
Human toxicity, carcinogens (kg C2H3Cl-eq)	Human health (DALY)	1 QALY= - DALY = 74 000 €
Human toxicity, non-carcinogens (kg C2H3Cl-eq)		
Respiratory inorganics (kg PM2.5-eq)		
Ionizing radiation (Bq C-14-eq)		
Ozone layer depletion (kg CFC-11-eq)		
Respiratory organics (kg C2H4-eq)		
Aquatic ecotoxicity (kg TEG water)	Ecosystem quality (PDF.m2.y)	1 BAHY= - 10 000 PDF.m2.y = 1 400 €
Terrestrial ecotoxicity (kg TEG soil)		
Terrestrial acid/nutri (kg SO2-eq)		
Land occupation (m2 org ara.y)		
Aquatic acidification (kg SO2-eq)		
Aquatic eutrophication (kg PO4-eq)		
Water turbines (m3)		
Non-renewable energy (MJ primary)	Resources Productivity (MJ)	0,004 €/ MJ
Mineral extraction (MJ surplus)		
Global warming (IPCC 2013, 100a) (kg CO2-eq)	Climate change (kg CO2-eq)	0,08 €/kgCO2-eq

Environmental values traduced by these indicators may interest several stakeholders' typologies – private and public – at different scales – from local to global (e.g. decrease of respiratory organics interests the local community, while global warming reduction interests national to global institutions). These values can thus be captured by different stakeholders and LCA results should be discussed by the whole organisation's ecosystem.

3.2.3 Calculation process

The methodology used is based on the intrinsic value of the resource that is used by the synergy type. Four main parameters are required to estimate the socio-economic assessment:

- The wastes stream volume

- The final valuable volume (volume of the element of interest for the synergy) in the waste stream.
- The waste stream price in the business as usual scenario
- The substituted resource equivalent price

Several calculations are used to estimate the substituted resource price

- The market price of a similar resource purchased by the receiving industry (e.g. market lime)
- The market price of a similar waste resource that is usually sold on the market (e.g. granulated slag) purchased by the receiving industry
- The equivalent price of the chemical composition of the resource (e.g. sum of an aluminium and calcium composition prices)

Once the 4 initial data variables required are obtained, the methodology applied is described in Figure 6.

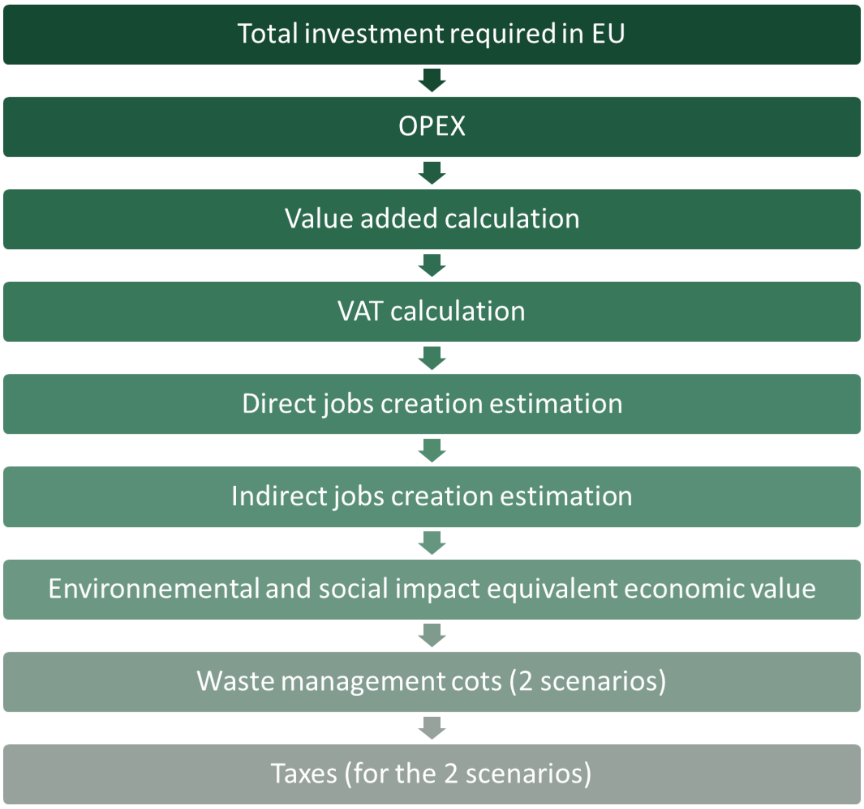


Figure 6: Calculation process (Source: Strane)

3.2.4 Data used for calculation

This chapter introduce all data that have been gathered to perform a relevant socio-economic assessment of the 100 synergy types.

a. Waste management costs and taxes

Landfilling

The European Environment Agency provided in 2013 typical charge data (gate fee and landfill tax) for legal landfilling of non-hazardous municipal waste in EU Member States and regions. This document does not present landfilling taxes and costs for hazardous wastes.

The CEWEP agency published an update of the landfilling taxes in 2017.[2]

Table 5: Gate fees and landfill taxes in EU Member States (Source: European Environment Agency / CEWEP / Strane) gather the two documents data. In order to provide a worst cases estimation, maximum prices were retained.

Table 5: Gate fees and landfill taxes in EU Member States (Source: European Environment Agency / CEWEP / Strane)

Member State	Landfill tax (€ per tonne) In 2013	Landfill Tax (€ per tonne) updated	Year	Current typical landfill gate fee (€ per tonne)	Total typical charge for landfill (€ per tonne)
AUSTRIA	26,00	87	Applied since 2006	70,00	157
BELGIUM, FLANDERS	82,03	101,91	2017	50,00	151,91
BELGIUM, WALLONIA	65,00	113,01	2017	50,00	163,01
BULGARIA	3,00	30	2019		30
CYPRUS				56,00	56
CZECH REPUCLIC	20,00	20	2017	16,00	36
DENMARK	63,00	63,3	2017	44,00	107,3
ESTONIA	12,00	29,84	2017	40,00	69,84
FINLAND	30,00	70	2017	59,40	129,4
FRANCE	20,00	40	2017	60,50	100,5
GERMANY†	0,00	0,00	2017	140,00	140
GREECE†	0,00	60	2019 - 2020	23,50	83,5
HUNGARY	0,00	19,35	2017	35,00	54,35
IRELAND†	50,00	75	Since 2013	70,00	145
ITALY†	30,00	25,82	2017	90,00	115,82
LATVIA	8,00	43	2019	30,00	73
LITHUANIA	0,00	21,72	2019	16,25	37,97
LUXEMBOURG†	0,00	8	2017	149,48	157,48
MALTA	0,00	0,00	2017	20,00	20
NETHERLANDS†	107,49	13,11	2017	25,00	38,11
POLAND	26,60	40	2019	69,50	109,5
PORTUGAL	3,50	9,9	2019	10,50	20,4
ROMANIA	0,00	26	2018	3,70	29,7
SWEDEN†	49,00	50	2017	106,50	156,5
SLOVAKIA	0,00	9,96	Since 2016	6,80	16,76
SLOVENIA	11,00	11	2017	105,50	116,5
SPAIN	12,40	41,30	2019	32,75	74,05
UK	64,40	100	2018	26,80	126,8
EU 28	23,81	38,82		53,10	91,91

The average landfilling tax updated with the CEWEP publication is around **38,82€/t of landfilled wastes**. The average landfill gate fees in EU Members countries are around **53,10€/t**.

Incineration

Waste incineration gate fees are presented in the Waste Incineration BREF [3]. Value are old so the maximum value was retained.

Table 6 : European incineration gate fees (Source: BREF / Strane)

Member States	Municipal waste Gate fees in €/t	Hazardous waste Gate fees in €/t	Maximum gate fees
BELGIUM	57	100 – 1 500	57
DENMARK	40 – 70	100 – 1 500	70
FINLAND	50 – 100	NI	100
FRANCE	50 – 120	50 – 1 500	120
GERMANY	100 – 350	50 – 1 500	350
ITALY	70 – 120	100 – 1 000	120
NETHERLANDS	90 – 180	50 – 5 000	180
SWEDEN	38 – 67	50 – 2 500	67
UNITED KINGDOM	20 - 40	NI	40
AVERAGE	20 - 350	50 – 5 000	122,6 (Average)

The 100 synergies waste streams are randomly hazardous or non-hazardous wastes. The hazardous waste gate fees range of value is wide. Therefore, the retained value is based on the municipal waste maximum gate fees: 122,6€/t of wastes incinerated.

Strane used several sources to identify the variety of incineration taxes : a European comparative study of waste disposal taxation [4] carried out and published by the ADEME (French Environmental Agency) in 2017, Waste incineration BREF [3], a waste environment study by the European commission [5] and the French Custom [6]. Data available are gathered in the Table 7 : Incineration taxes (Source: ADEME / Waste incineration BREF / European Commission / French Custom).

Table 7 : Incineration taxes (Source: ADEME / Waste incineration BREF / European Commission / French Custom)

Countries	Incineration tax (€/t)	Date	Source
UNITED KINGDOM			[4]
AUSTRIA			[4]
BELGIUM – WALLONIE	11,3	2016	[4]
DENMARK	52	2011	[4]
SPAIN - CATALONIA	11,7	2016	[4]
FINLANDE			[4]
NETHERLANDS	13	2016	[4]
SWEDEN			[4]
FRANCE	15		[6]
AVERAGE	20,6		

An average value was estimated (20,6 €/t) but due to the lack of information regarding waste incineration taxes in Europe (only data for 5 countries), this indicator has not been assessed in this study.

b. Tax

a. <u>Carbon tax</u>

The COP 21 advised to apply a carbon tax of 40 – 80 € per tonne of CO_2 emitted.

The French environment and energy management agency ADEME published a document updated in 2016 and focused on the carbon tax in Europe. Rates vary from a symbolic level (2 €/tCO_2 in Estonia) to more than 120 €/tCO_2 in Sweden. If an average rate could be defined for all European countries, it would be between 20 and 30 € per ton of emitted CO_2 [7].

In the context of SCALER study, and **considering that all EU countries will try to reach the COP 21's targets**, the carbon tax retained is **40€ per ton of C02 emitted**. That would correspond to local authorities' potential benefits in case of the application of COP21's recommendations.

b. VAT

The definition of VAT provided by the European Union is the following one [8] : "The Value Added Tax, or VAT, in the European Union is a general, broadly based consumption tax assessed on the value added to goods and services. It applies to all goods and services that are bought and sold for use or consumption in the European Union. Thus, goods which are sold for export or services which are sold to customers abroad are normally not subject to VAT. Conversely imports are taxed to keep the system fair for EU producers so that they can compete on equal terms on the European market with suppliers situated outside the Union."

The European Commission lists the standard VAT rate in Europe [9] (situation in 2019).

Table 8 : List of VAT rates applied in the Member States, 2019 (Source: European Commission)

Country	Standard VAT Rate (%)	Country	Standard VAT Rate (%)
Belgium	21	Lithuania	21
Bulgaria	20	Luxembourg	17
Czech Republic	21	Hungary	27
Denmark	25	Malta	18
Germany	19	Netherlands	21
Estonia	20	Austria	20
Ireland	23	Poland	23
Greece	24	Portugal	23
Spain	21	Romania	19
France	20	Slovenia	22
Croatia	25	Slovakia	20
Italy	22	Finland	24
Cyprus	19	Sweden	25
Latvia	21	United Kingdom	20

Table 9 : Average VAT rate in EU (Source: Strane)

Average standard VAT Rate in Member State	21,46 %

The final VAT rate retained for the socio-economic assessment is 21,46%

c. Transport modes costs

It was assumed that a pipeline costs on average about 1.4 M€ per kilometre (Smith, 2015). The economics of pipelines depends on the resource to be transported, its physical characteristics (e.g. corrosion, temperature, risks, porosity, etc.) requiring different types of pipelines (materials, isolation, protections…), as well as its local characteristics (land ownership, type of land, landscape…).

Truck transportation generic price was provided by an industrial partner. It is assumed that the truck transportation costs are between 0,15 and 0,2 €/t/km. This generic price is not applicable for specific or exceptional lorry transportation (e.g. pressurised gas transportation).

Table 10: Transportation modes price (Source: Strane)

Transport modes	CAPEX	OPEX	Unit	Source

Pipeline	1400000	85000	€/km	Smith, 2015
Trucks		0,0298841	€/t/km	Strane
Trucks		15 – 20 0,15 – 0,2	€/t/100km €/t/km	Industrial partner

d. Transport viability radius

Pipeline transportation modes were not modelled in this study because of a lack of information regarding geolocated data. Geolocated data gathered in T3.1 will be crossed with the socio-economic assessment in the T3.6.

In this study, the viability distance assessed for lorry transportation is a rough estimation [10]. It considers only the viability radius for one ton of resource. The distance radius of viability is a data made in relation with the price of the resource studied. The formula used does not depend on the resources volume.

A deeper analysis will be provided for each synergy type in the D3.5.

$$\boldsymbol{Viability\ radius} = \frac{\boldsymbol{Resource\ valuable\ volume}\ (\boldsymbol{t}) * \boldsymbol{Raw\ material\ susbtitiuted\ price}\ (€.\boldsymbol{t})}{\boldsymbol{Tranport\ generic\ price}\ (€.\boldsymbol{t}.\boldsymbol{km}) * \boldsymbol{Resource\ valuable\ volume}\ (\boldsymbol{t})}$$

A viability radius to estimate the maximum transportation is proposed. In order to have an industrial approach, it is assumed that the transportation costs do not exceed 10% of the transported merchandise value.

e. Labour share in added value

The IMF declares that the value-added share accrued to labour, commonly known as the labour share, the ratio of labour compensation (wages and benefits) to national income, was around 46% in 2017 [11].

In 2016, the European commission’s database (AMECO) mentioned that the labour share represented 53% of the total added value in industrialised countries according to the Federal Reserve Bank of Cleveland [12]. That confirms the relevancy of the IMF data.

This value (46%) will be used to estimate the part of the labour share (including wages and benefits) in the global value added associated the synergies implementation at European level.

f. Total labour costs

In order to estimate the number of jobs generated by the synergies’ added value, the wages and salaries in Europe where used. A survey performed in 2016 details the labour costs, wages and salaries by activity [13].

Table 11 : Labour costs indicators (Source: Eurostat)

Labour costs indicators	2016
Total Labour costs Sectors: Industries, construction and services per employee in full-time equivalent, per year	44 071 €
Wages and salaries Sectors: Industries, construction and services Per employee in full-time equivalent, per year	33 643 €

g. Tax to GDP Ratio

According to Eurostat publications [14] [15], in 2017, tax revenue (including social contributions) in the EU stood at 40.2 % of GDP, and accounted for around 90 % of total government revenue.

h. Maintenance costs

Due to the lack of information on synergies' OPEX and CAPEX, the maintenance costs where overpassed during this study. The ratio that would be applied in the D3.5 is:

$$Maintenance = 0.02\ to\ 0.06 * Capital\ Investment\ (€)$$

i. Resources price

Table 12 : Resources prices (Source: Strane)

Resource	Price	Unit	Year	Source
Hydrogen	0,204	€/m3		
Natural gas	0,260369888	€/Nm3		
Zinc dusts	2 315	€/t	2015	[16]
Raw zinc	1 717,6	€/t	2014	[16]
Iron ore	71	€/t	2018	[17]
Gyspum	36,2	€/t	2015	[16] [18]
Salt	Industrial salt: 66,5 Salt: 31	€/t €/t	2015 2012	[16] [19]
Lime	85	€/t	2012	[19]
Fuel gas	561	€/t	2018	[17]
Sulphuric acid	Around 90	€/t	2015	[16]
Hydrogen	2259	€/t	2018	[16]
Nickel bullion	13 013	€/t	2018	[17]
Ferronickel	3 152	€/t	2015	[16]
Rough Nickel	13 156	€/t	2015	[16]
Nickel Powder	20 265	€/t	2015	[16]
All type of sulphur	302	€/t	2015	[16]
Rough sulphur non-refined	118,1	€/t	2015	[16]
Silica	1453,5	€/t	2015	[16]
Alumina	488	€/t	2012	[19]
Granulated slag	16,5	€/t	2015	[16]
Aluminium	1824	€/t	2018	[17]
Aluminium oxide	341,1 488	€/t €/t	2015 2010	[16] [19]
Lead bullion	2 515	€/t	2018	[17]
Lead	1 789	€/t	2010	[19]
Lead debris and waste	1 053,7	€/t	2015	[16]
Pure benzene	919	€/t	2018	[17]
Benzene	701,8 €	€/t	2015	[16]
Copper	5 772	€/t	2010	[17]
Copper alloys	1 933,2	€/t	2015	[16]
Antimony	6 868,9	€/t	2015	[16]
Diethyl ether	2 636	€/t	2018	[20]
Sulfuric acid	90.9	€/t	2015	[21]
Hydrocloric acid	78.7	€/t	2015	[22]
Methanol	372	€/t	2018	[17]
Anhydre ammonia	423	€/t	2015	[23]
Sand	155	€/t		[24]
Cooling water	1.26	€/m3	1995 but consider the inflation	[25]
Nickel	13 013	€/t	2018	[17]
Cobalt	74 424	€/t	2018	[17]
Aluminium	1 824	€/t	2018	[17]
Zinc	3 440	€/t	2010	[19]

Chrome	298	€/t	2015	[26]
Calcium carbonate	151.2	€/t	2015	[27]
Calcium oxide	224.7	€/t	2015	[28]

j. LHV

Fuels and waste fuels LHV are presented in SCALER D3.1.

k. Resource density

Table 13 : Resources density (Source: Strane)

Resource	Density	Source
Hydrogen	0,08988 kg/m3	[29]
Vacuum gas oil	0,925 g/mL	[30]
Diethyl ether	713 kg/m3	[31]
Acetaldehyde	788 kg/m3	[32]
Ethyl acetate	902 kg/m3	[33]
Ethyl propionate	884,3 kg/m3	[34]
BOF Gas	1,33 kg/Nm3	[35]
BF Gas	1,250 kg/Nm3	[35]
Crude oil	0.88 kg/L	[36]

l. Money change

For investment costs and operational costs, a money change calculator website [37] was used to convert money in Euros. The source year is selected by using the date of the publication or the date mentioned in the paper.

m. Inflation

In case of old papers and data, a website calculator was used to quantify the inflation.

n. Energy and water prices

According to Eurostat [38], in 2017 for EU 28 members, the price 0,0779 €/kWh for medium size industries.

In 2017, water average price in Europe is 4,01€/m3 according to a French bi-annual study [39].

3.2.5 Socio-economic indicators obtained with the methodology

All data previously gathered will enable the calculation of several socio-economic indicators provided:

- **Waste stream price.** A synergy is a waste valorisation. A waste does not have any intrinsic value. Most of the time, it is a cost source. A waste can have a value if it can be valorised as a commodity or if it presents another intrinsic value, a calorific power for example. In that case, the waste stream can replace the use of a conventional fuel. The associated price chosen for the socio-economic modelling is the substituted resource equivalent price.

- **Resource estimated price.** Depending the resource and data availability, three types of resources prices calculation were used:
  - If the resource can be directly sold on the market, the price used is the resource market price (e.g. pure lime market price).
  - Equivalent price of the substituted resource (e.g. natural gas for a gaseous fuel), for the same energy content in case of a fuel.
  - Sum of the chemical element prices.

- **The waste stream volume** is the total waste volume produced by the emitter industry.

- **Final volume recovered** corresponds to the elements of interest volume, after considering the technology recovery rate.
- **Value Added** is calculated as follow:

$$Final\ recoverable\ flow\ volume * Resource\ estimated\ price - Waste\ stream\ volume * Initial\ waste\ stream\ price\ (-OPEX\ when\ availabale)$$

- The **VAT** is 21,46 % of the value added.
- **Labour share** is considered 46% of the value added.
- **Direct jobs creation** is calculated through the total labour costs, 44 071€ per year and per employee.
- **Induced indirect jobs creation.** SCALER is a project funded under the SPIRE's public-private partnership. SPIRE is an alliance of 8 sectors of the European industry (cement, ceramics, chemicals, engineering, minerals and ore, non-ferrous metals, steel and water). These sectors include more than 450 individual enterprises, provide 6,8 million jobs and generate annually more than 1.600 billion euros in turnover, which represents 20% of the total European industry, both in terms of employment and turnover. SPIRE estimates that the process industry represents more than 56% of industrial value added in the EU and around 10% of all economic activity. It provides 6.3 million direct jobs in the EU and a further 19 million indirect jobs [40]. The process industry indirect jobs creation is therefore directly correlated with the direct jobs creation with a ratio:

$$SPIRE\ Ratio : Indirect\ jobs\ created = Direct\ job\ created * 3{,}02$$

  It is assumed that one industrial job creates 0.5 indirect jobs (this lower bound is largely underestimated, as an example, in France one direct job generates 1,5 indirect job [41])
- **Landfilling taxes** for both scenarios
- **Avoided waste management costs (landfilling and incineration) costs** for both scenarios
- **Economic viability radius** which is a rough estimation and will be deeply analysed in the D3.5.
- **Carbon tax reduction** based on the climate change indicator (CO2 emissions decrease) provided by the LCA
- **Total investment required in EU (associated number of technologies),** based on the CAPEX and operational yield

3.2.6 Assumptions

Assumptions considered for each synergy are detailed in synergies tables.

Procedures and technologies: it is assumed that in process industries procedures and treatment equipment operate 24h a day and 7 days a week. Total operating time in a year is around 8640 hours (5 days off for maintenance stop or company closure).

Lack of data: In case of missing data, the following action plan is defined (Table 14)

Table 14: Action plan in case of missing data (Source: Strane)

Missing data	Action plan
OPEX	Neglect the economic impact on the value added
CAPEX	No investment amount calculated

Recovery rates	Assume that 100% of the element of interest can be recovered
Receiving sector demand	The total volume can be valorised in the dedicated sector or another one
Sender sector emitting volume	Calculation made on the receiver sector demand
Sender/emitter sectors volume unknown	Synergy not modelled

3.2.7 Methodology limits and improvements

The methodology chosen focus on the resource intrinsic value evolution with the synergy implementation and do not take into account some important value in a socio-economic assessment perspective (e.g. raw material provider financial losses).

When no market price is available, the estimation of the price is a key challenge as it is based on the chemical components' prices and overestimate the financial benefits. As an example, in the case of Synergy #6, BOF slag estimated price is around 370€/t but the market value of granulated slag is around 16,5€/t. The same issue is encountered for fly ash, red mud, slags, and other residues price estimation.

Economic values of avoided environmental impacts present also a high uncertainty. Calculation are based on LCA results which were carried out with wide ranges and data uncertainty. LCA indicators like climate change are therefore overestimated as well and the final calculation of economic values of environmental and social impacts and the associated carbon tax.

4. Results

4.1 Overall results

82 synergy types were modelled. The estimated total value-added created is around 33 500 M€ for the full implementation of the 100 synergy types. 349 associated direct jobs could be created and between 174 902 and 1 056 410 indirect jobs could be generated.

The sum of environmental and social impacts economic value corresponds to 100'000 M€ and compensates for any financial losses related to implementation.

The full implementation of the 100 synergy types would reduce the carbon tax by 7'500'000 M€.

Table 15 presents the overall socio-economic assessment results of the synergy types modelled, with corresponding benchmarks, to have an idea of the order of magnitude of the potential.

Table 15: Socio-economic indicators rough results (Source: Strane)

Socio-economic indicators	Values
VA	33 513 576 237 €
VAT	7 192 013 460 €
Labour Share (€/y)	15 416 245 069 €
Direct jobs (number)	349 805
Indirect jobs (min)	174 902
Indirect jobs (max)	1 056 410
Total investment in EU	69 857 153 732
External impacts	
Climate change (kg. CO2-eq)	-188 673 037 706
Human health (DALY)	-169 762
Ecosystem quality (PDF.m2.y)	-42 398 542 668
Use of resources (MJ)	-3 139 168 587 042
€ Climate change	15 093 843 016 €
€ DALY	12 562 422 781 €
€ Ecosystem quality	59 357 959 735 €
€ Use of resources	12 556 674 348 €
Sum of external impacts economic value (€)	99 570 899 881 €
Carbon tax evolution (€/y)	-7 546 141 073 914 €
	-
Waste tax balance	-2 239 623 012 318 €
Waste treatment costs balance (€/y)	-41 144 034 496 €

Results clearly show the potential of industrial symbiosis in Europe, from an economic, social and environmental point of view. Industrial symbiosis is thus a key driver to leverage the circular economy in Europe.

As indicated in the Figure 7, most of the synergy types have a positive economic impact. It would be valuable for the emitter industries to implement this type of exchanges. Only 7% (not 7 synergy types), are not directly profitable.

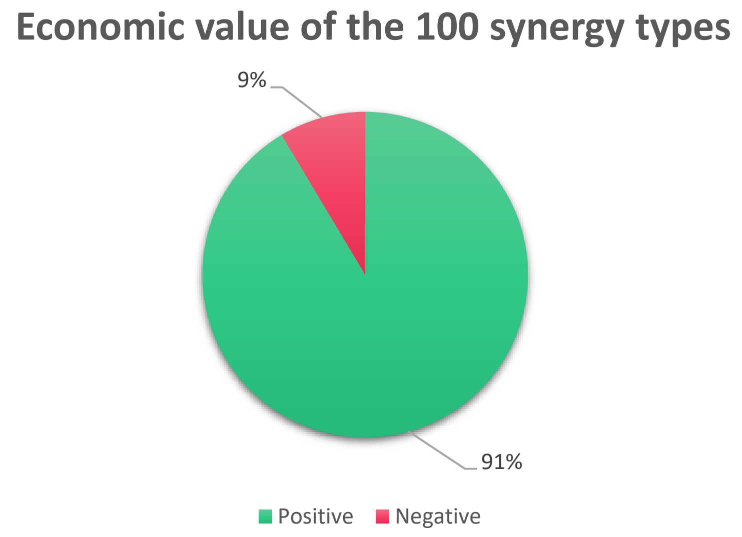


Figure 7: Economic assessment of the 100 synergy types (Source: Strane)

An added value pareto chart (Figure 8) was performed to isolate synergy types presenting most significant economic benefits. This figure clearly shows that the benefits come mainly from less than 30 synergies. 20 synergy types have an added value greater than 1% of the whole 100 synergy types sample.

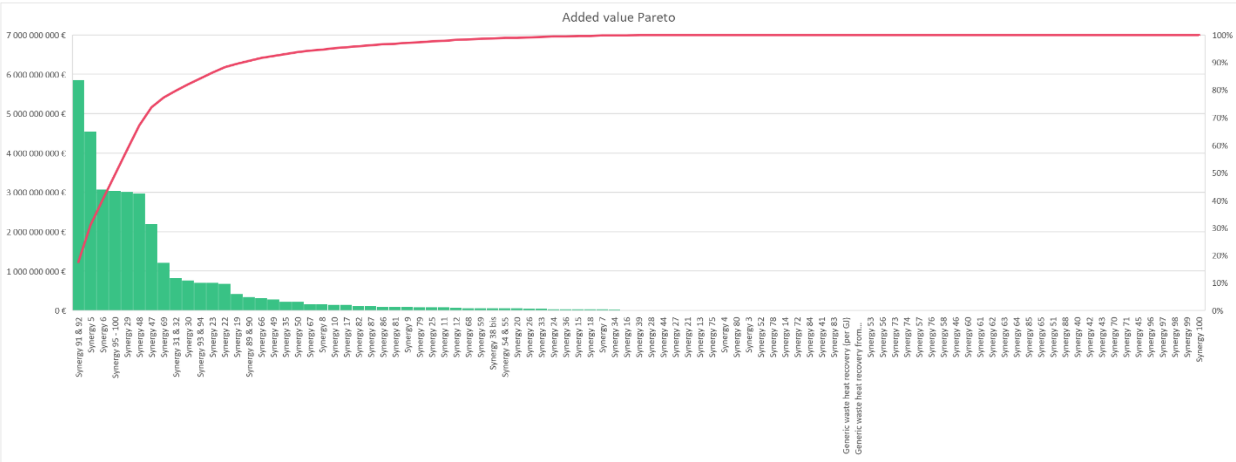


Figure 8: Synergy types added value pareto diagram (Source: Strane)

A zoom on theses most profitable synergy types is introduced in the Table 16: Synergy types added value pareto diagram (Source: Strane). 10 synergy types generate more than 80% of the total added value and 15 synergies more than 90% of the total added value.

An additional work is carried out on the next chapter to perform a more sensitive study on these 15 synergy types. It aims to weight the results obtained by considering whether synergies are common practices or not. By considering the implementation level, the study will thus provide a more sensitive analysis on the remaining potential.

Table 16: Synergy types added value pareto diagram (Source: Strane)

Synergy	Added value	Added value percentage	Cumulative percentage

Synergy 91 & 92	5 855 483 025 €	17,5 %	17,5 %
Synergy 5	4 546 523 765 €	13,6 %	31,0 %
Synergy 6	3 075 310 080 €	9,2 %	40,2 %
Synergy 95 - 100	3 036 854 220 €	9,1 %	49,3 %
Synergy 29	3 011 721 300 €	9,0 %	58,3 %
Synergy 48	2 974 456 845 €	8,9 %	67,1 %
Synergy 47	2 192 210 180 €	6,5 %	73,7 %
Synergy 69	1 218 978 479 €	3,6 %	77,3 %
Synergy 31 & 32	834 415 840 €	2,5 %	79,8 %
Synergy 30	764 186 346 €	2,3 %	82,1 %
Synergy 93 & 94	707 384 551 €	2,1 %	84,2 %
Synergy 23	701 970 000 €	2,1 %	86,3 %
Synergy 22	676 876 200 €	2,0 %	88,3 %
Synergy 19	425 492 331 €	1,3 %	89,6 %
Synergy 89 & 90	342 720 000 €	1,0 %	90,6 %

The distribution of environmental economic values (Figure 9: External environmental impacts estimated economic values (Source: Strane)) clearly show that the eco-system quality improvement is the most important from an economic point of view with 60% of the whole external impacts benefits. Climate change (15%), impacts on human health (13%) and the use of resource (12%) have roughly the same economic importance.

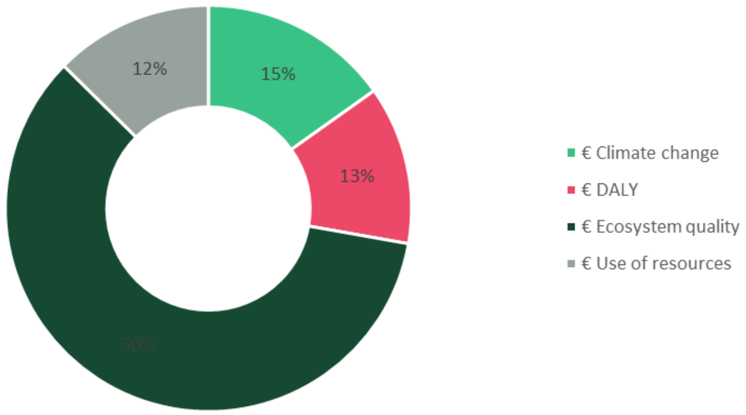
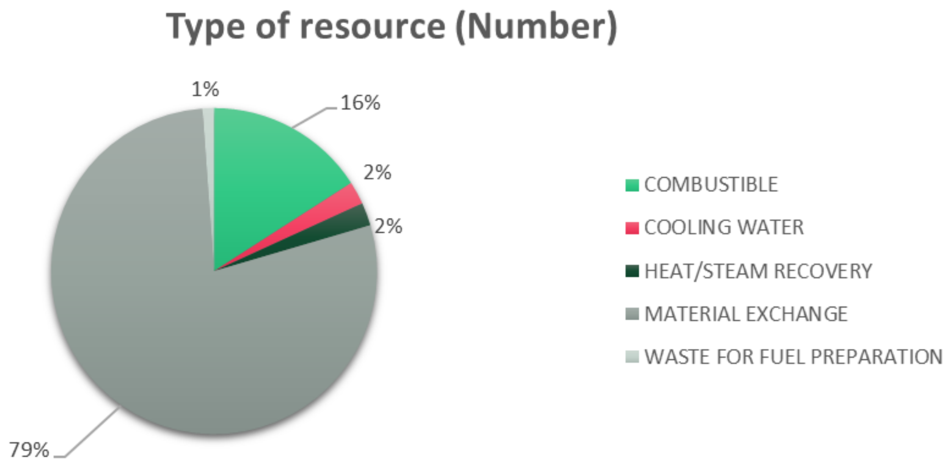


Figure 9: External environmental impacts estimated economic values (Source: Strane)

By comparing the number of synergies per type of resource and the added value sum per type of resource (Figure 10: Value added per type of resource (Source: Strane)), several learnings are highlighted:

- The creation of fuel from waste (6 synergy types) generate around 10% of the value added
- The 2 Heat/Steam recovery synergy types (heat recovery from 11 processes thorough Europe) represent 20% of the whole added value of the sample

- The 79% of material exchanges generate 52% of the value added. It means that some material exchanges do not have a great economic impact
- Colling water synergies avoid the water purchase



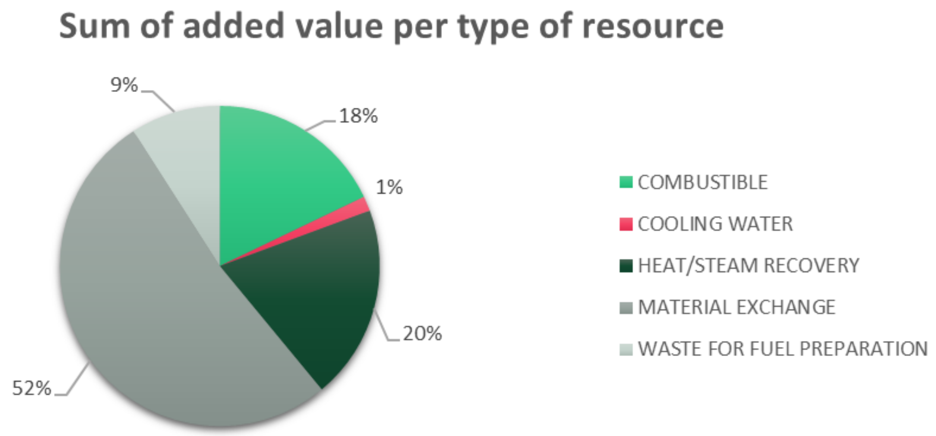


Figure 10: Value added per type of resource (Source: Strane)

The comparison between the number of direct/indirect synergies (updated after T3.3 and D3.2 findings) and the added value sum per type of synergy (Figure 11: Value added per type of synergy (Source: Strane)) shows that direct synergies are sensitively more profitable, probably because of low operating costs. In addition, indirect synergies require investments that decrease their immediate profitability.

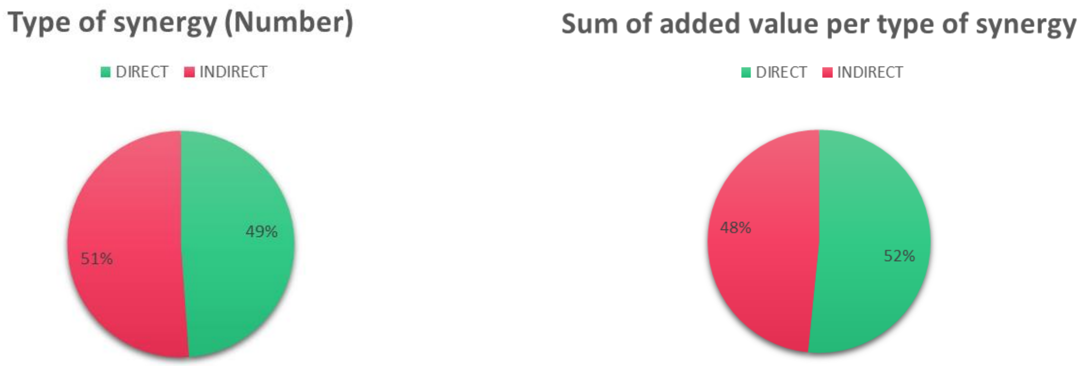


Figure 11: Value added per type of synergy (Source: Strane)

Synergy types for which financial losses are expected are synergy types 1, 2, 38 (and 38 bis), 76 that corresponds respectively to:

- Hydrogen production from coke oven gas
- Methanol production from COG
- Valorisation of Benzene solid residues from COG gas cleaning to organic chemical sites in ethylbenzene manufacturing. The synergy 38 bis is positive but there is an enormous sensitivity with the resource price.
- BOF slag aluminium oxide valorisation in non-ferrous metals industries for their aluminium content

Hydrogen and methanol recovery to provide raw material is not a profitable solution. Indeed, the market price of both resources is not high enough to balance the direct use as a fuel and the natural gas purchase costs avoided.

The same explanation applies to benzene residues that can be directly burnt on site due to its calorific power.

Unfortunately, it is difficult to economically justify the implementation of fuel synergies with high PCIs that can be directly used as fuel on site. On the other hand, considering the economic benefits of the avoided environmental impacts make it possible to turn the synergy viable. In addition, it is always better to give a product another life cycle before burning it.

BOF slags have a poor aluminium content and such a synergy type would require a huge operational expenditure, that is why the synergy 76 would not be profitable.

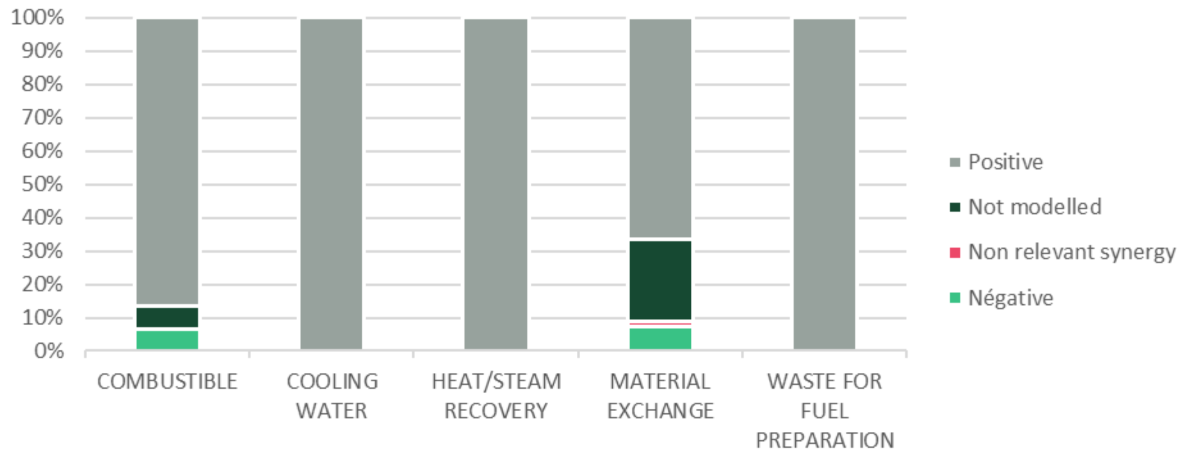


Figure 12: Economic impact per type of synergy (Source: Strane)

Synergy types job creation quartiles and deciles analysis presented in Table 17 and Table 18 show that 25% of the synergy types generate less than 64 direct jobs, 50% of the synergy types generate less than 633 jobs in Europe and 30% of the synergy types generate more than 1 640 jobs thorough Europe. That means only around 50% of the synergies will generate a significant value added and associated jobs thorough Europe and 30% of the synergies have a huge impact on the value added and employment in Europe.

Synergies which generate more than 1 000 jobs and 250 M€ per year in Europe are presented in the Table 19. It clearly shows that the maximum industrial symbiosis potential is concentrated in a few synergies.

Table 17: Number of direct jobs quartiles (Source: Strane)

Quartile	Number of direct jobs
Minimal	0
Quartile 1	64
Quartile 2	633
Quartile 3	2 664
Maximal	61 118

Table 18: Number of direct jobs deciles (Source: Strane)

Decile	Number of direct jobs
10%	2
20%	28
30%	91
40%	337
50%	633
60%	973
70%	1 640
80%	4 268
90%	16 787
100%	61 118

Nevertheless, some of these synergies **are already widely implemented thorough Europe**. As an example, if it still exists BF slags deposits in Europe, this synergy is a **current practice** and the potential is already mostly exploited. The following section aims at performing a more sensitive assessment of the industrial symbiosis economic benefit potential by excluding waste heat recovery which is the most significant and by far added value generator.

Table 19: 18 Synergies with the most significant economic impact on added value and job creation (Source: Strane)

Synergy	Jobs created (N)	Added value	Short description	Arbitrary estimation of the implementation level
91 & 92	61 118	5 855 483 025 €	Waste heat valorisation. Widely used in Europe but still a significant potential. Arbitrary estimation	60% already exploited
5	47 455	4 546 523 765 €	The annual demand of EAF dusts residues in waelz kiln operation is 603 000 t/y. Nevertheless, the annual EAF dusts production volume is around 12 574 960 t/y. That show a significant potential, but the production capacity is limited. We consider doubling the waelz kiln oxide production capacity	603 000 additional tons of EAF dusts can be valorised

6	32 099	3 075 310 080 €	According to Figure 16, 34% (Final deposit, interim storage, other) of steel slags do not have a valuable fate.	66 % already exploited
95 - 100	31 698	3 036 854 220 €	Not included in this section since it is full-fledged business	-
29	31 435	3 011 721 300 €	Full potential but modelling updated with a new price because the first estimated price was probably overestimated	Price update: 85€ as a calcium source even if the silicate content of red mud I more important
48	31 046	2 974 456 845 €	Most of the time reused directly in the process and mixed with COG but the synergy is commonly used	50% already exploited
47	22 882	2 192 210 180 €	Mainly directly reused on site but the synergy is commonly used. It is more interesting to valorise COG than BFG due to its higher LHV	70% already exploited
69	12 723	1 218 978 479 €	Already widely implemented	70% already exploited
31 & 32	8 709	834 415 840 €	Aluminium oxide residues are most of the time sold to cement, ceramic and insulation sector. Still deposits to exploit in cement and glass industries	50% already exploited
30	7 976	764 186 346 €	Highly implemented but still some BF deposits stored on site in EU	75% already exploited
93 & 94	7 383	707 384 551 €	Waste steam valorisation. Widely used in Europe but still a significant potential. Arbitrary estimation	60% already exploited
23	7 327	701 970 000 €	No reported utilisation in mineral wool production	Not implemented now
22	7 065	676 876 200 €	Price probably over estimated	Update price divided by two: 161,13€
19	4 441	425 492 331 €	This practice exists but may not be widespread unlike direct on-site combustion.	25% already exploited
89 & 90	3 577	342 720 000 €	No information	Same value conserved
66	3 315	317 625 000 €	BF slags are widely used in EU	75% already exploited
49	2 977	285 201 860 €	Most of the time reused directly in the process and mixed with COG but the synergy is commonly used	50% already exploited

The arbitrary estimation made it possible to perform an assessment probably closer to reality.

Heat and steam recovery are removed from the study in order to focus on the value added generated by the material exchanges.

The use of waste to produce conventional fuels (synergies 95 to 100) is also out of scope.

Final results of the socio-economic assessment are introduced in the Table 20.

Table 20: Final SEA indicators (Source: Strane)

Socio-Economic indicators	Value
VA	12 664 819 709 €
VAT	2 717 870 310 €
Labour Share (€/y)	5 825 817 066 €/y
Direct jobs (number)	132 192
Indirect jobs (min)	66 096
Indirect jobs (max)	399 219

The final SEA (excluding synergies 95 – 100 which are a core business currently exploited) shows that the industrial symbiosis potential in EU is equivalent to:

- 12 664 M€/y of added value compare to the initial use of the waste stream
- 5 825 M€/y of labour share
- 132 192 direct jobs created and between 66 000 and 400 000 indirect jobs generated

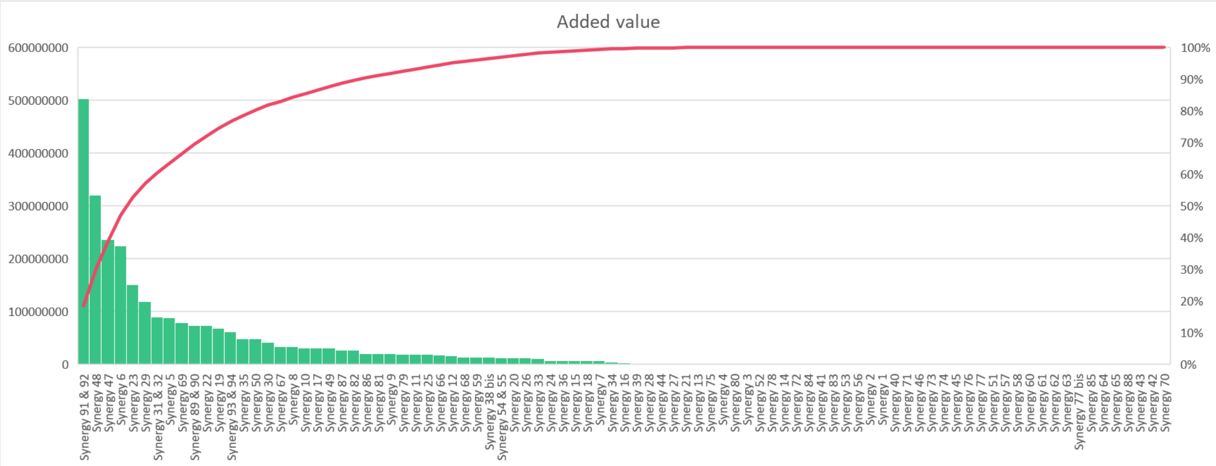


Figure 13: More sensitive added value pareto (Source: Strane)

4.2 Focus on synergy 38

Two assessments were carried out for this synergy in order to highlight the methodology's limits and sensitivity. In the case of synergy 38, the price of an economic value rate of 701,8 € was applied whereas in the 38 bis, the price applied was 919€/t.

The two assessments' results are significantly different. In the first case, the value-added decrease about 40M€ and in the second case increase about 60M€. This synergy is therefore broadly equivalent to the initial scenario from an economic point of view. That means a company who can recover benzene do not have an economic advantage to valorise it otherwise than burning it like a fuel. Unfortunately, in that specific case, the avoiding environmental impacts are not huge because the extraction of coal to replace benzene require a lot of negative actions on the environment.

There is a strong impact of market price fluctuations on economic benefits and viability.

This may also explain why industrial sites choose storing resources on their site and waiting for the right time to sell at a more profitable moment.

5. Socio-economic assessment of 100 synergy types sample

5.1 Synergy #1

Baseline business scenario

The COG has a valuable calorific value (18,7 MJ/m3). It is most of time directly reused on the site to provide furnaces and replace conventional gaseous fuels required for the combustion (in the same or other steel processes). The economic benefit of the baseline scenario is to avoid the use and purchase of another gaseous fuel as natural gas.

Synergy

A partial volume of the waste stream is recoverable to produce hydrogen. It is assumed that the remaining flow is still incinerated to avoid natural gas purchase and consumption. The global economic value of the synergy considers:

- Economic value of the recoverable hydrogen
- Equivalent natural gas consumption avoided economic value

Assumptions and calculation method

- The minimum COG production volume (18 122 400 000 m3/y) was used for the calculation.
- The minimum H2 content was retained to use a conservative approach (H2 COG concentration is 39 - 65 %)
- The average value of the hydrogen separation CAPEX was used to calculate the required investment in whole Europe (10 – 50 €/Nm3/h)
- The hydrogen can be valorised as a commodity
- Price of the natural gas: 0,260369888 €/Nm3
- The membrane separator recovery rate (85%) was used to calculate the final hydrogen flow recovered

Table

Table 21: Synergy 1 (Source: Strane)

Synergy 1	
Waste stream price in BaU scenario (€/Unit)	0,12096688
Waste stream volume (Unit/y)	18 122 400 000
Substituted material equivalent price (€/Unit)	0,204
Final volume recovered (Unit/y)	5 853 535 200
Operational costs (€/y)	Unknown
VA	-998 088 999 €
VAT	-214 189 899 €
Labour Share (€/y)	-459 120 940 €
Direct jobs (€)	-10418
Indirect jobs (min)	-5209
Indirect jobs (max)	-31462
Investment	
CAPEX	35 €/Nm/h
Total investment in EU	
External impacts	

Climate change (kg. CO2-eq)	-1892599900
Human health (DALY)	-784,75039
Ecosystem quality (PDF.m2.y)	-162736080
Use of resources (MJ)	-67669960000
€ Climate change	151 407 992 €
€ DALY	58 071 529 €
€ Ecosystem quality	227 830 512 000 €
€ Use of resources	270 679 840 €
Sum of external economic impacts (€)	228 310 671 361 €
Carbon tax evolution (€/y)	-75 703 996 000 €
Waste tax	
Waste tax BaU (€/y)	0
Waste tax Synergy (€/y)	0
Waste tax balance	0
Viability distance (100% of the resource price)	0
Viability distance (10% of resource price)	0
Waste treatment costs BaU (€/y)	0
Waste treatment costs Synergy (€/y)	0
Waste treatment costs balance (€/y)	0

Conclusion or comments

The hydrogen economic value is lower than the avoiding natural gas consumption cost in the baseline scenario. The remaining flow need to be valorised as well. This synergy is not profitable but environmental impact economic value can make the synergy viable.

The viability radius of the hydrogen transportation is around 13 000 km.

5.2 Synergy #2

Baseline business scenario

The COG has a valuable calorific value (18,7 MJ/m3). It is most of time directly reused on the site to provide furnaces and replace conventional gaseous fuels required for the combustion (in the same or other steel processes). The economic benefit of the baseline scenario is to avoid the use and purchase of another gaseous fuel as natural gas.

Synergy

The COG waste stream is recoverable to produce methanol.

Assumptions and calculation method

- The minimum COG production volume (18 122 400 000 m3/y) was used for the calculation.
- According to the technology database (D3.3) the process recovery rate is 1449 m3COG/t methanol.
- As defined in the technology database (D3.3), the process OPEX is 281.81€/t.
- The process generates 1,56 tCO2/t methanol, the tax associated to the CO2 emission was retained in the carbon tax evolution.
- As the flow studied is gaseous, the economic viability radius is not calculated in this study.
- The incineration takes place in the site.

Table

Table 22: Synergy 2 (Source: Strane)

Synergy 2	
Waste stream price in BaU scenario (€/Unit)	0,12096688
Waste stream volume (Unit/y)	18 122 400 000
Substituted material equivalent price (€/Unit)	372
Final volume recovered (Unit/y)	12506832
Operational costs (€/y)	3 524 550 410 €
VA	-1 064 218 975 €
VAT	-228 381 392 €
Labour Share (€/y)	-489 540 728 €
Direct jobs (€)	-11108
Indirect jobs (min)	-5554
Indirect jobs (max)	-33546
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	-10224519000
Human Heath (DALY)	-9451,517
Ecosystem quality (PDF.m2.y)	-1195999900
Use of resources (MJ)	-5,53952E+11
€ Climate change	817 961 520 €
€ DALY	699 412 258 €
€ Ecosystem quality	1 674 399 860 000 €
€ Use of resources	2 215 806 080 €
Sum of external economic impacts (€)	1 678 133 039 858 €
Carbon tax evolution (€/y)	-408 200 333 665 €
Waste tax	
Waste tax BaU (€/y)	2 221 806 240 000 €
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	-2 221 806 240 000 €
Viability distance (100% of the resource price)	
Viability distance (10% of the good transported price)	
Waste treatment costs BaU (€/y)	
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	0 €

Conclusion or comments

These results should be interpreted remembering the fact that the economic value of the residue stream is not known. In addition, transport and investment costs would reduce the final figures.

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of -1 064 M€/y, and an associated VAT around 220 M€. This synergy is therefore not sustainable. This result is mainly due to operating expenses (3 524 M€/y). Nevertheless, it is interesting to notice that economic value with external factors is 1 678 133 M€. Environmental and human health impact would be significantly improved. The implementation of this synergy will generate a decrease of the carbon tax up than 408 200 M€.

5.3 Synergy #3

Baseline business scenario

The primary liquid fuel from organic chemical industry is mainly burnt to generate heat and avoid fuel consumption on site.

Synergy

The aim of this synergy is to recover waste fuels from ethyl acetate cleaning operation and send it to cement sector for clinker kiln combustible supply. This flow is composed by two fractions, organic and acid. The organic one (composed by a mix of waste fuel: (Acetaldehyde, Diethyl ether, Ethyl acetate, ethyl propionate) is sent to the cement sector to provide fuel for kiln. The acid acetic fraction is directly reused in the ethyl acetate production process.

Assumptions and calculation method

- The incineration charges are 200 €/t.
- The price of the liquid has been based on the price of the diethyl ether (2636 €/t) to sell it to cement sector.
- The recovering rate is 75% (between 50% and 98%).
- Price of the crude oil: 390,72 €/t.

Table

Table 23: Synergy 3 (Source: Strane)

Synergy 3	
Waste stream price in BaU scenario (€/Unit)	197
Waste stream volume (Unit/y)	2400
Substituted material equivalent price (€/Unit)	2636
Final volume recovered (Unit/y)	1026
Operational costs (€/y)	NA
VA	2 231 277 €
VAT	478 832 €
Labour Share (€/y)	1 026 388 €
Direct jobs (€)	23
Indirect jobs (min)	12
Indirect jobs (max)	70
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-4998581

Human health (DALY)	-2,2620575
Ecosystem quality (PDF.m2.y)	-334880
Use of resources (MJ)	-49503758
€ Climate change	399 887 €
€ DALY	167 392 €
€ Ecosystem quality	468 832 126 €
€ Use of resources	198 015 €
Sum of external economic impacts (€)	469 597 420 €
Carbon tax evolution (€/y)	-199 943 260 €
Waste tax	
Waste tax BaU (€/y)	294240
Waste tax Synergy (€/y)	125788
Waste tax balance (€/y)	-168452
Viability distance (100% of the resource price)	12427
Viability distance (10% of the good transported price)	1506
Waste treatment costs BaU (€/y)	480000
Waste treatment costs Synergy (€/y)	205200
Waste treatment costs balance (€/y)	-274800

Conclusion or comments

The value added of the valorisation of the whole flow is around 2,2 M€/y, and the associated VAT is around 479 k€. The investment for the synergy implementation is not defined because it is related to the diameter column of the equipment, and the OPEX is quite marginal because it is mostly associated to maintenance procedures. The expected direct job creation is around 23 throughout Europe.

The implementation of this synergy will generate a decrease of the carbon tax of 200 M€. Environmental and human health impact would be significantly improved.

5.4 Synergy #4

Baseline business scenario

Coke residues produced during cleaning operations is send to a utility. The cost of this service is around 200 – 600 €/t of coke residues. The utility company use the coke as a fuel to produce heat which is sold to these clients. The economic benefit of the baseline scenario is to avoid the use and purchase of another solid fuel as coal.

Synergy

The total volume of coke residues can be recovered. No technology is required to treat the coke residues. The global economic value of the synergy considers the market price of the coke.

Assumptions and calculation method

- The minimum costs for the stream management by the utility was retained (200 €/t)
- Coke market price 120 – 300 €/t (Industrial partners and Strane). The final coke price value is the average of the range: 210 €/t

- The coke can be valorised as a commodity. The average price of the coke is around 210€/t (120 – 300 €/t; source: industrial partners and Strane)

Table

Table 24: Synergy 4 (Source: Strane)

Synergy 4	
Waste stream price in BaU scenario (€/m3)	41,87
Waste stream volume (m3/y)	15600
Substituted material equivalent price (€/m3)	210
Final volume recovered (m3/y)	15600
Operational costs (€/y)	
VA	2 622 828 €
VAT	562 859 €
Labour Share (€/y)	1 206 501 €
Direct jobs	27
Indirect jobs (min)	14
Indirect jobs (max)	83
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment required
External impacts	
Climate change (kg. CO2-eq)	-267634600
Human health (DALY)	-736,97343
Ecosystem quality (PDF.m2.y)	-63436589
Use of resources (MJ)	-14065594000
€ Climate change	21 410 768 €
€ DALY	54 536 034 €
€ Ecosystem quality	88 811 224 600 €
€ Use of resources	56 262 376 €
Sum of external economic impacts (€)	88 943 433 778 €
Carbon tax evolution (€/y)	-10 705 384 000 €
Waste tax	
Waste tax BaU (€/y)	0
Waste tax Synergy (€/y)	0
Waste tax balance (€/y)	0
Viability distance (100% of the resource price)	961
Viability distance (10% of the good transported price)	120
Waste treatment costs BaU (€/y)	3 120 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-3 120 000 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 16 000 000 €/y. The expected job creation is around 80 throughout Europe and economic benefits from avoided environmental and social impacts corresponds to around 140 000 000€.

No investment is required for this synergy. The viability radius of the coke transportation and valorisation in steel industries is around 1 200 km.

5.5 Synergy #5

Baseline business scenario

Dusts from EAF are sent to a waste management company. Associated landfilling costs are landfilling tax and gate fees.

Synergy

Zinc residues from are send tons of non-ferrous metals industries in waelz kiln process to be transformed in waelz oxydes. Residues produced (salt and slag) are sent to waste management industries for landfill.

The annual demand of zinc residues in waelz kiln operation is 603 000 t/y.

Assumptions and calculation method

- Dusts production in EAF: 4 – 300 g/t. The retained value is the average 152 g/t. The total volume of dust produced is 152 g/t.
- Zinc content: 200 – 24 000 mg/kg. The retained value is the average 12 100 mg/kg of dusts.
- The retained value of zinc available volume is 1 001 060 t/y
- Theoretical 100% of recovery rate
- 3,02 tons of EAF dusts to produce 1 ton of waelz oxides
- 55 – 70 % of zinc content in waelz oxides
- Residues from the process: waelz slag (1600 kg/ t dry product) and salt residue from waelz oxide washing (130 kg/t product)
- The required investment to process the whole EAF dusts in Europe has been estimated around 1 995 000 000€ (considering US$ conversion in Euros and inflation rate).
- Operational costs to process the whole European flow has been estimated at 1 117 122 399 €/y (considering US$ conversion in Euros and inflation rate).

Table

Table 25: Synergy 5 (Source: Strane)

Synergy 5	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	12 574 960
Substituted material equivalent price (€/Unit)	2 315
Final volume recovered (Unit/y)	2 290 142
Operational costs (€/y)	1 117 122 399
VA	4 546 523 765 €
VAT	975 684 000 €
Labour Share (€/y)	2 091 400 932 €
Direct jobs (€)	47455
Indirect jobs (min)	23728
Indirect jobs (max)	143315

Investment	
CAPEX	
Total investment in EU	1 994 861 427 €
External impacts	
Climate change (kg. CO2-eq)	-38688,093
Human health (DALY)	-0,18054476
Ecosystem quality (PDF.m2.y)	-155601,88
Use of resources (MJ)	-436825,8
€ Climate change	3 095 €
€ DALY	13 360 €
€ Ecosystem quality	217 843 €
€ Use of resources	1 747 €
Sum of external economic impacts (€)	236 045 €
Carbon tax evolution (€/y)	-1 547 524 €
Waste tax	
Waste tax BaU (€/y)	488 159 947 €
Waste tax Synergy (€/y)	279 641 306 €
Waste tax balance	-208 518 641 €
Viability distance (100% of the resource price)	11344
Viability distance (10% of resource price)	1323
Waste treatment costs BaU (€/y)	667 730 376 €
Waste treatment costs Synergy (€/y)	210 379 289 €
Waste treatment costs balance (€/y)	-457 351 087 €

Conclusion or comments

Results obtained above consider zinc and lead content of the waelz oxides.

Currently, the annual demand of EAF dusts residues in waelz kiln operation is 603 000 t/y (and the annual EAF dusts production volume is around 12 574 960 t/y) that show there is a still a huge potential for this synergy.

The total investment required in Europe is around 2 000 M€ with a potential value added of 4 500M€ (including operational costs). Value added and jobs creation are probably over estimated due to the significant economic value of zinc and lead.

This synergy is viable with truck transportation in all Europe.

5.6 Synergy #6

Baseline business scenario

BOF slags are often stored on site, send to waste management industries for landfill or send to road construction operation. Even if a lot of companies store BOF slags directly on site, the retained scenario is landfill.

Synergy

The aim of this synergy is to valorise BOF slag in cement industries, which is not a widely used practice, unlike the use of BF slags. BOF slags can directly be reused in cement industries but a process allows to separate iron oxide and improve the stream characteristics/quality for the raw materials preparation step.

The BOF economic value is calculated as fallow:

Table 26: BOF slag equivalent economic value (Source: Strane)

BOF slag volume	15360000 t/y				
Composition	%	t	Price		Total price
SiO2	22,5	3456000	1453,5	€/t	5 023 296 000,00 €
CaO	44	6758400	85	€/t	574 464 000,00 €
Fe	8,5	1305600	71	€/t	92 697 600,00 €
Total				€/y	5 690 457 600,00 €
Price				€/t	370,47 €

Additives are required to treat the flow and make it compliant with the cement requirements.

Table 27: BOF slag additive prices (Source:Stane)

Volume total	15360000 t/y			
Additives used	t	Price	Unit	Total Price
Kaolin	0,41	197,1	€/t	1 241 256 960 €
Carbon powder	0,06	1182	€/t	1 089 331 200 €
Total OPEX				2 330 588 160 €

Assumptions and calculation method

- Recovery rate: 0,95%
- Equipment investment: 10.72 USD/ton of BOF slag; Water quenching treatment and grinding cost: 413.6 USD/ton of BOF slag
- Associated to reagent costs (Kaolin and carbon powder)
- 1 ton of steel slag needs 0.41 tons of kaolin and 0.06 tons of carbon powder

Table

Table 28: Synergy 6 (Source: Strane)

Synergy 6	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	15 360 000
Substituted material equivalent price (€/Unit)	370
Final volume recovered (Unit/y)	14 592 000
Operational costs (€/y)	2 330 588 160
VA	3 075 310 080 €
VAT	659 961 543 €
Labour Share (€/y)	1 414 642 637 €
Direct jobs (€)	32099
Indirect jobs (min)	16050
Indirect jobs (max)	96940
Investment	
CAPEX	9,56
Total investment in EU	146 855 141 €
External impacts	

Climate change (kg. CO2-eq)	-10010534000
Human health (DALY)	-5119,4973
Ecosystem quality (PDF.m2.y)	-3014204400
Use of resources (MJ)	-72080234000
€ Climate change	800 842 720 €
€ DALY	378 842 800 €
€ Ecosystem quality	4 219 886 160 000 €
€ Use of resources	288 320 936 €
Sum of external economic impacts (€)	4 221 354 166 456 €
Carbon tax evolution (€/y)	-400 421 360 000 €
Waste tax	
Waste tax BaU (€/y)	596 275 200 €
Waste tax Synergy (€/y)	29 813 760 €
Waste tax balance	-566 461 440 €
Viability distance (100% of the resource price)	1204
Viability distance (10% of resource price)	212
Waste treatment costs BaU (€/y)	815 616 000 €
Waste treatment costs Synergy (€/y)	40 780 800 €
Waste treatment costs balance (€/y)	-774 835 200 €

Conclusion or comments

This synergy presents a real potential as BOF slags are not widely used in cement industries. Nevertheless, the receiving capacity might be a problem.

The total investment required in Europe is around 146 855 141€ with a potential value added of 3 500 000 000€ (including operational costs). The valorisation of the whole BOF flows in Europe could lead to the creation of 35 000 jobs in Europe.

The transport of this flow is economically viable on 2 000km.

5.7 Synergy #7

Baseline business scenario

The sulphate process generates 5 470 kg od gypsum per ton of titanium dioxide produced (2 270 kg of white gypsum and 3 200 kg of red gypsum), or 2 543 550 t of gypsum per year

The white gypsum is currently directly valorised as a commodity and the whole Red gypsum fraction is sent to landfill.

Synergy

For gypsum valorisation in cement industries, the best results were obtained incorporating up to 10% of Red Gypsum with clinker while complying with all quality requirements. The maximum amount of red gypsum incorporation in the whole Europe is then 11 800 000 t/y (118 000 000 t of clinker produced per year).

Only the benefit as red gypsum used were modelled.

Assumptions and calculation method

- Red gypsum volume: 3 200 kg/t of TiO_2 or 1 488 000 t/y
- No required equipment

Table

Table 29: Synergy 7 (Source: Strane)

Synergy 7	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	1 488 000
Substituted material equivalent price (€/Unit)	20
Final volume recovered (Unit/y)	1 488 000
Operational costs (€/y)	
VA	29 760 000 €
VAT	6 386 496 €
Labour Share (€/y)	13 689 600 €
Direct jobs (€)	311
Indirect jobs (min)	155
Indirect jobs (max)	938
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment required
External impacts	
Climate change (kg. CO2-eq)	-36038975,65
Human health (DALY)	-2228,608
Ecosystem quality (PDF.m2.y)	-87489111,52
Use of resources (MJ)	-708898047,5
€ Climate change	2 883 118 €
€ DALY	164 916 992 €
€ Ecosystem quality	122 484 756 124 €
€ Use of resources	2 835 592 €
Sum of external economic impacts (€)	122 655 391 827 €
Carbon tax evolution (€/y)	-1 441 559 026 €
Waste tax	
Waste tax BaU (€/y)	57 764 160 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-57 764 160 €
Viability distance (100% of the resource price)	114
Viability distance (10% of resource price)	11
Waste treatment costs BaU (€/y)	79 012 800 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-79 012 800 €

Conclusion or comments

This synergy presents a real potential as the valorisation of red gypsum is not currently used.

With an incorporation rate of 10%, cement industries can absorb the red gypsum volume produced by inorganic chemical sites.

This synergy generates 168 000 000€ of added value thorough Europe and can potentially create 1700 (without considering flow transportation).

No investment is required for this synergy and the flow transport is economically viable for 114 km.

5.8 Synergy #8

Baseline business scenario

Flue-gas desulphurization (FGD) process for emission control of coal combustion plants generate artificial gypsum. It is assumed that this flow is currently send to landfill. The annual artificial gypsum production is unknown.

Synergy

The flow modelled for the socio-economic assessment is the same than the LCA provided in D3.3.

Assumptions and calculation method

- The gypsum generated is sent to landfill which generate an enormous landfilling tax and is probably a wrong assumption.

Table

Table 30: Synergy 8 (Source: Strane)

Synergy 8	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	7 850 000
Substituted material equivalent price (€/Unit)	20
Final volume recovered (Unit/y)	7 850 000
Operational costs (€/y)	
VA	157 000 000 €
VAT	33 692 200 €
Labour Share (€/y)	72 220 000 €
Direct jobs (€)	1639
Indirect jobs (min)	819
Indirect jobs (max)	4949
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment required
External impacts	
Climate change (kg. CO2-eq)	-126775460
Human health (DALY)	-640,70159
Ecosystem quality (PDF.m2.y)	-153481360
Use of resources (MJ)	-2546866600
€ Climate change	10 142 037 €
€ DALY	47 411 918 €
€ Ecosystem quality	214 873 904 000 €
€ Use of resources	10 187 466 €
Sum of external economic impacts (€)	214 941 645 421 €
Carbon tax evolution (€/y)	-5 071 018 400 €

Waste tax	
Waste tax BaU (€/y)	304 737 000 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-304 737 000 €
Viability distance (100% of the resource price)	114
Viability distance (10% of resource price)	11
Waste treatment costs BaU (€/y)	416 835 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-416 835 000 €

Conclusion or comments

This synergy type presents a potential as the valorisation of gypsum from combustion plants is not widely used.

This synergy generates 160 M€ of added value thorough Europe and can potentially create 1 600 jobs (without considering flow transportation).

No investment is required for this synergy and the flow transport is economically viable for a distance of 114 km.

5.9 Synergy #9

Baseline business scenario

Usually, the flow of SO2 produced is released into the air. It therefore has no economic value.

Synergy

The aim of this synergy is to recover sulphuric acid, as a by-product of copper primary smelting route, and provide sulphate process in inorganic chemical industries. The technology database from D3.3 does not provide information on potential residues. Therefore, the global economic value of the synergy considers only the sulfuric acid stream economic value.

Assumptions and calculation method

- Sulfuric acid annual volume is 1 018 000 t/y.
- As there are 104 sites in Europe, 104 pieces of equipment will be considered when calculating the investment. Indeed, according to the technology database (D3.3), one piece of equipment can handle between 11 and 1200 MTPD (Metric Ton Per Day), and the 104 European sites process approximatively 2800 t/day of sulfuric acid (27 t/day/site).

Table

Table 31: Synergy 9 (Source: Strane)

Synergy 9	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	90,9
Final volume recovered (Unit/y)	1018000
Operational costs (€/y)	
VA	92 536 200 €

VAT	19 858 269 €
Labour Share (€/y)	42 566 652 €
Direct jobs (€)	966
Indirect jobs (min)	483
Indirect jobs (max)	2917
Investment	
CAPEX	2900000
Total investment in EU	301600000
External impacts	
Climate change (kg. CO2-eq)	-110097770
Human health (DALY)	-804,60463
Ecosystem quality (PDF.m2.y)	-81044672
Use of resources (MJ)	-7526784100
€ Climate change	8 807 822 €
€ DALY	59 540 743 €
€ Ecosystem quality	113 462 540 800 €
€ Use of resources	30 107 136 €
Sum of external economic impacts (€)	113 560 996 501 €
Carbon tax evolution (€/y)	-4 403 910 800 €
Waste tax	
Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	519
Viability distance (10% of the good transported price)	52
Waste treatment costs BaU (€/y)	
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	

Conclusion or comments

The value added of the valorisation of the whole flow is around 92 M€/y, and the associated VAT is around 20 M€. An investment of 301 M€ would be necessary and would be amortized in approximately three years. The expected job creation is around 966 throughout Europe.

The implementation of this synergy will generate a decrease of the carbon tax up than 4 400 M€. Environmental and human health impact would be significantly improved.

These results should be interpreted remembering that there are no data available on residues.

5.10Synergy #10

Baseline business scenario

Usually, the flow of SO2 produced is released into the air. It therefore has no economic value.

Synergy

The aim of this synergy is to recover sulphuric acid, as a by-product of copper primary smelting route, and provide sulphate process in inorganic chemical industries. The technology database from D3.3 does not provide information on potential residues. Therefore, the global economic value of the synergy considers only the sulfuric acid stream economic value.

Assumptions and calculation method

- Sulfuric acid annual volume is 1 586 580 t/y. This data originates from the synergies environmental impact assessment (D3.4) and corresponds to the mean sector demand. The emitting sector data could be considered to estimate the potential for synergy if the receiving sector were to invest.
- As there are 33 sites in Europe, 33 pieces of equipment will be considered when calculating the investment. Indeed, according to the technology database (D3.3), one piece of equipment can handle between 11 and 1200 MTPD (Metric Ton Per Day), and the 33 European sites process approximatively 4200 t/day of sulfuric acid (40 t/day/site).

Table

Table 32: Synergy 10 (Source: Strane)

Synergy 10	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	90,9
Final volume recovered (Unit/y)	1586580
Operational costs (€/y)	
VA	144 220 122 €
VAT	30 949 638 €
Labour Share (€/y)	66 341 256 €
Direct jobs (€)	1505
Indirect jobs (min)	753
Indirect jobs (max)	4546
Investment	
CAPEX	2900000
Total investment in EU	95700000
External impacts	
Climate change (kg. CO2-eq)	-171590290
Human health (DALY)	-1253,9976
Ecosystem quality (PDF.m2.y)	-126310270
Use of resources (MJ)	-11730693000
€ Climate change	13 727 223 €
€ DALY	92 795 822 €
€ Ecosystem quality	176 834 378 000 €
€ Use of resources	46 922 772 €
Sum of external economic impacts (€)	176 987 823 818 €
Carbon tax evolution (€/y)	-6 863 611 600 €
Waste tax	

Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	519
Viability distance (10% of the good transported price)	52
Waste treatment costs BaU (€/y)	
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	

Conclusion or comments

The value added of the valorisation of the whole flow is around 144 M€/y, and the associated VAT is around 31 M€. An investment of 95 M€ would be necessary and would be amortized in approximately less than one year. The expected job creation is around 1 500 throughout Europe.

The implementation of this synergy will generate a decrease of the carbon tax up than 6 800 M€. Environmental and human health impact would be significantly improved.

These results should be interpreted remembering that there are no data available on residues.

5.11Synergy #11

Baseline business scenario

It is assumed that lime used in sugar manufacturing in internally reused until a quality degradation. At the end of the cycle, it is sent to landfill.

Synergy

The aim of this synergy is to send sugar production plant lime to calcium carbide process to substitute lime purchased on the market. This synergy is not implemented yet. This synergy was technically assessed as a NOGO in the D3.2. However, the composition of sugar lime sludge could potentially be compliant with its use in calcium carbide manufacturing if metal oxide composition does not exceed acceptable limits. In case of uncompliant composition, complementary treatments might be needed

The whole flow is modelled to estimate the potential benefits. The result could be interesting to focus researches activities on the development and implementation of such a synergy.

Assumptions and calculation method

- Price of the lime on the market: 85€/t
- The whole flow is modelled

Table

Table 33: Synergy 11 (Source: Strane)

Synergy 11	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	1 002 000
Substituted material equivalent price (€/Unit)	85
Final volume recovered (Unit/y)	1 002 000

Operational costs (€/y)	
VA	85 170 000 €
VAT	18 277 482 €
Labour Share (€/y)	39 178 200 €
Direct jobs (€)	889
Indirect jobs (min)	444
Indirect jobs (max)	2685
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment required
External impacts	
Climate change (kg. CO2-eq)	-44467283
Human health (DALY)	-55,224909
Ecosystem quality (PDF.m2.y)	-24095060
Use of resources (MJ)	-651766320
€ Climate change	3 557 383 €
€ DALY	4 086 643 €
€ Ecosystem quality	33 733 084 000 €
€ Use of resources	2 607 065 €
Sum of external economic impacts (€)	33 743 335 091 €
Carbon tax evolution (€/y)	-1 778 691 320 €
Waste tax	
Waste tax BaU (€/y)	38 897 640 €
Waste tax Synergy (€/y)	0 €
Waste tax balance (€/y)	-38 897 640 €
Viability distance (km)	486
Waste treatment costs BaU (€/y)	53 206 200 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-53 206 200 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 85 M€ and an associated VAT around 18M€. This value added can generate around 900 direct jobs.

The implementation of this synergy will generate 50M€ of costs saving for the emitting industries, a decrease of the carbon tax up than 1 500 M€. Environmental and human health impact would be significantly improved.

Indeed, this synergy, which is technically unviable now, has an interesting potential for next developments and some research effort might be develop infield t confirm the compliance between sugar industries and calcium carbide industries.

5.12Synergy #12

Baseline business scenario

Salt slag are sent to landfill and do not have any intrinsic value.

Synergy

The aim of this synergy is to recover salt from salt slag and send it to sodium chlorate production companies to substitute industrial salt purchased on the market. The recovery route is a partial salt slag recycling process.

Assumptions and calculation method

- Operational costs are similar to classic waste management costs (only avoid 'future liability'). As the company must pay these costs anyway, they have been overlooked.
- Industrial salt price defined in Table 12

Table

Table 34: Synergy 12 (Source: Strane)

Synergy 12	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	3 100 000
Substituted material equivalent price (€/Unit)	66,5
Final volume recovered (Unit/y)	1 085 000
Operational costs (€/y)	
VA	72 152 500 €
VAT	15 483 927 €
Labour Share (€/y)	33 190 150 €
Direct jobs (€)	753
Indirect jobs (min)	377
Indirect jobs (max)	2274
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment required
External impacts	
Climate change (kg. CO2-eq)	-654785280
Human health (DALY)	-298,90257
Ecosystem quality (PDF.m2.y)	-105422790
Use of resources (MJ)	-3396080800
€ Climate change	52 382 822 €
€ DALY	22 118 790 €
€ Ecosystem quality	147 591 906 000 €
€ Use of resources	13 584 323 €
Sum of external economic impacts (€)	147 679 991 936 €

Carbon tax evolution (€/y)	-26 191 411 200 €
Waste tax	
Waste tax BaU (€/y)	120 342 000 €
Waste tax Synergy (€/y)	78 222 300 €
Waste tax balance	-42 119 700 €
Viability distance (100% of the resource price)	380
Viability distance (10% of resource price)	38
Waste treatment costs BaU (€/y)	164 610 000 €
Waste treatment costs Synergy (€/y)	106 996 500 €
Waste treatment costs balance (€/y)	-57 613 500 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 72 M€ and an associated VAT around 15M€. This value added can generate around 750 direct jobs.

The implementation of this synergy will generate up than 55M€ of costs saving for the emitting industries, a decrease of the carbon tax up than 1 500 M€. Environmental and human health impact would be significantly improved, in particular for the eco-system quality.

This synergy type is probably implemented in some cases but still presents a potential. The receiver sector demand is only 377 000 t/y so other potential salt consumers need to be identified for this synergy.

5.13Synergy #13

Baseline business scenario

Spent slats from slaughterhouses are sent to landfill and do not have any intrinsic value.

Synergy

The aim of this synergy is to recover salt from sheep slaughter process in slaughterhouses and animal by products industries to provide inorganic chemical industries (sodium chlorate) by replacing industrial salt purchased on the market.

In slaughterhouses, the hides and skins are slated to improve preservation, using sodium chloride (94 kg of salt/tone of sheep carcase). After approximately 6 days they are packed with additional salt and stored or transported to tanneries for leather production. The salt is recovered in tanneries and is send to sodium chlorate production. The leather industry usually recycles sodium chloride to reduce the impact of the disposal and send it to another sectors. (Source: SCALER D3.2)

Assumptions and calculation method

- No recovery rate: the full stream can be recovered: 68127 tons of salt
- Net expenditure on processing 1 kg of the salt solid waste was 0.04 US $ (0,0324€ in 2019)
- Industrial salt price defined in Table 12

Table

Table 35: Synergy 13 (Source: Strane)

Synergy 13	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	68127
Substituted material equivalent price (€/Unit)	66,5
Final volume recovered (Unit/y)	68127
Operational costs (€/y)	2207,3148
VA	4 528 238 €
VAT	971 760 €
Labour Share (€/y)	2 082 990 €
Direct jobs (€)	47
Indirect jobs (min)	24
Indirect jobs (max)	143
Investment	
CAPEX	Some companies are already able to treat this flow
Total investment in EU	No Investment required
External impacts	
Climate change (kg. CO2-eq)	-13309202
Human health (DALY)	-27,445159
Ecosystem quality (PDF.m2.y)	-10784602
Use of resources (MJ)	-208030610
€ Climate change	1 064 736 €
€ DALY	2 030 942 €
€ Ecosystem quality	15 098 442 800 €
€ Use of resources	832 122 €
Sum of external economic impacts (€)	15 102 370 600 €
Carbon tax evolution (€/y)	-532 368 080 €
Waste tax	
Waste tax BaU (€/y)	2 644 690 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-2 644 690 €
Viability distance (100% of the resource price)	380
Viability distance (10% of resource price)	38
Waste treatment costs BaU (€/y)	3 617 544 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-3 617 544 €

Conclusion or comments

The evolution of the resource’s intrinsic value between the business as usual scenario and the synergy scenario create a value added of 4,5M€ and an associated VAT around 1M€. This value added can generate around 50 direct jobs.

The implementation of this synergy will generate up than 3M€ of costs saving for slaughterhouses, a decrease of the carbon tax up than 500 M€. Environmental and human health impact would be significantly improved, in particular for the eco-system quality. That can be explained because the release of salted element in the nature have a dramatic impact on eco-system (desertification of the seabed, pollutants, increased salinisation of waters and marine ecosystems)

This synergy type presents a small benefit because of the considered volume only refers to the salt from sheep slaughterhouses. If this synergy is scaled-up to all type of slaughterhouses, the benefit would be much greater.

5.14Synergy #14

Baseline business scenario

D3.2: Coke is formed by the thermal cracking of EDC and may contain residual chlorinated hydrocarbons, but is free of PCDD/F. Coke is removed from the cracked gas with liquid EDC in a quench column, the coke-containing stream may then be filtered.

Coke residues is probably sent to a utility. The cost of this service is around 200 – 600 €/t of coke residues. The utility company use the coke as a fuel to produce heat which is sold to these clients. The economic benefit of the baseline scenario is to avoid the use and purchase of another solid fuel as coal.

Synergy

The coke is recovered and stored to be sent to Blast furnace.

This synergy has not been identified; indeed, the potential is still total.

The total volume of coke residues can be recovered. No technology is required to treat the coke. The global economic value of the synergy considers the market price of the coke. The only costs are from transport and storage.

Assumptions and calculation method

- The minimum costs for the stream management by the utility was retained (200 €/t)
- Coke market price 120 – 300 €/t (Industrial partners and Strane). The final coke price value is the average of the range: 210 €/t
- Flow modelled: 1244 t/y

Table

Table 36: Synergy 14 (Source: Strane)

Synergy 14	
Waste stream price in BaU scenario (€/Unit)	41,87
Waste stream volume (Unit/y)	1244
Substituted material equivalent price (€/Unit)	210
Final volume recovered (Unit/y)	1244
Operational costs (€/y)	
VA	209 154 €
VAT	44 884 €
Labour Share (€/y)	96 211 €
Direct jobs (€)	2
Indirect jobs (min)	1

Indirect jobs (max)	7
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment required
External impacts	
Climate change (kg. CO2-eq)	-267634600
Human health (DALY)	-736,97343
Ecosystem quality (PDF.m2.y)	-63436589
Use of resources (MJ)	-14065594000
€ Climate change	21 410 768 €
€ DALY	54 536 034 €
€ Ecosystem quality	88 811 224 600 €
€ Use of resources	56 262 376 €
Sum of external economic impacts (€)	88 943 433 778 €
Carbon tax evolution (€/y)	-10 705 384 000 €
Waste tax	
Waste tax BaU (€/y)	0
Waste tax Synergy (€/y)	0
Waste tax balance	0
Viability distance (100% of the resource price)	961
Viability distance (10% of resource price)	120
Waste treatment costs BaU (€/y)	248 800 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-248 800 €

Conclusion or comments

The evolution of the resource’s intrinsic value between the business as usual scenario and the synergy scenario create a value added of 210 000€ and an associated VAT around 45 000€. This value added can generate only 2 direct jobs.

The implementation of this synergy will generate up than 250 000€/y of costs saving for slaughterhouses, a decrease of the carbon tax up than 10 000 M€. Environmental and human health impact would be significantly improved, for the eco-system quality.

This synergy type presents a small benefit because of coke volume produced in Europe is too small. It would be interesting to study the other organic chemical coke producing processes (hydrofining of steam cracked naphtha / styrene manufacturing by dehydrogenation), but the coke production volume was unknown.

No investment is required for this synergy. The viability radius of the coke transportation and valorisation in steel industries is around 120 km (less than 961km so as not to be in deficit).

5.15Synergy #15

Baseline business scenario

It is assumed that lime from production of pulp and paper industries is sent to landfill and the waste does not have any intrinsic value.

Synergy

The aim of this synergy is to recover lime from kraft pulping process in pulp and paper production sector, and provide electrical arc furnaces for steel manufacturing.

D3.2 outcomes:

- Lime sludges could potentially be used directly in the steel scrap melting industry as a substitute for limestone. However, limestone used for metallurgical purposes requires a minimum of 95% of carbonates which limits the applicability of lime sludges for this purpose
- Kraft pulp lime sludges utilizations were found predominantly in the agriculture, cementitious materials production, and as a reagent for wastewater treatment processes and sewage sludge stabilization.
- This synergy is not reported in scientist publications for the moment, and due to the high requirements for limestone grade in Steelmaking industry, the implementation of this synergy is limited by the composition of the Lime sludge. The potential is therefore total. The whole flow was modelled to estimate the potential benefits. The result could be interesting to focus researches activities on the development and implementation of such a synergy (treatment of lime to be compliant with the EAF production).

Assumptions and calculation method

- Price of the lime on the market: 85€/t
- The whole flow is modelled

Table

Table 37: Synergy 15 (Source: Strane)

Synergy 15	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	378000
Substituted material equivalent price (€/Unit)	85
Final volume recovered (Unit/y)	378000
Operational costs (€/y)	
VA	32 130 000 €
VAT	6 895 098 €
Labour Share (€/y)	14 779 800 €
Direct jobs (€)	335
Indirect jobs (min)	168
Indirect jobs (max)	1013
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment required
External impacts	
Climate change (kg. CO2-eq)	-16775083
Human health (DALY)	-2,08E+01
Ecosystem quality (PDF.m2.y)	-9,09E+06
Use of resources (MJ)	-2,46E+08
€ Climate change	1 342 007 €

€ DALY	1 541 668 €
€ Ecosystem quality	12 725 654 200 €
€ Use of resources	983 504 €
Sum of external economic impacts (€)	12 729 521 378 €
Carbon tax evolution (€/y)	-671 003 320 €
Waste tax	
Waste tax BaU (€/y)	14 673 960 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-14 673 960 €
Viability distance (100% of the resource price)	486
Viability distance (10% of resource price)	49
Waste treatment costs BaU (€/y)	75 600 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-75 600 000 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 32 M€ and an associated VAT around 7M€. This value added can generate around 335 direct jobs.

The implementation of this synergy will generate 75M€ of waste management costs saving and 14M€ of waste management tax for the emitting industries, a decrease of the carbon tax up than 700 M€. Environmental and human health impact would be significantly improved.

The viability radius of the lime transportation and valorisation in EAF steel industries is around 50 km (less than 500km so as not to be in deficit).

Indeed, this synergy, which is technically unviable now, has an interesting potential for next developments and some research efforts might be deployed infield to confirm the compliance between paper production lime and EAF industries.

5.16Synergy #16

Baseline business scenario

It is assumed that initially, coke oven air emissions were not recovered and were rejected in the environment. The baseline scenario retained for the LCA (D3.3) was the incineration.

Synergy

The aim of this synergy is to recover H2SO4 from coke oven emission and send it to pulp and paper production plants for using in sulphite pulping processes.

D3.2 outcomes:

- The treatment procedure is to feed the wet sulphuric acid process by the acid gas
- Sulphuric acid recovery is already a standard procedure for the treatment of flue-gases of the steel sector

- As an example, more than 55 units have been contracted for gas flows ranging from 2600 Nm3/h to 1000000 Nm3/h
- A plant in Kazahktsan with 6% Volume of SO2 gas entry: 2508,3 m3 H2SO4 / m3 SO2; 1755 t H2SO4 / t SO2 98% achievable Acid concentration

Assumptions and calculation method

- Recovery rate: 98% of acid concentration
- CAPEX: 2,9M euros (Compressor + Sulphur Burner, Heat exchangers, Contact Group, Absorbers)
- Price of the sulphuric acid: see Table 12 : Resources prices (Source: Strane)
- Production volume per site around 11 000t/y that require one process per site.
- Sulfuric acid annual volume is 156 000 t/y. As there are 38 sites in Europe, the local production for equipped industrial sites is around 11 tons per day. That corresponds to one equipment per site.

Table

Table 38: Synergy 16 (Source: Strane)

Synergy 16	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	156 500
Substituted material equivalent price (€/Unit)	90,9
Final volume recovered (Unit/y)	156 500
Operational costs (€/y)	
VA	14 225 850 €
VAT	3 052 867 €
Labour Share (€/y)	6 543 891 €
Direct jobs (€)	148
Indirect jobs (min)	74
Indirect jobs (max)	448
Investment	
CAPEX	2900000
Total investment in EU	110 200 000 €
External impacts	
Climate change (kg. CO2-eq)	-9341,6834
Human health (DALY)	-0,005039046
Ecosystem quality (PDF.m2.y)	-650,63754
Use of resources (MJ)	-44804,225
€ Climate change	747 €
€ DALY	373 €
€ Ecosystem quality	910 893 €
€ Use of resources	179 €
Sum of external economic impacts (€)	912 192 €
Carbon tax evolution (€/y)	-373 667 €
Waste tax	
Waste tax BaU (€/y)	0 €
Waste tax Synergy (€/y)	0 €

Waste tax balance	0 €
Viability distance (100% of the resource price)	519
Viability distance (10% of resource price)	52
Waste treatment costs BaU (€/y)	0 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	0 €

Conclusion or comments

The current use of H2SO4 produced in coke oven plants is not known. Nevertheless, the evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 14 M€ and an associated VAT around 3M€. This value added can generate around 148 direct jobs.

The implementation of this synergy will not generate waste management costs saving. The carbon tax will only decrease by 300 000€ because of the low amount of CO2 savings.

Despite the small volume, this synergy is economically interesting from the point of view of added value and the jobs creation. However, will have a reduce benefit on the environment and human health.

The viability distance is only 52 km (around 500km so as not to be in deficit).

5.17Synergy #17

Baseline business scenario

Styrene manufacturing process emit hydrogen rich off gas. As the hydrogen has a calorific power, it assumed that off-gas are incinerated to produce energy that allow to avoid the use of a conventional fuel like fuel gas.

Synergy

A fraction of the waste stream can be recovered to produce hydrogen and send it in refining oil and gas industries. The synergy allows to:

- Improve the economic value of the off-gas stream
- Avoid producing the same volume of conventional hydrogen

D3.2 outcomes:

- PSA are popular technologies among hydrogen separation plants
- Pipeline transportation is advised in near facilities; Gaseous hydrogen can be transported in small to medium quantities in compressed gas containers. Liquid hydrogen can be transported in liquid hydrogen trailers. Over longer distance it is usually more cost-effective to transport hydrogen in liquid form since a liquid hydrogen can hold substantially more hydrogen than a pressurized gas tank. Gas containers could be used by train or truck mobility.

Assumptions and calculation method

- Fuel gas LHV: 39MJ/kg, see **Erreur ! Source du renvoi introuvable.**
- Price of the fuel gas: 561 €/t, see Table 12 : Resources prices (Source: Strane)
- The PSA Unit recovery rate of hydrogen is from 70 – 90%. The retained value is 80%
- The average value of the hydrogen separation CAPEX was used to calculate the required investment in whole Europe (10 000 - 50 000 €1000 Nm3/h)

- The hydrogen can be valorised as a commodity. Price of the hydrogen: see Table 12 : Resources prices (Source: Strane)
- Hydrogen density: see Table 13 : Resources density (Source: Strane)
- No OPEX was considered. It is explained in the D3.3 that the OPEX is low, except for the purchase of the adsorbent. The absorbent price and consumption is unknown.

Table

Table 39: Synergy 17 (Source: Strane)

Synergy 17	
Waste stream price in BaU scenario (€/Unit)	899
Waste stream volume (Unit/y)	156 000
Substituted material equivalent price (€/Unit)	2 270
Final volume recovered (Unit/y)	124 800
Operational costs (€/y)	Unknown
VA	143 013 312 €
VAT	30 690 657 €
Labour Share (€/y)	65 786 124 €
Direct jobs (€)	1493
Indirect jobs (min)	746
Indirect jobs (max)	4508
Investment	
CAPEX	10 000 - 50 000€/Nm3/h
Total investment in EU	6 026 554 €
External impacts	
Climate change (kg. CO2-eq)	-1892599900
Human health (DALY)	-784,75039
Ecosystem quality (PDF.m2.y)	-162736080
Use of resources (MJ)	-67669960000
€ Climate change	151 407 992 €
€ DALY	58 071 529 €
€ Ecosystem quality	227 830 512 000 €
€ Use of resources	270 679 840 €
Sum of external economic impacts (€)	228 310 671 361 €
Carbon tax evolution (€/y)	-75 703 996 000 €
Waste tax	
Waste tax BaU (€/y)	0
Waste tax Synergy (€/y)	0
Waste tax balance	0
Viability distance (100% of the resource price)	6548
Viability distance (10% of resource price)	1297
Waste treatment costs BaU (€/y)	0
Waste treatment costs Synergy (€/y)	0
Waste treatment costs balance (€/y)	0

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 140 M€ and an associated VAT around 30M€. This value added can generate around 1 500 direct jobs.

The implementation of this synergy will generate a decrease of the carbon tax up than 75 000 M€. Environmental and human health impact would be significantly improved.

The viability radius here is just for information because the more convenient transportation mode is the pipeline or compressed gas containers transported by trucks for small distances.

The investment required thorough Europe to deploy this synergy type is only 6 000 000€. 20 PSA are required to treat the total waste stream from styrene manufacturing or more than two per site (7 styrene manufacturing plants in Europe, excluding Ethylbenzene manufacturing)

This synergy has a great potential, but the actual implementation level is unknow.

5.18Synergy #18

Baseline business scenario

Sodium chlorate production architecture of processes allow to recover hydrogen. This stream is used as a gaseous fuel to produce energy (heat, steam, electricity). The use as fuel oil avoids the purchase of a conventional fuel like fuel gas.

Synergy

The aim of this synergy is to recover hydrogen and provide refining oil and gas plants to replace hydrogen purchased on the market. This synergy generates:

- A global improvement of the economic value of the off-gas stream
- Avoid producing the same volume of conventional hydrogen

D3.2 outcomes:

- Hydrogen is produced during one conventional step of the sodium chlorate production: The electrolysis.
- The process produces 60 kg of H2 per ton of sodium chlorate. The recovery rate is 53 – 85%. The final volume of H2 recovered is 31,8 kg of H2 per ton of sodium chlorate.
- Pipeline transportation is advised in near facilities as well as transportation in compressed gas containers (Technic used in EU). A liquefaction is advised for long transportation.

Assumptions and calculation method

- Fuel gas LHV: 39MJ/kg, see **Erreur ! Source du renvoi introuvable.**
- Price of the fuel gas: 561 €/t, see Table 12 : Resources prices (Source: Strane)
- Recovery rate retained: 69%.
- CAPEX: No information
- The hydrogen can be valorised as a commodity. Price of the hydrogen: see Table 12 : Resources prices (Source: Strane)
- Hydrogen density: see Table 13 : Resources density (Source: Strane)
- OPEX not applicable
- It is assumed that the remaining hydrogen gas is incinerated

Table

Table 40: Synergy 18 (Source: Strane)

Synergy 18	
Waste stream price in BaU scenario (€/Unit)	899
Waste stream volume (Unit/y)	41 220
Substituted material equivalent price (€/Unit)	2 270
Final volume recovered (Unit/y)	21 847
Operational costs (€/y)	Unknown
VA	29 944 916 €
VAT	6 426 179 €
Labour Share (€/y)	13 774 661 €
Direct jobs (€)	313
Indirect jobs (min)	156
Indirect jobs (max)	944
	Calculation formula modified due to a special case
Investment	
CAPEX	NF
Total investment in EU	No information
External impacts	
Climate change (kg. CO2-eq)	-28279639
Human health (DALY)	-11,725911
Ecosystem quality (PDF.m2.y)	-2431638
Use of resources (MJ)	-1011139300
€ Climate change	2 262 371 €
€ DALY	867 717 €
€ Ecosystem quality	3 404 293 200 €
€ Use of resources	4 044 557 €
Sum of external economic impacts (€)	3 411 467 846 €
Carbon tax evolution (€/y)	-1 131 185 560 €
Waste tax	
Waste tax BaU (€/y)	0
Waste tax Synergy (€/y)	0
Waste tax balance	0
Viability distance (100% of the resource price)	7833
Viability distance (10% of resource price)	1297
Waste treatment costs BaU (€/y)	0
Waste treatment costs Synergy (€/y)	0
Waste treatment costs balance (€/y)	0

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 30 M€ and an associated VAT around 6,5M€. This value added can generate around 300 direct jobs.

The implementation of this synergy will generate a decrease of the carbon tax up than 1 000 M€. Environmental and human health impact would be significantly improved, in particular for the eco-system quality.

The information on the viability radius is not relevant because the more convenient transportation mode is the pipeline or compressed gas containers transported by trucks for small distances.

No information is available regarding the investment and operational costs.

Even if the hydrogen volume production in sodium chlorate production site is small, this synergy has a great potential. According to the LVIC BREF, two routes are used for hydrogen valorisation: direct use as a fuel or sold as a commodity. The implementation level of this synergy is not known for the moment.

A scaling-up of this solution for all hydrogen producers (by-product or off-gas) inorganic and organic chemicals industries would generate a great economic and environmental benefit.

5.19Synergy #19

Baseline business scenario

According to LVOC BREF [42], the hydrogen/methane fraction is used as fuel gas in the cracker furnace, replacing natural gas. Any excess can be fed into the fuel gas system for the LVOC plant (or refinery). Hydrogen can also be recovered and purified for use in hydrogenation reactions. So, the business as usual retained is the incineration of the hydrogen/methanol fraction.

Synergy

Instead of a direct combustion of the hydrogen, the aim of this synergy is to recover it and provide refining oil and gas plants, in particular hydrodesulphurisation processes to replace hydrogen purchased on the market. This synergy generates:

- A global improvement of the economic value of the off-gas stream
- Avoid producing the same volume of conventional hydrogen

D3.2 outcomes:

- Already a standard process in lower olefin production companies
- Yield: 10000 Nm3/h

Assumptions and calculation method

- Hydrogen recovered each year is 310 422 tons.
- Recovery rate 70 – 90 %
- CAPEX: 10 000 - 50 000 € /1000 Nm3/h

Table

Table 41: Synergy 19 (Source: Strane)

Synergy 19	
Waste stream price in BaU scenario (€/Unit)	899
Waste stream volume (Unit/y)	388 027

Substituted material equivalent price (€/Unit)	2 270
Final volume recovered (Unit/y)	310 422
Operational costs (€/y)	Low, except for the purchase of the adsorbent
VA	425 492 331 €
VAT	91 310 654 €
Labour Share (€/y)	195 726 472 €
Direct jobs (€)	4441
Indirect jobs (min)	2221
Indirect jobs (max)	13412
Investment	
CAPEX	10 000 - 50 000 € /1000 Nm3/h
Total investment in EU	14 990 164 €
External impacts	
Climate change (kg. CO2-eq)	-690686250
Human health (DALY)	-286,38716
Ecosystem quality (PDF.m2.y)	-59388980
Use of resources (MJ)	-24695506000
€ Climate change	55 254 900 €
€ DALY	21 192 650 €
€ Ecosystem quality	83 144 572 000 €
€ Use of resources	98 782 024 €
Sum of external economic impacts (€)	83 319 801 574 €
Carbon tax evolution (€/y)	-27 627 450 000 €
Waste tax	
Waste tax BaU (€/y)	0
Waste tax Synergy (€/y)	0
Waste tax balance	0
Viability distance (100% of the resource price)	7833
Viability distance (10% of resource price)	1297
Waste treatment costs BaU (€/y)	0
Waste treatment costs Synergy (€/y)	0
Waste treatment costs balance (€/y)	0

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 425 M€ and an associated VAT around 91 M€. This value added can generate around 4 500 direct jobs.

The implementation of this synergy will generate a decrease of the carbon tax up than 27 500 M€. Environmental and human health impact would be significantly improved, mainly the eco-system quality.

The information on the viability radius is not relevant because the more convenient transportation mode is the pipeline or compressed gas containers transported by trucks for small distances.

The total investment required is around 15 M€ corresponding to 428 standard equipment. This value is derisory in comparison with the benefit of this synergy type full implementation.

The Lower Olefin production is the most interesting process to implement hydrogen recovery in Europe. This practice exists but may not be widespread unlike direct on-site combustion.

5.20 Synergy #20

Baseline business scenario

The considered scenario is to send BOF gas treatment dusts to landfill.

Synergy

The aim of this synergy is to recover nickel residues from BOF slags and provide non-ferrous metals industries for nickel and cobalt production.

D3.2 outcomes:

- Hydrometallurgical extraction procedure is required (with Solvent Extraction – Electrowinning)
- No specific study was found regarding the extraction of nickel from BOF slags.
- A technical NOGO was decided for this synergy because the technology implementation for nickel residues recovery is still unavailable.

Assumptions

- Several prices for nickel were identified, see Table 12 : Resources prices (Source: Strane). The selected value was the rough nickel one: 13 156 €/t

Table

Table 42: Synergy 20 (Source: Strane)

Synergy 20	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	9 655
Substituted material equivalent price (€/Unit)	13 156
Final volume recovered (Unit/y)	4 113
Operational costs (€/y)	
VA	54 110 628 €
VAT	11 612 141 €
Labour Share (€/y)	24 890 889 €
Direct jobs (€)	565
Indirect jobs (min)	282
Indirect jobs (max)	1706
Investment	
CAPEX	Relatively low
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	-1550,4976
Human health (DALY)	-0,02523386
Ecosystem quality (PDF.m2.y)	-4408,7966
Use of resources (MJ)	-20308,73
€ Climate change	124 €
€ DALY	1 867 €
€ Ecosystem quality	6 172 315 €
€ Use of resources	81 €
Sum of external economic impacts (€)	6 174 388 €

Carbon tax evolution (€/y)	-62 020 €
Waste tax	
Waste tax BaU (€/y)	374 807 €
Waste tax Synergy (€/y)	215 140 €
Waste tax balance	-159 667 €
Viability distance (100% of the resource price)	75177
Viability distance (10% of resource price)	7518
Waste treatment costs BaU (€/y)	1 931 000 €
Waste treatment costs Synergy (€/y)	1 108 400 €
Waste treatment costs balance (€/y)	-822 600 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 54 M€ and an associated VAT around 11 M€. This value added can generate around 550 direct jobs.

The implementation of this synergy will not generate a lot of waste management costs saving (only 1 M€). The carbon tax will only decrease by 60 000€ because of the low amount of CO2 savings.

This synergy is economically very interesting from the point of view of added value and the jobs creation. However, will have a reduce benefit on the environment and human health. Only benefits on eco-system quality are significant.

The economic viability radius is very interesting because of the material intrinsic monetary value (more than 7 500km).

Capital costs associated with the leaching operation are relatively low but, capital costs for the SX and EW circuits are high with very little economy of scale available (D3.2). A complementary with real industrial data would be promising to assess the effective economic viability of this synergy.

Operationally, BOF dusts are managed with on-site recycling, external use and landfilling. An extraction of Nickel residues would be possible before these three scenarios.

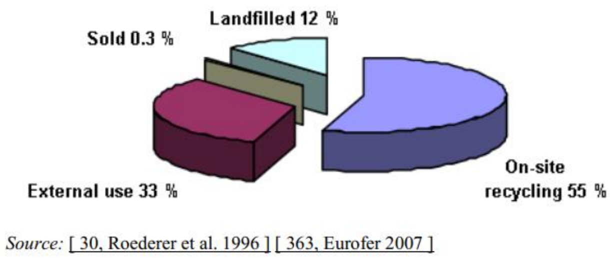


Figure 14 : Fate of dust from dry BOF gas treatment (Source: BREF)

5.21Synergy #21

Baseline business scenario

In the case of SO2 absorption, it is possible to recover elemental sulphur from coke oven emissions. The baseline scenario defined in D3.3 is sulphur landfilling.

Synergy

The objective of this synergy is to send the sulphur recovered from coke ovens and send it to pulp and paper production industries (sulphite pulping process).

D3.2 findings:

- Sulphur recovery is already a standard procedure in the steel sector.
- CAPEX : 50 t/d: 12 M; 100 t/d: 19 M€; 250 t/d: 35M€),

Assumptions

- Costs from electricity and water consumption were considered. Estimated total price: 3 310 835 per year (cooling water consumption 0 - 20 m3/t; 60-75 kWh/t).The water costs are been overloaded with a price of 4,01 €/m3.
- Several sulphur types were identified, see Table 12 : Resources prices (Source: Strane). The selected price is the Rough sulphur non-refined one.

Table

Table 43: Synergy 21 (Source: Strane)

Synergy 21	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	72 993
Substituted material equivalent price (€/Unit)	118,1
Final volume recovered (Unit/y)	70 803
Operational costs (€/y)	3 310 835
VA	5 051 024 €
VAT	1 083 950 €
Labour Share (€/y)	2 323 471 €
Direct jobs (€)	53
Indirect jobs (min)	26
Indirect jobs (max)	159
Investment	
CAPEX	Available
Total investment in EU	1 equipment per site: 456M€ (50 tons/day) 1 equipment in Europe 35M€ (250 tons/day)
External impacts	
Climate change (kg. CO2-eq)	-17086973
Human health (DALY)	-43,917231
Ecosystem quality (PDF.m2.y)	-6548107,5
Use of resources (MJ)	-2075919200
€ Climate change	1 366 958 €
€ DALY	3 249 875 €
€ Ecosystem quality	9 167 350 500 €
€ Use of resources	8 303 677 €
Sum of external economic impacts (€)	9 180 271 010 €
Carbon tax evolution (€/y)	-683 478 920 €

Waste tax	
Waste tax BaU (€/y)	2 833 588 €
Waste tax Synergy (€/y)	85 008 €
Waste tax balance	-2 748 581 €
Viability distance (100% of the resource price)	408
Viability distance (10% of resource price)	67
Waste treatment costs BaU (€/y)	14 598 600 €
Waste treatment costs Synergy (€/y)	437 958 €
Waste treatment costs balance (€/y)	-14 160 642 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 5 M€ and an associated VAT around 1 M€. This value added can generate around 50 direct jobs.

The carbon tax will only decrease by 680 M€. The environmental benefit is significant for the eco-system quality. The landfilling tax will also decrease by 3 M€ for the emitter industry.

The implementation of this synergy will generate 14M€ of waste management costs saving.

The economic viability radius is not very large because of the moderate sulphur market price: 70 km.

Considering the treatment capacity of the new SRU including TGTU (50 t/d: 12 M; 100 t/d: 19 M€; 250 t/d: 35M€), and the production level for coke oven plant (less than 2 000 ton per year and per site), it would be interesting to share this processing installation. If all site required to be equipped by a new SRU, the total investment thorough Europe would be around 450M€. Nevertheless, only one SRU is necessary to treat the entire sulphur flow in Europe with a cost of 35M€.

This synergy has a medium economic and environmental impact.

5.22Synergy #22

Baseline business scenario

Refractories products are usually landfilled and do not have any monetary value.

Synergy

Refractory products contain valuable element of interest: magnesite, dolomite and mullite.

Table 44 : Example of annual amount of spent refractory material in one installation (Source: BREF)

Refractory used	EAF	Steel ladle	Ladle furnace RH degaser	Strand caster	Ingot casting
Magnesite	1200	3800	600 ([1])	2400	
Dolomite		600			
Mullite (clay)					500

([1]) Chromium magnesite.
NB: Values in tonnes per year.
Source: [386, Cores et al. 2005].

The total recoverable volume of interesting elements is 9 100 tons per year per site that corresponds to 2 102 100 tons per thorough Europe.

The aim of the synergy was to provide ceramics industries with these materials.

Assumptions

- Only the recoverable flow was considered in the socio-economic assessment: magnesia, dolomite and mullite volumes.
- Calculation of the material economic value: see Table 45 : Refractory product economic value calculation (Source: Strane)
- The recovered product can be sold on the market and not only to ceramic industries

Table 45 : Refractory product economic value calculation (Source: Strane)

Total Volume	2102100	t/y				
Composition	%	t		Prix		Prix total
Magnesite	22,5	8000	0,879120879	326,7	€/t	287,21 €
Dolomite	44	600	0,065934066	30,9	€/t	2,04 €
Mullite	8,5	500	0,054945055	600,8	€/t	33,01 €
Total price					€/t	322,26 €

Table

Table 46: Synergy 22 (Source: Strane)

Synergy 22	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	2 102 100
Substituted material equivalent price (€/Unit)	322,0
Final volume recovered (Unit/y)	2 102 100
Operational costs (€/y)	
VA	676 876 200 €
VAT	145 257 633 €
Labour Share (€/y)	311 363 052 €
Direct jobs (€)	7065
Indirect jobs (min)	3533
Indirect jobs (max)	21336
Investment	
CAPEX	Not available
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	-336269680
Human health (DALY)	-280,4272
Ecosystem quality (PDF.m2.y)	-62051898
Use of resources (MJ)	-3269935800
€ Climate change	26 901 574 €
€ DALY	20 751 613 €
€ Ecosystem quality	86 872 657 200 €
€ Use of resources	13 079 743 €
Sum of external economic impacts (€)	86 933 390 130 €
Carbon tax evolution (€/y)	-13 450 787 200 €

Waste tax	
Waste tax BaU (€/y)	81 603 522 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-81 603 522 €
Viability distance (100% of the resource price)	1840
Viability distance (10% of resource price)	184
Waste treatment costs BaU (€/y)	420 420 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-420 420 000 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 600 M€ and an associated VAT around 1 M€. This value added can generate around 7 000 direct jobs.

The carbon tax will only decrease by 13 500 M€. The environmental benefit is significant for the eco-system quality. The landfilling tax will also decrease by 80M€ for the emitter industry.

The implementation of this synergy will generate 420M€ of waste management costs saving.

The 184 km economic viability radius is relevant (10% of the stream value) to find potential receiving industries.

The valorisation of magnesite, dolomite and mullite in all sectors and not only in ceramic industries would have a significant economic and environmental impact.

A significant research effort is required to develop and deploy refractory processing technology is required. A mutualisation centre would help to massify for EAF plants hotspot (ex: Italy). This solution will be studied in the overall potential study D3.5.

5.23Synergy #23

Baseline business scenario

The considered fate of combustion plants slags is landfill.

Synergy

The aim of this synergy is to recover valuable materials from coal combustion plants slags and provide glass industries to produce mineral wool.

D3.2 findings:

- There are no reported utilisations of boiler slag in mineral wool production (MWP). Despite, boiler slags and blast furnace slags having similar compositions of silica, aluminium and calcium, all elements of interest for the cement industry, the presence of toxic compounds could restrict the application of boiler slags for mineral wool production. Further studies should be performed to assess the environmental and technical viability of boiler slag in MWP.
- Although the boiler slag could potentially be used for mineral wool production, the stability and presence of toxic compounds needs to be carefully evaluated

Assumptions

- Flow modelled: 1 000 000 t (Source: BREF)
- Slag composition [43]
  - SiO2: 32,98 – 55,38%. The selected value for calculation is 44,18%
  - Al2O3: 20,50 – 23,22%. The selected value for calculation is 21,86%
  - Fe2O3: 5,46 – 11,44%. The selected value for calculation is 8,45%
  - CaO: 1,05 – 11,71. The selected value for calculation is 6,38%
- Slag economic value calculation: see Table 47: Combustion slags economic calculation (Source : Strane)

Table 47: Combustion slags economic calculation (Source : Strane)

Total Volume	1000000	t/y			
Composition	%	t	Prix		Prix total
SiO2	44,18	441800	1453,5	€/t	642 156 300,00 €
CaO	21,86	218600	85	€/t	18 581 000,00 €
Al2O3	8,45	84500	488	€/t	41 236 000,00 €
Fe2O3	6,38	63800	322,2	€/t	20 556 360,00 €
Total price				€/y	701 973 300,00 €
Price per ton				€/t	701,97 €

Table

Table 48: Synergy 23 (Source: Strane)

Synergy 23	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	1 000 000
Substituted material equivalent price (€/Unit)	702
Final volume recovered (Unit/y)	1 000 000
Operational costs (€/y)	
VA	701 970 000 €
VAT	150 642 762 €
Labour Share (€/y)	322 906 200 €
Direct jobs (€)	7327
Indirect jobs (min)	3663
Indirect jobs (max)	22127
Investment	
CAPEX	Not available
Total investment in EU	Unknow
External impacts	
Climate change (kg. CO2-eq)	-1393841600
Human health (DALY)	-1788,6013
Ecosystem quality (PDF.m2.y)	-398934180
Use of resources (MJ)	-17114936000
€ Climate change	111 507 328 €
€ DALY	132 356 496 €
€ Ecosystem quality	558 507 852 000 €
€ Use of resources	68 459 744 €
Sum of external economic impacts (€)	558 820 175 568 €
Carbon tax evolution (€/y)	-55 753 664 000 €

Waste tax	
Waste tax BaU (€/y)	38 820 000 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-38 820 000 €
Viability distance (100% of the resource price)	4011
Viability distance (10% of resource price)	401
Waste treatment costs BaU (€/y)	200 000 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-200 000 000 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 700 M€ and an associated VAT around 150 M€. This value added can generate around 7 000 direct jobs.

The carbon tax will only decrease by 55 000 M€. The environmental benefit is significant for the eco-system quality. The landfilling tax will also decrease by 40M€ for the emitter industry.

The implementation of this synergy will generate 200M€ of waste management costs saving.

The 401 km economic viability radius is very relevant to find potential receiving industries: glass wool manufacturing plants but also cement plants, more promising regarding the resource compliance.

The valorisation of magnesite, dolomite and mullite in all sectors and not only in mineral wool production would have a significant economic and environmental impact.

Analysis are required to check the compliance of combustion plants slags with all mineral materials consumers (cement, ceramic, glass, etc.) but the valorisation of combustion plants slags has a great potential even if the production will decrease in Europe with the Energy transition engaged by some countries.

5.24Synergy #24

Baseline business scenario

The selected baseline scenario is landfill.

Synergy

The aim of this synergy is to send BF slags to mineral wool manufacturing

Assumptions

- Flow considered: receiving sector silica demand (D3.3): 1 973 340 t/y
- Silica price: see Table 12 : Resources prices (Source: Strane)

Table

Table 49: Synergy 24 (Source: Strane)

Synergy 24	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	1 973 340

Substituted material equivalent price (€/Unit)	16,5
Final volume recovered (Unit/y)	1 973 340
Operational costs (€/y)	
VA	32 560 110 €
VAT	6 987 400 €
Labour Share (€/y)	14 977 651 €
Direct jobs (€)	340
Indirect jobs (min)	170
Indirect jobs (max)	1026
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment
External impacts	
Climate change (kg. CO2-eq)	-2750523300
Human health (DALY)	-3529,5185
Ecosystem quality (PDF.m2.y)	-787232770
Use of resources (MJ)	-33773588000
€ Climate change	220 041 864 €
€ DALY	261 184 369 €
€ Ecosystem quality	1 102 125 878 000 €
€ Use of resources	135 094 352 €
Sum of external economic impacts (€)	1 102 742 198 585 €
Carbon tax evolution (€/y)	-110 020 932 000 €
Waste tax	
Waste tax BaU (€/y)	76 605 059 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-76 605 059 €
Viability distance (100% of the resource price)	94
Viability distance (10% of resource price)	9
Waste treatment costs BaU (€/y)	394 668 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-394 668 000 €

Conclusion or comments

Although blast furnace slags are widely used in road construction and the cement industries (Figure 15: Finale use of blast furnace slag in the EU (Source: BREF)), the mineral wool sector is a relevant alternative outlet.

This synergy modelled only consider the flow required for mineral wool silica demand. This synergy is currently used but it is difficult to assess the implementation rate.

The benefit estimated is:

- 30 M€ of intrinsic value added created.
- 340 direct jobs
- A significant non-damage on the eco-system quality

An analyse will be carried out to compare this synergy with the two other valorisation routes (cement and road construction).

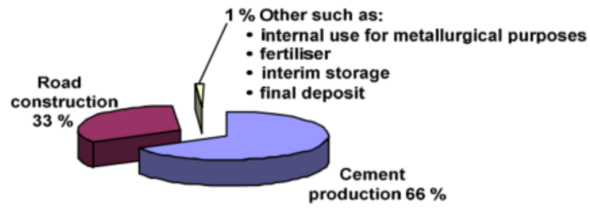


Figure 15: Finale use of blast furnace slag in the EU (Source: BREF)

5.25Synergy #25

Baseline business scenario

It is assumed that lime from sugar plants is sent to landfill and the waste does not have any intrinsic value.

Synergy

The aim of this synergy is to recover lime sugar plants and cement industries.

D3.3 findings:

- Sugar factory lime is already acknowledged as a valuable waste material to produce cement (BREF_FDM). Reported utilisations involve the admixture of sugar lime sludges with portland cement and in the production of foam concrete.

Assumptions

- Lime price: see Table 12 : Resources prices (Source: Strane)
- The total volume ca be valorised

Table

Table 50: Synergy 25 (Source: Strane)

Synergy 25	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	1 002 000
Substituted material equivalent price (€/Unit)	85,0
Final volume recovered (Unit/y)	1 002 000
Operational costs (€/y)	
VA	85 170 000 €
VAT	18 277 482 €
Labour Share (€/y)	39 178 200 €
Direct jobs (€)	889
Indirect jobs (min)	444
Indirect jobs (max)	2685
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment
External impacts	
Climate change (kg. CO2-eq)	-44467283
Human health (DALY)	-55,224909
Ecosystem quality (PDF.m2.y)	-24095060
Use of resources (MJ)	-651766320

€ Climate change	3 557 383 €
€ DALY	4 086 643 €
€ Ecosystem quality	33 733 084 000 €
€ Use of resources	2 607 065 €
Sum of external economic impacts (€)	33 743 335 091 €
Carbon tax evolution (€/y)	-1 778 691 320 €
Waste tax	
Waste tax BaU (€/y)	38 897 640 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-38 897 640 €
Viability distance (100% of the resource price)	486
Viability distance (10% of resource price)	49
Waste treatment costs BaU (€/y)	200 400 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-200 400 000 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 85 M€ and an associated VAT around 18M€. This value added can generate around 889 direct jobs.

The implementation of this synergy will generate 200M€ of waste management costs saving and 38M€ of waste management tax for the emitting industries, a decrease of the carbon tax up than 1 800 M€. Environmental and human health impact would be significantly improved, especially eco-system quality.

The viability radius of the lime transportation and valorisation in EAF steel industries is around 50 km (less than 500km so as not to be in deficit).

Indeed, this synergy, which is technically viable, is known but it remains a potential to exploit.

5.26 Synergy #26

Baseline business scenario

It is assumed that lime from paper and pulp production plants is sent to landfill and the waste does not have any intrinsic value.

Synergy

The aim of this synergy is to recover lime from paper and pulp production plants to provide cement industries.

D3.3 findings:

- Lime slurries are already acknowledged as a valuable waste material to produce cement (BREF_FDM). Reported utilisations involve the admixture of sugar lime sludges with portland cement and in the production of foam concrete.
- Maheswaran et al, 2011 reported that up to 10% of sludge in the mix could be used in concrete production without negatively affecting the mechanical properties.

Assumptions

- Lime price: see Table 12 : Resources prices (Source: Strane)
- The total volume ca be valorised
- 10% of total cement raw material preparation = 11 800 000 tonnes per year > 627 000 t/y
- Flow modelled: 627 000 tons of lime per year

Table

Table 51: Synergy 26 (Source: Strane)

Synergy 26	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	627 000
Substituted material equivalent price (€/Unit)	85,0
Final volume recovered (Unit/y)	627 000
Operational costs (€/y)	
VA	53 295 000 €
VAT	11 437 107 €
Labour Share (€/y)	24 515 700 €
Direct jobs (€)	556
Indirect jobs (min)	278
Indirect jobs (max)	1680
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment
External impacts	
Climate change (kg. CO2-eq)	-27825336
Human health (DALY)	-34,556904
Ecosystem quality (PDF.m2.y)	-15077447
Use of resources (MJ)	-407841800
€ Climate change	2 226 027 €
€ DALY	2 557 211 €
€ Ecosystem quality	21 108 425 800 €
€ Use of resources	1 631 367 €
Sum of external economic impacts (€)	21 114 840 405 €
Carbon tax evolution (€/y)	-1 113 013 440 €
Waste tax	
Waste tax BaU (€/y)	24 340 140 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-24 340 140 €
Viability distance (100% of the resource price)	486
Viability distance (10% of resource price)	49
Waste treatment costs BaU (€/y)	125 400 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-125 400 000 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 53 M€ and an associated VAT around 11,5M€. This value added can generate around 550 direct jobs.

The implementation of this synergy will generate 200M€ of waste management costs saving and 38M€ of waste management tax for the emitting industries, a decrease of the carbon tax up than 1 100 M€. Environmental and human health impact would be significantly improved, especially eco-system quality.

The viability radius of the lime transportation is 50km (less than 500km so as not to be in deficit).

Indeed, this synergy is known as technically viable, it still have a potential to exploit.

5.27Synergy #27

Baseline business scenario

There are 34 sinter plants referenced installations in European Union which produce 130 000 000 t of sinter /y (3 823 529 tons per site). Sinter plants generates from 472 and 4 492 g of sludge /t of sinter. The annual associated sludge production is between 61 360 and 583 983 t of sludge /year. Sludge from sinter plants is usually landfilled.

Synergy

The aim of this synergy is to recover sludge from sinter plants to provide cement raw material preparation. Cement industries can use sludge as a calcium and aluminium sources. There are 268 plants in Europe Union. Clinker annual production is 118 Mt/y.

Assumptions and calculation method

- The waste stream volume used for calculation is 322 672 t/y.
- The calcium and aluminium content of the sludge is given in the following table.

Table 52 : Typical composition in (wt-%) of sludge from BF gas treatment

Parameter	Concentration (wt-%)		Parameter	Concentration (wt-%)
C	15 – 47		S	2.4 – 2.5
Fe	7 – 35		SiO_2	3 – 9
Pb	0.8 – 2.0		P_2O_5	0.1 – 0.44
Zn	1 – 10		CaO	3.5 – 18
Mn	0.12 – 0.14		MgO	3.5 – 17
Al_2O_3	0.8 – 4.6		Na_2O	0.15 – 0.24
			K_2O	0.08 – 0.36
Source: [64, IISI 1985] [95, Mertins 1986].				

The values used will be 10.75% for calcium oxide and 2.7% for aluminium.

- The total calcium and aluminium volume is 43 399 t/y.
- The resale price of the sludge is estimated using an average weighted by the calcium and aluminium composition: 545 €/t.

Table

Table 53: Synergy 27 (Source: Strane)

Synergy 27	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	322672
Substituted material equivalent price (€/Unit)	165

Final volume recovered (Unit/y)	43399
Operational costs (€/y)	
VA	7 160 835 €
VAT	1 536 715 €
Labour Share (€/y)	3 293 984 €
Direct jobs (€)	75
Indirect jobs (min)	37
Indirect jobs (max)	226
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-9011406,6
Human health (DALY)	-56,061954
Ecosystem quality (PDF.m2.y)	-13607333
Use of resources (MJ)	-432058750
€ Climate change	720 913 €
€ DALY	4 148 585 €
€ Ecosystem quality	19 050 266 200 €
€ Use of resources	1 728 235 €
Sum of external economic impacts (€)	19 056 863 932 €
Carbon tax evolution (€/y)	-360 456 264 €
Waste tax	
Waste tax BaU (€/y)	12 526 127 €
Waste tax Synergy (€/y)	10 841 378 €
Waste tax balance (€/y)	-1 684 749 €
Viability distance (100% of the resource price)	943
Viability distance (10% of the good transported price)	94
Waste treatment costs BaU (€/y)	17 133 883 €
Waste treatment costs Synergy (€/y)	14 829 396 €
Waste treatment costs balance (€/y)	-2 304 487 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 7 M€/y, and the associated VAT is around 1.5 M€. The expected job creation is around 75 throughout Europe. 2.3 M€ of landfilled tax and costs could be avoided thanks to this synergy.

The implementation of this synergy will generate a decrease of the carbon tax up than 360 M€. Environmental and human health impact would be significantly improved.

This synergy seems promising. Nevertheless, transportation, investment and operational costs should be considered in further analysis.

5.28Synergy #28

Baseline business scenario

Starch production generates sand that is usually landfilled. 18 starch production installations are referenced European Union. They produce 11 058 000 t of raw material /y (614 333 t/site). Sand is starch production process output resource. The annual sand volume is between 1,7 and 7 kg/ t of starch. The annual associated sand volume is from 16 587 to 77 406 t/y (between 921 and 4 300 t/site).

Synergy

The aim of this synergy is to recover sand from food and drink industries and provide cement sector raw material preparation. This synergy is direct. Cement industries are sand consumers. They require sand to produce clinker and finally cement. 268 cement plants are referenced in Europe Union. 118 000 000 tons of clinker are produced each year (440 298 t per site).

Assumptions and calculation method

- The waste stream volume used for calculation is 46 997 t/y.

Table

Table 54: Synergy 28 (Source: Strane)

Synergy 28	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	46997
Substituted material equivalent price (€/Unit)	155
Final volume recovered (Unit/y)	46997
Operational costs (€/y)	
VA	7 284 535 €
VAT	1 563 261 €
Labour Share (€/y)	3 350 886 €
Direct jobs (€)	76
Indirect jobs (min)	38
Indirect jobs (max)	230
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-1086106,5
Human health (DALY)	-6,7820746
Ecosystem quality (PDF.m2.y)	-1062190,8
Use of resources (MJ)	-21332963
€ Climate change	86 889 €
€ DALY	501 874 €
€ Ecosystem quality	1 487 067 120 €
€ Use of resources	85 332 €
Sum of external economic impacts (€)	1 487 741 214 €
Carbon tax evolution (€/y)	-43 444 260 €

Waste tax	
Waste tax BaU (€/y)	1 824 424 €
Waste tax Synergy (€/y)	0 €
Waste tax balance (€/y)	-1 824 424 €
Viability distance (100% of the resource price)	886
Viability distance (10% of the good transported price)	89
Waste treatment costs BaU (€/y)	2 495 541 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-2 495 541 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 7.2 M€/y, and the associated VAT is around 1.5 M€. The expected job creation is around 76 throughout Europe.

The implementation of this synergy will generate a decrease of the carbon tax up 43 M€ and will avoid landfill costs of 2.5 M€ and landfill tax of 1.8 M€. Environmental and human health impact would be significantly improved. The distance is enough to reach the receiving sector in several case.

The investment is low and mostly insignificant. The synergy is already implemented.

5.29 Synergy #29

Baseline business scenario

The baseline scenario selected for red mud management is landfilling

Synergy

The aim of this synergy is to recover red mud from non-ferrous metals industries to provide cement industries, which have an interest to recover calcium, Fe2O3 and Al2O3 contents for clinker raw material preparation.

D3.2 findings:

- Red mud can be directly utilised for cement production
- Incorporation of red mud in cement mix is limited

Assumptions

- Red mud annual volume: 627 000 tons
- Red Mud composition (Table 55)
- Only Al2O3, CaO and Fe2O3 volumes were considered in the price estimation:

Table 55: Red mud chemical composition (Source: BREF)

Element	Weight%
Al2O3	10 - 20
CaO	2 - 8
Fe2O3	30 - 60
Na2O	2 - 10
SiO2	3 - 50

TiO_2	0 - 25

Table 56: Red mud economic value estimation (Source: BREF)

Total Volume	**6 510 000**	**t/y**			
Composition	%	t	Prix		Prix total
SiO_2	0,265	1 725 150	1453,5	€/t	2 507 505 525,00 €
CaO	0,05	325 500	85	€/t	27 667 500,00 €
Al_2O_3	0,15	976 500	488	€/t	476 532 000,00 €
Fe_2O_3	0,4	2 604 000	322,2	€/t	839 008 800,00 €
Total price				€/y	3 011 705 025,00 €
Price per ton				€/t	462,63 €

Table

Table 57: Synergy 29 (Source: Strane)

Synergy 29	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	6 510 000
Substituted material equivalent price (€/Unit)	462,6
Final volume recovered (Unit/y)	6 510 000
Operational costs (€/y)	
VA	3 011 721 300 €
VAT	646 315 391 €
Labour Share (€/y)	1 385 391 798 €
Direct jobs (€)	31435
Indirect jobs (min)	15718
Indirect jobs (max)	94935
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment
External impacts	
Climate change (kg. CO2-eq)	-4297804,7
Human health (DALY)	-139,95343
Ecosystem quality (PDF.m2.y)	-30942968
Use of resources (MJ)	-82922322
€ Climate change	343 824 €
€ DALY	10 356 554 €
€ Ecosystem quality	43 320 155 200 €
€ Use of resources	331 689 €
Sum of external economic impacts (€)	43 331 187 267 €
Carbon tax evolution (€/y)	-171 912 188 €
Waste tax	
Waste tax BaU (€/y)	252 718 200 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-252 718 200 €
Viability distance (100% of the resource price)	2644
Viability distance (10% of resource price)	264

Waste treatment costs BaU (€/y)	1 302 000 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-1 302 000 000 €

Conclusion or comments

Current practice is to deposit red mud on or near the site in specially designed, sealed ponds.

According the Non-ferrous metals BREF: "Some refineries use high-pressure filtration as a last step for red mud treatment. The output from this operation is a solid bauxite residue, which can be easily and safely transported over long distances and which can be used in various applications, such as in the cement industry for the production of clinker, in the ceramic industry as an alternative raw material, or in road construction.

That confirms a high potential. Moreover, other material than bauxite can be theoretically reused. The titanium dioxide content (0-25%weight) would be very valuable for inorganic chemical industries. The price of this resource is around 2 214 €/t: the annual titanium dioxide economic value in red mud is equivalent to 3,6M€.

Analysis are required to know the chemical composition of red mud and check the compliance with cement sector. The calculation probably overestimates the value of this flow, since impurities are present in red muds.

The viability radius of the red mud transportation is 264km which is enough to find nearby partners.

Researches efforts are necessary to develop procedures to extract valuable materials and remove impurities.

5.30Synergy #30

Baseline business scenario

The selected baseline scenario is landfill.

Synergy

The aim of this synergy is to send BF slags to the cement sector.

Assumptions

- The total volume of BF slags is considered
- Slags granulated price: see Table 12 : Resources prices (Source: Strane)

Table

Table 58: Synergy 30 (Source: Strane)

Synergy 30	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	46 314 324
Substituted material equivalent price (€/Unit)	16,5
Final volume recovered (Unit/y)	46 314 324
Operational costs (€/y)	
VA	764 186 346 €
VAT	163 994 390 €
Labour Share (€/y)	351 525 719 €
Direct jobs (€)	7976
Indirect jobs (min)	3988
Indirect jobs (max)	24089
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment

External impacts	
Climate change (kg. CO2-eq)	-7496613500
Human health (DALY)	-12315,214
Ecosystem quality (PDF.m2.y)	-8138684400
Use of resources (MJ)	-1,19967E+11
€ Climate change	599 729 080 €
€ DALY	911 325 836 €
€ Ecosystem quality	11 394 158 160 000 €
€ Use of resources	479 869 560 €
Sum of external economic impacts (€)	11 396 149 084 476 €
Carbon tax evolution (€/y)	-299 864 540 000 €
Waste tax	
Waste tax BaU (€/y)	1 797 922 058 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-1 797 922 058 €
Viability distance (100% of the resource price)	94
Viability distance (10% of resource price)	9
Waste treatment costs BaU (€/y)	9 262 864 800 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-9 262 864 800 €

Conclusion or comments

This synergy is the most famous industrial symbiosis case. Indeed, there is even a standard category of cement composed by BF slags. BF slags' composition is totally compliant with the cement requirements (Not the case of BOF slags). Today, cement industries think European BF slags deposits are depleted and are looking to news partners to provide their facilities.

This synergy created 8 000 jobs, with a value added by 800 M€ and has a great benefit on the environment.

The viability distance is low because of the resource cheap price, that why significant slag volumes are stored directly on steel facilities, waiting a nearby purchaser.

This synergy is widely used so associated statistics will be removed for the final potential analysis.

5.31Synergies #31 & 32

Synergies 31 and 32 deals with the same resource: aluminium oxide. Moreover, both receiver sector demands are unknown and the LCA present the same results for the aluminium oxide stream valorisation. The two synergies are modelled together, with a 50-50 distribution to cement and mineral wool production.

Baseline business scenario

Salt slag process in non-ferrous metals industries (aluminium production by-product treatment) lead to separate aluminium oxide.

Synergy

The aim of this synergy is to recover aluminium oxide from salt slag process and provide cement and glass industries.

D3.2 findings:

- Process already currently used in salt slag plants

- A full salt slag process recycling is required
- 0,46 – 0,68 tons of aluminium oxides per ton of salt slag processed
- Recovery rate: 100%
- Electricity demand 1 900 – 3845 MJ per tonne of salt slag
- OPEX and CAPEX are expensive, but the payback period is less than two years
- Treatment costs are like disposal costs

Assumptions

- Aluminium oxide volume
- Aluminium dioxide price
- Electricity costs: average 2 872,5MJ is equivalent to 798 kWh per ton of salt slag. That corresponds to 392 179 760 €/y.

Table

Table 59: Synergies 31 & 32 (Source: Strane)

Synergies 31 & 32	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	3 596 000
Substituted material equivalent price (€/Unit)	341,1
Final volume recovered (Unit/y)	3 596 000
Operational costs (€/y)	392 179 760
VA	834 415 840 €
VAT	179 065 639 €
Labour Share (€/y)	383 831 286 €
Direct jobs (€)	8709
Indirect jobs (min)	4355
Indirect jobs (max)	26302
Investment	
CAPEX	HIGH
Total investment in EU	Unknown
External impacts	
Climate change (kg. CO2-eq)	-4953541300
Human health (DALY)	-7682,3349
Ecosystem quality (PDF.m2.y)	-2002798500
Use of resources (MJ)	-78071597000
€ Climate change	396 283 304 €
€ DALY	568 492 783 €
€ Ecosystem quality	2 803 917 900 000 €
€ Use of resources	312 286 388 €
Sum of external economic impacts (€)	2 805 194 962 475 €
Carbon tax evolution (€/y)	-198 141 652 000 €
Waste tax	
Waste tax BaU (€/y)	139 596 720 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-139 596 720 €
Viability distance (100% of the resource price)	1326
Viability distance (10% of resource price)	195
Waste treatment costs BaU (€/y)	719 200 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-719 200 000 €

Conclusion or comments

Aluminium oxide residues are most of the time sold to cement, ceramic and insulation sector to produce mineral products. This is a well-known synergy and that is not a surprise to discover such a potential when analysing assessment results. The synergy generates 800M€ of valued added and 8 700 associated jobs. The better environmental impact is on eco-system preservation.

Two parameters, the fact that there are 18 aluminium plants in EU which might be equipped with such a process and the theoretical viability radius of the synergy, suggest that some new geolocated viable matching would be identified in T3.6. during the assessment of the European IS potential.

5.32Synergy #33

Baseline business scenario

Bottom ashes are landfilled

Synergy

The objective of this synergy is to recover bottom ashes and provide pelletisation plants that can use these ashes. Pelletisation plants can process directly iron content residues. The technology identified in D3.2 will also be considered for the synergies 41 and 59.

D3.2 findings:

- A magnetic separator is used for ash processing
- 90% of recovery rate
- This procedure is highly implemented
- For a full dry processing plant with 90 000 tons processed per year:
    - Electricity demand: 10 KWh/t
    - OPEX: 15,2 € /t
    - CAPEX: 10 000* throughput^0,5; For 90 000, CAPEX = 3 000 000 €
    - Payback period 6 years
- Non-magnetic fraction of ash

Assumptions

- Only copper, iron and aluminium content were considered in the economic value estimation
- Incinerators bottom ash chemical composition was identified in a RECORD study [44]
- Only 54 990 is a valuable stream (copper, iron and aluminium content)

Table 60: Bottom ash equivalent price (Source: Strane)

Bottom ash volume	447 440	t/y			
Composition	%	t	Prix		Prix total
Al	6,9	30 873	1453,5	€/t	44 874 428,76 €
Ca	12,5	55 930	1824	€/t	NC
Fe	4,9	21 925	71	€/t	1 556 643,76 €
K	1,1	4 922	NC	€/t	NC
Mg	1,7	7 606	NC	€/y	NC
Na	2,1	9 396	NC	€/t	NC
P	0,6	2 685	NC	€/t	NC
S	0,5	2 237	NC	€/t	NC
Si	16,8	75 170	NC	€/t	NC
Cl	0,24	1 074	NC	€/t	NC

SO4	1,4	6 264	NC	€/t	NC
Cu	0,49	2 192	3619,2	€/t	7 934 936,76 €
Total price				€/y	54 366 009,28 €
Price per ton				€/t	121,50458

Table

Table 61: Synergy 33 (Source: Strane)

Synergy 33	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	447 440
Substituted material equivalent price (€/Unit)	988,0
Final volume recovered (Unit/y)	54 990
Operational costs (€/y)	6 801 088 €
VA	47 529 032 €
VAT	10 199 730 €
Labour Share (€/y)	21 863 355 €
Direct jobs (€)	496
Indirect jobs (min)	248
Indirect jobs (max)	1498
Investment	
CAPEX	10 000* throughput^0,5
Total investment in EU	6 689 096 €
External impacts	
Climate change (kg. CO2-eq)	3323338
Human health (DALY)	9,4462368
Ecosystem quality (PDF.m2.y)	2677038,5
Use of resources (MJ)	45002321
€ Climate change	-265 867 €
€ DALY	-699 022 €
€ Ecosystem quality	-3 747 853 900 €
€ Use of resources	-180 009 €
Sum of external economic impacts (€)	-3 748 998 798 €
Carbon tax evolution (€/y)	132 933 520 €
Waste tax	
Waste tax BaU (€/y)	17 369 621 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-17 369 621 €
Viability distance (100% of the resource price)	4939
Viability distance (10% of resource price)	565
Waste treatment costs BaU (€/y)	89 488 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-89 488 000 €

Conclusion or comments

The recovery of ferrous and non-ferrous metals is a procedure highly implemented. Most of the time, dedicated centres take over this work.

Nevertheless, pelletisation plants can receive these bottom ashes without any treatment. Waste treatment costs and associated landfilling tax are then reduced respectively around 90M€ and 17M€.

This synergy is a great benefit to the eco-system quality by avoid raw material extraction and associated impacts.

500 jobs can be created thorough Europe and the viability radius to transport these residues is around 500km.

This synergy has a relevant socio-economic impact, but its potential is probably already well consumed.

5.33Synergy #34

Baseline business scenario

The bottom ash from the combustion plant is landfilled, and the industrial has to pay the landfilling tax and charges.

Synergy

The aim of this synergy is to recover waste incineration bottom ash to provide pelletisation plants in steel sector.

There are 950 coal combustion referenced process in European Union. Coal combustion uses 186 000 t of coal/year and generates bottom ash.

Bottom ash are ferrous metals sources. Pelletisation plants require ferrous metal. There are only 6 pelletisation plants in European Union. 27 000 000 of pellets are produced each year or 4 500 000 tons per site.

There are no reported utilisations of bottom ash as a feedstock for iron pelletizing operations. Due to high requirements of this industry, the material may not be suitable for use in pelletizing operations. Beneficiation treatment of bottom ash may render this waste suitable for use, however, studies should be performed to evaluate the techno-economic feasibility of feeding bottom ash to beneficiation processes.

High grade Iron ores (60-70% Fe) are used as feed for the pelletization process. Low-grade ores (40% Fe) requires a beneficiation process in order to increase the quality and Iron content of the feed of the pelletizing plant. The Iron content of the bottom ash (4-8%) limits the utilization of this waste as a feed for the pelletization plant even when considering a beneficiation process. The development of new technologies for processing of iron-bearing wastes are advised.

Assumptions and calculation method

- The bottom ash volume (4 050 000 t/y) was used for the calculation.
- The iron content of the bottom ash is 6%.
- The price of the iron extracted is the one of iron ore (71 €/t).
- The hypothesis that the iron content can be extracted from the bottom ash (strong assumption to measure the value of this iron lost even if the synergy is not technically possible).

Tab

Table 62: Synergy 34 (Source: Strane)

Synergy 34	
Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	4 052 000
Substituted material equivalent price (€/t)	71
Final volume recovered (t/y)	243120
Operational costs (€/y)	NA
VA	17 261 520 €
VAT	3 704 322 €
Labour Share (€/y)	7 940 299 €

Direct jobs	180
Indirect jobs (min)	90
Indirect jobs (max)	544
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-16556957
Human health (DALY)	-244,89227
Ecosystem quality (PDF.m2.y)	-59764167
Use of resources (MJ)	-367852000
€ Climate change	1 324 557 €
€ DALY	18 122 028 €
€ Ecosystem quality	83 669 833 800 €
€ Use of resources	1 471 408 €
Sum of external economic impacts (€)	83 690 751 793 €
Carbon tax evolution (€/y)	-662 278 280 €
Waste tax	
Waste tax BaU (€/y)	157298640
Waste tax Synergy (€/y)	147860721,6
Waste tax balance (€/y)	-9437918,4
Viability distance (100% of the resource price)	406
Viability distance (10% of the good transported price)	41
Waste treatment costs BaU (€/y)	215161200
Waste treatment costs Synergy (€/y)	202251528
Waste treatment costs balance (€/y)	-12909672

Conclusion or comments

This synergy seems to be technically not viable because of the content of iron is too low for the pelletisation process. A detailed study has to be performed for this synergy.

Therefore, the economic viability has been made with strong assumptions (possibility to recover iron content from the flow to study the potential loss of the landfilling operation in this case). The value added of the valorisation of the whole flow is around 17,2 M€/y, and the associated VAT is around 3,7 M€. 180 direct jobs can be created.

The investment to make is unknown. This synergy could be a good opportunity for industrial site to reduce their landfilling fees and taxes by removing iron from bottom ash and use it in a pelletisation process.

5.34Synergy #35

Baseline business scenario

The most common practice for EAF slags management is landfilling and storing (64% of total EAF slags produced by 57 plants, see Table 63: Fate of EAF slags in EU (Source: BREF)). Indeed, the baseline scenario selected for these production residues is landfill.

Table 63: Fate of EAF slags in EU (Source: BREF)

Kind of steel	Total slag quantity (kt/yr)	On-site recycling		External use		Sold		Landfilled and stored	
		(kt/yr)	(%)	(kt/yr)	(%)	(kt/yr)	(%)	(kt/yr)	(%)
Carbon steels ([1])	958	–	–	164	17.1	362	37.8	432	45.1
Carbon steels ([2])	1796	45.1	2.5	494.8	27.6	13.7	0.8	1242	69.2
Low alloyed steels ([2])	444	–	–	61.6	13.9	108.0	24.4	261	58.9
High alloyed steels ([2])	461	81.4	17.7	68.0	14.8	160.0	34.7	156	33.9
Total EAF slags ([2])	2701	126.5	4.7	624.4	23.1	281.7	10.4	1659	61.4
Total EAF slags ([3])	4408								

([1]) Data from 11 plants producing 958 kt/yr of slags (131.7 kg/t LS) in 2008.
([2]) Data from 57 plants producing 2.7 million t/yr of slags (133 kg/t LS) in 1996.
([3]) Data from 2004 and related to the following EU countries: AT, BE, DE, DK, ES, FR, FI, LU, NL, UK, SE, SK.
Source: [30, Roederer et al. 1996] [195, Werner 2010] [365, Eurofer 2007].

Synergy

The aim of this synergy is to valorise EAF slag in cement industries. This is a known practice but not totally deployed because only 23,1% of EAF slags have an external use (most interesting for carbon steel) and 10,4 are sold, unlike BF slags which are very coveted. BOF slags can directly be reused in cement industries but a process allows to separate iron oxide and improve the stream characteristics/quality for the raw materials preparation step.

D3.2 findings:

- A chemical/mineralogical analysis is required to determine the composition of slags
- Cooling process and magnetic separation are required (metals content retrieve)
- Application limited compare to BF slags

Assumptions and calculation method

- Associated to reagent costs (Kaolin and carbon powder)
- 1 ton of steel slag needs 0.41 tons of kaolin and 0.06 tons of carbon powder
- No OPEX was found
- Granulated slag price: see Table 12 : Resources prices (Source: Strane)

Table

Table 64: Synergy 35 (Source: Strane)

Synergy 35	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	13 650 450
Substituted material equivalent price (€/Unit)	16,5
Final volume recovered (Unit/y)	13 650 450
Operational costs (€/y)	
VA	225 232 425 €
VAT	48 334 878 €
Labour Share (€/y)	103 606 916 €

Direct jobs (€)	2351
Indirect jobs (min)	1175
Indirect jobs (max)	7100
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment
External impacts	
Climate change (kg. CO2-eq)	-5041695900
Human health (DALY)	-2991,0197
Ecosystem quality (PDF.m2.y)	-1467892500
Use of resources (MJ)	-41413106000
€ Climate change	403 335 672 €
€ DALY	221 335 458 €
€ Ecosystem quality	2 055 049 500 €
€ Use of resources	165 652 424 €
Sum of external economic impacts (€)	2 845 373 054 €
Carbon tax evolution (€/y)	-201 667 836 000 €
Waste tax	
Waste tax BaU (€/y)	529 910 469 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-529 910 469 €
Viability distance (100% of the resource price)	94
Viability distance (10% of resource price)	9
Waste treatment costs BaU (€/y)	2 730 090 000 €
Waste treatment costs Synergy (€/y)	2 €
Waste treatment costs balance (€/y)	-2 730 089 998 €

Conclusion or comments

This synergy presents a real potential as EAF slags are not widely used in cement industries. We still find slag mountains directly stored on steel site. The only technical barrier is the incorporation rate of EAF slags in cement raw meal preparation and the chemical composition of EAF slags.

A total deployment of this synergy could generate 225 M€ of value added per year, 2 350 jobs and significant environmental benefit.

Nevertheless, the transportation of slags is not viable and limit the radius within which to find a partner site.

5.35Synergy #36

Baseline business scenario

We assume lime from paper and pulp production plants is sent to landfill and the waste does not have any intrinsic value.

Synergy

The aim of this synergy is to recover lime from paper and pulp production plants and provide waste incineration plants for flue gas treatment by replacing lime bought on the market.

D3.3 findings:

- Lime sludges could potentially be utilized directly in dry flue-gas treatment units due to its $CaCO_3$ composition. For semi-dry and wet flue-gas treatment units, a calcination (lime kiln) process is required to produce CaO.
- No reported use at industrial scale
- Lime sludges are use in the agriculture, cementitious materials production, and as a reagent for wastewater treatment processes and sewage sludge stabilisation

Assumptions

- Lime price: see Table 12 : Resources prices (Source: Strane)
- The receiver sector demand is unknow so we assumed the total lime volume can be valorised
- Flow modelled: 378 000 tons of lime per year (average)

Table

Table 65: Synergy 36 (Source: Strane)

Synergy 36	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	378 000
Substituted material equivalent price (€/Unit)	85,0
Final volume recovered (Unit/y)	378 000
Operational costs (€/y)	
VA	32 130 000 €
VAT	6 895 098 €
Labour Share (€/y)	14 779 800 €
Direct jobs (€)	335
Indirect jobs (min)	168
Indirect jobs (max)	1013
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment
External impacts	
Climate change (kg. CO2-eq)	-16775083
Human health (DALY)	-20,833349
Ecosystem quality (PDF.m2.y)	-9089753
Use of resources (MJ)	-245875920
€ Climate change	1 342 007 €
€ DALY	1 541 668 €
€ Ecosystem quality	12 725 654 €
€ Use of resources	983 504 €
Sum of external economic impacts (€)	16 592 832 €
Carbon tax evolution (€/y)	-671 003 320 €
Waste tax	
Waste tax BaU (€/y)	14 673 960 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-14 673 960 €

Viability distance (100% of the resource price)	486
Viability distance (10% of resource price)	49
Waste treatment costs BaU (€/y)	75 600 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-75 600 000 €

Conclusion or comments

The evolution of the resource's intrinsic value between the business as usual scenario and the synergy scenario create a value added of 32 M€ and an associated VAT around 7M€. This value added can generate around 330 direct jobs.

The implementation of this synergy will generate 75M€ of waste management costs saving and 14M€ of waste management tax for the emitting industries. A decrease of the carbon tax up than 660 M€ is expected. Environmental and human health impact would be significantly improved, especially eco-system quality.

The viability radius of the lime transportation is 50km (less than 500km so as not to be in deficit).

Indeed, this synergy has a great potential, but incinerators do not use for the moment lime sludges to replace limestone and market lime. Maybe machine adaptation or specific dosing need to be tested before synergy implementation and deployment.

5.36Synergy #37

This synergy is very similar to Synergy #5. It involves the same waste stream (EAF dusts) the same technology and the same level of investment and operational costs.

For the synergy 37, we only focus on the lead solid particles valorisation. Indeed, the only difference is the EAF dusts and waelz oxide lead content (EAF Dust contains 0.5 - 8% Lead. waelz oxide contains 10-20% Lead)

In order not to double-count environmental, economics (CAPEX and OPEX), taxes and costs avoided, the flow modelled is only lead recovered content (343 521 tons of the total waelz oxide volume produced in EU).

Three economic value where found for lead. The lowest one was selected not to overestimate the economic profitability of this synergy.

The value added of this synergy has been added retrospectively to the benefits of zinc recovery in the Synergy #5 table.

See the conclusion of Synergy #5 chapter.

5.37Synergies #38 & 38 bis

Baseline business scenario

Coke oven plants produce benzene solid residues. The selected baseline scenario for benzene is the direct incineration, due to its valuable calorific power (LHV benzene: 41.8 MJ/kg). The economic benefit of the baseline scenario is to avoid the use and purchase of another solid fuel as coal.

Synergy

The aim of this synergy is to send benzene to organic chemical sites in ethylbenzene manufacturing units to use it as a raw material and not as a fuel. Economic factors considered are:

- Economic value of the benzene

- Equivalent coal gas consumption avoided economic value

D3.2 findings:

- Benzene is generated during coke oven gas cleaning up process
- Maintenance costs are high
- Benzene can be valorised in ethylbenzene manufacturing

Assumptions and calculation method

- Benzene volume: 485 781 t/year
- COG volume treated to obtain Benzene: 18 122 400 000 m3/y (2 097 500 m3/h)
- Price of the coal: see Table 12 : Resources prices (Source: Strane)
- CAPEX: 2 000 – 30 000 EUR for 1 000 Nm³/h
- OPEX: 5 000 EUR per year

Two assessments were carried out for this synergy in order to highlight the methodology's limits and sensitivity. In the case of synergy 38, the price of an economic value rate of 701,8 € was applied whereas in the 38 bis, the price applied was 919€/t.

Table

Table 66: Synergy 38 & 38 bis (Source: Strane)

	Synergy 38	Synergy 38 bis
Waste stream price in BaU scenario (€/Unit)	796,5	796,5
Waste stream volume (Unit/y)	485 781,0	485 781,0
Substituted material equivalent price (€/Unit)	701,8	919,0
Final volume recovered (Unit/y)	485 781,0	485 781,0
Operational costs (€/y)	190 000,0	190 000,0
VA	-46 207 321 €	59 304 312 €
VAT	-9 916 091 €	12 726 705 €
Labour Share (€/y)	-21 255 368 €	27 279 983 €
Direct jobs (€)	-482	619
Indirect jobs (min)	-241	310
Indirect jobs (max)	-1457	1869
Investment		
CAPEX	2 000 – 30 000 EUR for 1 000 Nm³/h	2 000 – 30 000 EUR for 1 000 Nm³/h
Total investment in EU	33 560 000 000	33 560 000 000
External impacts		
Climate change (kg. CO2-eq)	-55547,327	-55547,327
Human health (DALY)	-0,01071334	-0,01071334
Ecosystem quality (PDF.m2.y)	-778,58537	-778,58537
Use of resources (MJ)	-734455,65	-734455,65
€ Climate change	4 444 €	4 444 €
€ DALY	793 €	793 €
€ Ecosystem quality	1 090 €	1 090 €
€ Use of resources	2 938 €	2 938 €
Sum of external economic impacts (€)	9 264 €	9 264 €
Carbon tax evolution (€/y)	-2 221 893 €	-2 221 893 €
Waste tax		
Waste tax BaU (€/y)	0 €	0 €
Waste tax Synergy (€/y)	0 €	0 €
Waste tax balance	0 €	0 €

Viability distance (100% of the resource price)	-544	698
Viability distance (10% of resource price)	401	525
Waste treatment costs BaU (€/y)	0 €	0 €
Waste treatment costs Synergy (€/y)	0 €	0 €
Waste treatment costs balance (€/y)	0 €	0 €

Conclusion or comments

The two assessments' results are significantly different. In the first case, the value-added decrease about 40M€ and in the second case increase about 60M€. This synergy is therefore broadly equivalent to the initial scenario from an economic point of view. That means a company who can recover benzene do not have an economic advantage to valorise it otherwise than burning it like a fuel. Unfortunately, in that specific case, the avoiding environmental impacts are not huge because the extraction of coal replacing benzene incineration require a lot of negative actions on the environment.

5.38Synergy #39

Baseline business scenario

Usually, the flow of SO2 produced is released into the air. It therefore has no economic value.

Synergy

The aim of this synergy is to recover sulphuric acid, as a by-product of copper primary smelting route, and provide sulphate process in inorganic chemical industries. The technology database from D3.3 does not provide information on potential residues. Therefore, the global economic value of the synergy considers only the sulfuric acid stream economic value.

Assumptions and calculation method

- Sulfuric acid annual volume is 100 000 t/y. This data originates from the synergies environmental impact assessment (D3.3).
- As there are 33 sites in Europe, 7 pieces of equipment will be considered when calculating the investment. Indeed, according to the technology database (D3.3), one piece of equipment can handle between 11 and 1200 MTPD (Metric Ton Per Day), and the 33 European sites process approximatively 300 t/day of sulfuric acid (3 t/day/site). 7 equipments would providing 15 t/day of sulfuric acid would be enough.

Table

Table 67: Synergy 39 (Source: Strane)

Synergy 39	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	90,9
Final volume recovered (Unit/y)	100000
Operational costs (€/y)	
VA	9 090 000 €
VAT	1 950 714 €
Labour Share (€/y)	4 181 400 €
Direct jobs (€)	95

Indirect jobs (min)	47
Indirect jobs (max)	287
Investment	
CAPEX	2900000
Total investment in EU	20300000
External impacts	
Climate change (kg. CO2-eq)	-2027589200
Human health (DALY)	-434,21736
Ecosystem quality (PDF.m2.y)	-76283168
Use of resources (MJ)	-3530963400
€ Climate change	162 207 136 €
€ DALY	32 132 085 €
€ Ecosystem quality	106 796 435 200 €
€ Use of resources	14 123 854 €
Sum of external economic impacts (€)	107 004 898 274 €
Carbon tax evolution (€/y)	-81 103 568 000 €
Waste tax	
Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	519
Viability distance (10% of the good transported price)	52
Waste treatment costs BaU (€/y)	
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	

Conclusion or comments

The value added of the valorisation of the whole flow is around 9 M€/y, and the associated VAT is around 2 M€. An investment of 20 M€ would be necessary and would be amortized in approximately two years. The expected job creation is around 95 throughout Europe.

The implementation of this synergy will generate a decrease of the carbon tax up than 81 103 M€. Environmental and human health impact would be significantly improved.

These results should be interpreted remembering that there are no data available on residues.

5.39Synergy #40

Baseline business scenario

BF slags are considered landfilled

Synergy

D3.2 findings:

- Blast furnace slags could potentially be used in secondary copper smelting processes after ferrous metal extraction
- Secondary copper smelting includes the use as feedstock of foundry slags with a copper concentration of 10 to 40%

Analysis & conclusion

As indicated in the **Erreur ! Source du renvoi introuvable.**, BF slags do not have a copper content of 10 – 40%.

Table 68: BF slags composition (Source: BREF)

Classification CaO/SiO_2	>1.0 middle	<1.0 high	BF1	BF2	BF3
Fe_{total}	0.2 –0.6	0.4			
FeO			0.49	0.24	0.80
Mn_{total}	0.2 – 0.7	0.3			
MnO			0.48	0.66	1.00
TiO_2	0.5 – 2.7	0.7		0.77	
Al_2O_3	9.0 – 14.0	9.2	13.09	12.63	10.90
S_{total}, mainly CaS	0.8 – 2.0	1.6		1.12	1.15
SiO_2	33.2 – 37.0	38.4	32.88	36.78	36.90
CaO	38.1 – 41.7	35.6	33.76	36.64	35.80
MgO	7.0 – 11.0	18.0	15.96	11.19	10.70
Na_2O	0.3 – 0.6	0.5		0.35	0.35
K_2O	0.6 – 0.8	0.8		0.54	0.40
CaO/SiO_2	1.1 – 1.2	0.9			
$(CaO+MgO)/SiO_2$	1.3 – 1.5	1.2			
TiO_2			2.05		
Source: [47, Geiseler 1992] [270, Reynard 2007] [385, Malmberg et al. 2005] [392, Schmidt et al. 2003] [394, Colletta et al. 2002].					

This synergy is not viable because only 20-40% copper rich secondary raw materials are integrated in the Kayser recycling system (Source: BREF). BF slags are copper poor and this synergy is not viable. Moreover, BF slags are mostly used by cements industries and in road construction for their iron, calcium and silica content. There is no interest (especially not financial) in using them in non-ferrous metals industries.

5.40 Synergy #41

Baseline business scenario

Ashes from hazardous wastes incineration are landfilled

Synergy

The objective of this synergy is to recover ashes and provide non-ferrous metals industries. Indeed, the technology identified in D3.2 for synergy 33, 41 and 59 is considered in this chapter.

D3.2 findings:

- A magnetic separator is used for ash processing
- 80% of recovery rate
- This procedure is highly implemented
- For a full dry processing plant with 90 000 tons processed per year:

- Electricity demand: 10 KWh/t
- OPEX: 15,2 € /t
- CAPEX: 10 000* throughput^0,5; For 90 000, CAPEX = 3 000 000 €
- Payback period 6 years

The copper content in incineration slags is too low to make this synergy viable (0 – 25,5 mg/L). In order to model the economic impact of this synergy, the flow considered is the ashes alumina content.

Table

Table 69: Synergy 41 (Source: Strane)

Synergy 41	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	185 640
Substituted material equivalent price (€/Unit)	98,2
Final volume recovered (Unit/y)	29 895
Operational costs (€/y)	2 821 728 €
VA	115 035 €
VAT	24 687 €
Labour Share (€/y)	52 916 €
Direct jobs (€)	1
Indirect jobs (min)	1
Indirect jobs (max)	4
Investment	
CAPEX	10 000* throughput^0,5
Total investment in EU	4 308 596 €
External impacts	
Climate change (kg. CO2-eq)	-43295843
Human health (DALY)	-34,346576
Ecosystem quality (PDF.m2.y)	-9028622,8
Use of resources (MJ)	-400383890
€ Climate change	3 463 667 €
€ DALY	2 541 647 €
€ Ecosystem quality	12 640 072 €
€ Use of resources	1 601 536 €
Sum of external economic impacts (€)	20 246 922 €
Carbon tax evolution (€/y)	-1 731 833 720 €
Waste tax	
Waste tax BaU (€/y)	7 206 545 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-7 206 545 €
Viability distance (100% of the resource price)	22
Viability distance (10% of resource price)	56
Waste treatment costs BaU (€/y)	37 128 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-37 128 000 €

Conclusion or comments

The recovery of ferrous and non-ferrous metals is a procedure highly implemented. Most of the time, dedicated centres take over this work.

This synergy does not present a big financial advantage but presents interesting environmental benefits comparing with the low wastes total volume.

Nevertheless, only for alumina recovery, waste treatment costs and associated landfilling tax are then reduced respectively around 37M€ and 7M€.

A few jobs can be created but this synergy has not an interesting impact. The only way to make this synergy viable is to massify the flows and use dedicated centres to treat waste streams from numerous sites and not only incinerators.

The viability distance to transport incineration ashes is 50 km so a distance probably too small to join massive non-ferrous This synergy metals industries sites.

Processing all incinerator ashes thorough Europe require to an 4 308 596 € investment.

5.41Synergy #42

Due to lack of data, this synergy is not modelled in this study.

5.42Synergy #43

Due to lack of data, this synergy is not modelled in this study.

5.43Synergy #44

Baseline business scenario

Starch production generates sand that is usually landfilled. 18 starch production installations are referenced European Union. They produce 11 058 000 t of raw material /y (614 333 t/site). Sand is starch production process output resource. The annual sand volume is between 1,5 and 7 kg/ t of starch. The annual associated sand volume is from 16 587 to 77 406 t/y (between 921 and 4 300 t/site).

Synergy

The aim of this synergy is to recover sand from food and drink industries and provide aluminium sector. This synergy is direct. 18 aluminium production plants are referenced in European Union. These facilities produce 6 200 000 tons of aluminium per year (344 444 tons per site). Primary aluminium production requires 0 to 1,5 kg of fluxes /t. Sand can be used as flux.

Assumptions and calculation method

- The waste stream volume used for calculation is 46 997 t/y.

Table

Table 70: Synergy 44 (Source: Strane)

Synergy 44

Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	46997
Substituted material equivalent price (€/Unit)	155
Final volume recovered (Unit/y)	46997
Operational costs (€/y)	
VA	7 284 535 €
VAT	1 563 261 €
Labour Share (€/y)	3 350 886 €
Direct jobs (€)	76
Indirect jobs (min)	38
Indirect jobs (max)	230
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-1086106,5
Human health (DALY)	-6,7820746
Ecosystem quality (PDF.m2.y)	-1062190,8
Use of resources (MJ)	-21332963
€ Climate change	86 889 €
€ DALY	501 874 €
€ Ecosystem quality	1 487 067 120 €
€ Use of resources	85 332 €
Sum of external economic impacts (€)	1 487 741 214 €
Carbon tax evolution (€/y)	-43 444 260 €
Waste tax	
Waste tax BaU (€/y)	1 824 424 €
Waste tax Synergy (€/y)	0 €
Waste tax balance (€/y)	-1 824 424 €
Viability distance (100% of the resource price)	886
Viability distance (10% of the good transported price)	89
Waste treatment costs BaU (€/y)	2 495 541 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-2 495 541 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 7.2 M€/y, and the associated VAT is around 1.5 M€. The expected job creation is around 76 throughout Europe.

The implementation of this synergy will generate a decrease of the carbon tax up 43 M€ and will avoid landfill costs of 2.5 M€ and landfill tax of 1.8 M€. Environmental and human health impact would be significantly improved. The distance is enough to reach the receiving sector in several case.

The investment is low and mostly insignificant. The synergy is already implemented.

5.44Synergy #45

Due to lack of data, this synergy is not modelled in this study.

5.45Synergy #46

Due to lack of data, this synergy is not modelled in this study.

5.46Synergy #47

Baseline business scenario

The COG has a valuable calorific value (18,7 MJ/m3). It is most of time directly reused on the site to provide furnaces and replace conventional gaseous fuels required for the combustion (in the same or other steel processes). The economic benefit of the baseline scenario is to avoid the use and purchase of another gaseous fuel as natural gas.

Synergy

The aim of this synergy is to recover coke oven gas from coke ovens and provide combustion plants for iron and steel process gases combustion.

There are 38 coke oven plants in European Union. They produce 50 340 000 t of coke /y (1 324 736 T/site).

Coke ovens process generates 360 - 518 Nm3 of coke oven gas / t of coke. The annual COG volume is between 18 122 400 000 - 26 076 120 000 Nm3/y. (476 905 263 - 686 213 684 Nm3/site).

In European Union, combustion of gaseous fuels generates 713 000 MWh of electricity per year. These plants can use steelmaking process gas, in particular COG, as gaseous fuel.

Assumptions and calculation method

- The minimum COG production volume (18 122 400 000 m3/y) was used for the calculation.
- Price of the natural gas: 0,26 €/Nm3

Tab

Table 71: Synergy 47 (Source: Strane)

Synergy 47	
Waste stream price in BaU scenario (€/m3)	0
Waste stream volume (m3/y)	18 122 400 000
Substituted material equivalent price (€/m3)	0,12096688
Final volume recovered (m3/y)	18 122 400 000
Operational costs (€/y)	
VA	2 192 210 180 €
VAT	470 448 305 €
Labour Share (€/y)	1 008 416 683 €
Direct jobs	22882
Indirect jobs (min)	11441

Indirect jobs (max)	69103
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-13201569000
Human health (DALY)	-15059,265
Ecosystem quality (PDF.m2.y)	-2936777200
Use of resources (MJ)	-63603778000
€ Climate change	1 056 125 520 €
€ DALY	1 114 385 610 €
€ Ecosystem quality	4 111 488 080 000 €
€ Use of resources	254 415 112 €
Sum of external economic impacts (€)	4 113 913 006 242 €
Carbon tax evolution (€/y)	-528 062 760 000 €
Waste tax	
Waste tax BaU (€/y)	NA
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	
Viability distance (10% of the good transported price)	
Waste treatment costs BaU (€/y)	0
Waste treatment costs Synergy (€/y)	0
Waste treatment costs balance (€/y)	0

Conclusion or comments

The value added of the valorisation of the whole flow is around 2,1 B€/y, and the associated VAT is around 470,4 M€. The investment is mainly on the implementation of the pipe between two processes and the distance viability is then not estimated here. The expected direct job creation is around 22 888 throughout Europe. To explain these digits, this synergy is already well implemented in Europe.

Waste tax balance is difficult to estimate because it depends if the combustion plant is part of the company that would make the synergy.

5.47Synergy #48

Baseline business scenario

The Blast Furnace Gas (BFG) is commonly used to be burnt because of its calorific value (3,3 MJ/m3). This gas is mixed with COG or natural gas as the calorific value is quite low. The synergy is already well implemented but some combustion plants still use a big amount of natural gas.

Synergy

The aim of this synergy is to recover blast furnace gas and provide combustion plants for iron and steel process gases combustion.

Blast furnace is a widely used steelmaking process with 86 installations in European Union. Blast furnaces annual production is 116 280 000 t/y of hot metal (1 352 093 t/site). Blast furnace generate 10 000 - 70 000 Nm3 of blast furnace gas per hour. The specific factor is 1200 - 2000 Nm3 of BF gas per ton of hot metal produce. The annual BF gas production is 139 536 000 000 - 232 560 000 000 Nm3/y (1 622 511 627 - 2 704 186 046 Nm3/y/site).

In European Union, combustion of gaseous fuels generates 713 000 MWh of electricity per year. These plants can use steelmaking process gas, in particular BF gas, as gaseous fuel.

Assumptions and calculation method

- The minimum BFG production volume (139 536 000 000 m3/y) was used for the calculation.

Table

Table 72: Synergy 48 (Source: Strane)

Synergy 48	
Waste stream price in BaU scenario (€/m3)	0
Waste stream volume (m3/y)	139 536 000 000
Substituted material equivalent price (€/m3)	0,02131677
Final volume recovered (m3/y)	139 536 000 000
Operational costs (€/y)	
VA	2 974 456 845 €
VAT	638 318 439 €
Labour Share (€/y)	1 368 250 149 €
Direct jobs	31046
Indirect jobs (min)	15523
Indirect jobs (max)	93760
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-96388848
Human health (DALY)	-39,966814
Ecosystem quality (PDF.m2.y)	-8288040,2
Use of resources (MJ)	-3446385900
€ Climate change	7 711 108 €
€ DALY	2 957 544 €
€ Ecosystem quality	11 603 256 280 €
€ Use of resources	13 785 544 €
Sum of external economic impacts (€)	11 627 710 476 €
Carbon tax evolution (€/y)	-3 855 553 920 €
Waste tax	
Waste tax BaU (€/y)	NA

Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	
Viability distance (10% of the good transported price)	
Waste treatment costs BaU (€/y)	0
Waste treatment costs Synergy (€/y)	0
Waste treatment costs balance (€/y)	0

Conclusion or comments

The value added of the valorisation of the whole flow is around 2,9 B€/y, and the associated VAT is around 638 M€. The investment is mainly on the implementation of the pipe between two processes and the distance viability is not estimated here. The expected direct job creation is around 31 046 throughout Europe. To explain these digits, this synergy is already well implemented in Europe and already avoids extra expenses in natural gas for many companies.

Waste tax balance is difficult to estimate because it depends if the combustion plant is part of the company that would make the synergy.

5.48Synergy #49

Baseline business scenario

The Blast Oxygen Furnace Gas (BOFG) is commonly used to be burnt because of its calorific value (8,8 MJ/m3). This gas is mixed with COG or natural gas as the calorific value is quite low. The synergy is already well implemented but some combustion plants still use a big amount of natural gas.

Synergy

The aim of this synergy is to recover blast furnace gas and provide combustion plants for iron and steel process gases combustion.

Basic oxygen furnaces are a steelmaking route. This technology is widely used in European Union with 101 referenced installations. European annual BOF steel production is around 123 Mt/year. (1 220 594 T/site).

BOF process generates 350 - 700 MJ of BOF gas per ton of liquid steel. The annual BOF gas energy is 43 148 000 000 - 64 722 000 000 MJ/y (427 270 000 - 640 811 881 MJ/site).

In European Union, combustion of gaseous fuels generates 713 000 MWh of electricity per year. These plants can use steelmaking process gas, in particular BOF gas, as gaseous fuel.

Assumptions and calculation method

- The minimum BOFG production volume (5 017 209 302 m3/y) was used for the calculation.

Tab

Table 73: Synergy 49 (Source: Strane)

Synergy 49	
Waste stream price in BaU scenario (€/m3)	0
Waste stream volume (m3/y)	5017209302

Substituted material equivalent price (€/m3)	0,05684472
Final volume recovered (m3/y)	5017209302
Operational costs (€/y)	NA
VA	285 201 860 €
VAT	61 204 319 €
Labour Share (€/y)	131 192 856 €
Direct jobs	2977
Indirect jobs (min)	1488
Indirect jobs (max)	8990
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-78722417
Human health (DALY)	-32,641579
Ecosystem quality (PDF.m2.y)	-6768983,8
Use of resources (MJ)	-2814722200
€ Climate change	6 297 793 €
€ DALY	2 415 477 €
€ Ecosystem quality	9 476 577 320 €
€ Use of resources	11 258 889 €
Sum of external economic impacts (€)	9 496 549 479 €
Carbon tax evolution (€/y)	-3 148 896 680 €
Waste tax	
Waste tax BaU (€/y)	NA
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	NA
Viability distance (10% of the good transported price)	NA
Waste treatment costs BaU (€/y)	0
Waste treatment costs Synergy (€/y)	0
Waste treatment costs balance (€/y)	0

Conclusion or comments

The value added of the valorisation of the whole flow is around 285 M€/y, and the associated VAT is around 61,2 M€. The investment is mainly on the implementation of the pipe between two processes and the distance viability is not estimated here. The expected direct job creation is around 2 977 throughout Europe. To explain these digits, this synergy is already well implemented in Europe and already avoids extra expenses in natural gas for many companies.

Waste tax balance is difficult to estimate because it depends if the combustion plant is part of the company that would make the synergy.

5.49Synergy #50

Baseline business scenario

Solvay processes 15 000 000 tons of sodium carbonate per year. 30 - 300 kg of limestone fines per ton of final product are emitted. The annual limestone fines volume is 450 000 - 2 475 000 tons per year. Limestone fines are usually landfilled.

Synergy

The aim of this synergy is to recover limestone fines from Solvay process to provide raw material preparation in cement industries. This synergy is direct.

Cement industries are steel fines consumers and use limestone as raw material. 268 cement plants are referenced in Europe Union. Limestone is used for raw material preparation. 118 000 000 tons of clinker (440 298 per site) and 267 000 000 tons of grey cement (996 268) are produced each year.

Assumptions and calculation method

- The average production of limestone fines is 1 462 500 t/y.
- Limestone fines are usually landfilled.

Table

Table 74: Synergy 50 (Source: Strane)

Synergy 50	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	1 462 500
Substituted material equivalent price (€/Unit)	151,2
Final volume recovered (Unit/y)	1 462 500
Operational costs (€/y)	
VA	221 130 000 €
VAT	47 454 498 €
Labour Share (€/y)	101 719 800 €
Direct jobs (€)	2308
Indirect jobs (min)	1154
Indirect jobs (max)	6970
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	-12276932
Human health (DALY)	-33,291727
Ecosystem quality (PDF.m2.y)	-22313367
Use of resources (MJ)	-295621090
€ Climate change	982 155 €
€ DALY	2 463 588 €
€ Ecosystem quality	31 238 713 800 €
€ Use of resources	1 182 484 €
Sum of external economic impacts (€)	31 243 342 027 €

Carbon tax evolution (€/y)	-491 077 280 €
Waste tax	
Waste tax BaU (€/y)	56 774 250 €
Waste tax Synergy (€/y)	0 €
Waste tax balance (€/y)	-56 774 250 €
Viability distance (100% of the resource price)	864
Viability distance (10% of the good transported price)	86
Waste treatment costs BaU (€/y)	77 658 750 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-77 658 750 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 221 M€/y, and the associated VAT is around 47 M€. The expected job creation is around 2 308 throughout Europe. 154 M€ of landfilled tax and costs could be avoided thanks to this synergy.

The implementation of this synergy will generate a decrease of the carbon tax up than 491 M€. Environmental and human health impact would be significantly improved.

This synergy seems promising. Nevertheless, transportation costs should be considered in further analysis.

5.50Synergy #51

Due to lack of data, this synergy is not modelled in this study.

5.51Synergy #52

Baseline business scenario

Primary copper smelting pyrometallurgical route generates electrolyte bleed. This by-product is composed by two fractions: acid and nickel. According to the synergies environmental impact assessment (D3.4), this flow is usually incinerated.

Synergy

The aim of this synergy is to recover hydrochloric acid contained in the electrolyte bleed. Nickel is internally reused.

Assumptions and calculation method

- The amount of recoverable hydrochloric acid is not known. The demand of the identified sector for synergy is 9,603 t/year. This value will be used for calculations. It is highly possible that the available flow will be greater than this assumption. Further analysis would determine this data with more precision. Other receiving sites should then be analysed.
- Since the flow used for the calculations is relatively low, it is assumed that only one piece of equipment would be used to process it. This hypothesis must be verified, but our sources have not allowed us to

identify the quantity of raw material that can be processed by the equipment. The OPEX and CAPEX are drawn from the technology database (D3.3).

Table

Table 75: Synergy 52 (Source: Strane)

Synergy 52	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	4800000
Substituted material equivalent price (€/Unit)	78,7
Final volume recovered (Unit/y)	9603
Operational costs (€/y)	247752
VA	508 004 €
VAT	109 018 €
Labour Share (€/y)	233 682 €
Direct jobs (€)	5
Indirect jobs (min)	3
Indirect jobs (max)	16
Investment	
CAPEX	439047
Total investment in EU	439047
External impacts	
Climate change (kg. CO2-eq)	-26732411
Human health (DALY)	-13
Ecosystem quality (PDF.m2.y)	-4009303
Use of resources (MJ)	-168421970
€ Climate change	2 138 593 €
€ DALY	936 860 €
€ Ecosystem quality	5 613 024 340 €
€ Use of resources	673 688 €
Sum of external economic impacts (€)	5 616 773 481 €
Carbon tax evolution (€/y)	-1 069 296 440 €
Waste tax	
Waste tax BaU (€/y)	588 480 000 €
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	-588 480 000 €
Viability distance (100% of the resource price)	302
Viability distance (10% of the good transported price)	45
Waste treatment costs BaU (€/y)	588 480 000 €
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	-588 480 000 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 508 000 €/y, and the associated VAT is around 110 000 €. An investment of 440 000 € would be necessary and would be amortized in approximately less than one year. The expected job creation is around 5 throughout Europe.

The implementation of this synergy will generate a decrease of the carbon tax up than 1 000 M€. Environmental and human health impact would be significantly improved.

These results should be interpreted remembering that there are no data available on the real raw material flow quantity. This synergy seems promising, but its study needs to be further developed.

5.52Synergy #53

Baseline business scenario

22 ceramic sites produce 150 000 t/y technical electro porcelain ceramic products (6 818 t/site). Water after flocculation contain 0,656 mg of non-ferrous metals per litter. Usually, the wastewater is sent to wastewater treatment plants.

Synergy

The aim of this synergy is to recover non-ferrous metals from electro porcelain manufacturing wastewater to provide nickel, cobalt and alloys production in non-ferrous metals industries.

Assumptions and calculation method

- 2.02 L of wastewater is discharged during the production of a brick. 200 000 bricks per day are produced, which corresponds to a volume of 145 440 000 L of wastewater per year. Due to lack of data, this is an overestimated volume and only applicable to bricks and not to ceramics [45].
- 95.4 kg of non-ferrous metals can be produced.
- The metal price used is the average of the price of nickel, cobalt, aluminium and zinc, that is to say 23 175 €/t.

Table

Table 76: Synergy 53 (Source: Strane)

Synergy 53	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	0,0954
Substituted material equivalent price (€/Unit)	23175
Final volume recovered (Unit/y)	0,0954
Operational costs (€/y)	
VA	2 211 €
VAT	474 €
Labour Share (€/y)	1 017 €
Direct jobs (€)	0
Indirect jobs (min)	0
Indirect jobs (max)	0
Investment	
CAPEX	
Total investment in EU	

External impacts	
Climate change (kg. CO2-eq)	
Human health (DALY)	
Ecosystem quality (PDF.m2.y)	
Use of resources (MJ)	
€ Climate change	
€ DALY	
€ Ecosystem quality	
€ Use of resources	
Sum of external economic impacts (€)	
Carbon tax evolution (€/y)	
Waste tax	
Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	
Viability distance (10% of the good transported price)	
Waste treatment costs BaU (€/y)	
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	

Conclusion or comments

The value added of the valorisation of the whole flow is around 2 000 €/y, and the associated VAT is around 400 €. No job creation is expected.

A further study should be carried out to estimate the social and environmental benefits of this synergy. In addition, since the price of water treatment is not known for the business as usual, the charges saved cannot be estimated.

Due to the lack of data on this synergy, the study is not conclusive. Many data are missing to establish the potential of this synergy.

5.53Synergies #54 & #55

Baseline business scenario

Wastewater is a waste stream from vacuum distillation in refining industries.

Synergy

The aim of this synergy is to recover ammonia contained in the wastewater.

Assumptions and calculation method

- Thera are approximatively 3.75 m3 of wastewater per ton of crude oil [46].
- According to the technology database (D3.3), there are between 1 to 100 mg_{NH3}/L in the wastewater. The calculation was made with the average: 50 mg_{NH3}/L.

- Calculations are based on a crude oil volume of 864 000 000 m3/year [47]. This volume includes the flows of synergies 54 and 55. The calculation will consider the ammonia contained in the wastewater of all refineries.
- According to the technology database (D3.2), ammonia recovery rate is 92.5%.
- The synergies environmental impact assessment (D3.4) does not provide information on the life cycle analysis of this synergy.
- The cost of wastewater treatment is not estimated in this study. In all cases, synergy or not, the same amount of wastewater should be treated.

Table

Table 77: Synergies 54 & 55 (Source: Strane)

Synergy 54-55	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	2851200000
Substituted material equivalent price (€/Unit)	423
Final volume recovered (Unit/y)	131155,2
Operational costs (€/y)	
VA	55 478 650 €
VAT	11 905 718 €
Labour Share (€/y)	25 520 179 €
Direct jobs (€)	579
Indirect jobs (min)	290
Indirect jobs (max)	1749
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	
Human health (DALY)	
Ecosystem quality (PDF.m2.y)	
Use of resources (MJ)	
€ Climate change	
€ DALY	
€ Ecosystem quality	
€ Use of resources	
Sum of external economic impacts (€)	
Carbon tax evolution (€/y)	
Waste tax	
Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	2417
Viability distance (10% of the good transported price)	242

Waste treatment costs BaU (€/y)	
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	

Conclusion or comments

The value added of the valorisation of the whole flow is around 60 M€/y, and the associated VAT is around M13 €. The expected job creation is around 629 throughout Europe.

A further study should be carried out to estimate the social and environmental benefits of this synergy. In addition, estimating the costs of wastewater treatment would be interesting information.

The investment and operating costs are difficult to estimate according to the technology database (D3.3). The investment required depends greatly on the operating conditions and the operating cost is generally high.

Many data are missing to establish the potential of this synergy

5.54Synergy #56

Baseline business scenario

22 ceramic sites produce 150 000 t/y technical electro porcelain ceramic products (6 818 t/site). Water after flocculation contain 0,656 mg of non-ferrous metals per litter. Usually, the wastewater is sent to wastewater treatment plants.

Synergy

The aim of this synergy is to recover non-ferrous metals from electro porcelain manufacturing wastewater to provide nickel, cobalt and alloys production in non-ferrous metals industries.

Assumptions and calculation method

- 2.02 L of wastewater is discharged during the production of a brick. 200 000 bricks per day are produced, which corresponds to a volume of 145 440 000 L of wastewater per year. Due to lack of data, this is an overestimated volume and only applicable to bricks and not to ceramics [45].
- 95.4 kg of non-ferrous metals can be produced.
- The metal price used is the average of the price of nickel, cobalt, aluminium and zinc, that is to say 3 440 €/t.

Table

Table 78: Synergy 56 (Source: Strane)

Synergy 56	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	0,0954
Substituted material equivalent price (€/Unit)	3440
Final volume recovered (Unit/y)	0,0954
Operational costs (€/y)	
VA	328 €
VAT	70 €
Labour Share (€/y)	151 €
Direct jobs (€)	0

Indirect jobs (min)	0
Indirect jobs (max)	0
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	
Human health (DALY)	
Ecosystem quality (PDF.m2.y)	
Use of resources (MJ)	
€ Climate change	
€ DALY	
€ Ecosystem quality	
€ Use of resources	
Sum of external economic impacts (€)	
Carbon tax evolution (€/y)	
Waste tax	
Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	
Viability distance (10% of the good transported price)	
Waste treatment costs BaU (€/y)	
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	

Conclusion or comments

The value added of the valorisation of the whole flow is around 330 €/y, and the associated VAT is around 70 €. No job creation is expected.

A further study should be carried out to estimate the social and environmental benefits of this synergy. In addition, since the price of water treatment is not known for the business as usual, the charges saved cannot be estimated.

Due to the lack of data on this synergy, the study is not conclusive. Many data are missing to statute on the potential of this synergy.

5.55 Synergy #57

Due to lack of data, this synergy is not modelled in this study.

5.56Synergy #58

Due to lack of data, this synergy is not modelled in this study.

5.57Synergy #59

Baseline business scenario

The reference scenario for slag ash produces in MSWI is landfilling.

Synergy

The aim of this synergy is to recover slags as a rich-non-ferrous metals raw materials and provide non-ferrous metals industries.

D3.2 findings are the same as for Synergy #33 and Synergy #41 .

Assumptions and calculation method

- We consider in this synergy a full recovery treatment that allows to extract ferrous metals and non-ferrous metals (magnetic separator and Eddy current).
- Slag ash volume: 12378932,5 tons/year
- Slag composition: *"Feasibility study of using brick made from municipal solid waste incinerator fly ash slag"* [48] provide the composition of slag ash from municipal solid waste incineration (**Erreur ! Source du renvoi introuvable.**).

Table 79: Waste incineration slag ash composition [48]

	Clay	MSWI fly ash	MSWI slag	Taiwan TCLP regulatory limits
Composition (%)				
SiO_2	61.5 ± 0.2	35.8 ± 4.4	35.0 ± 3.3	
Al_2O_3	15.8 ± 0.2	9.8 ± 0.8	16.5 ± 2.9	
Fe_2O_3	6.1 ± 0.1	4.9 ± 0.2	3.8 ± 0.9	
CaO	0.4 ± 0.0	14.7 ± 1.1	25.0 ± 2.3	
MgO	1.3 ± 0.0	0.8 ± 0.0	2.9 ± 0.0	
SO_3	0.1 ± 0.0	2.2 ± 0.6	1.4 ± 0.4	
K_2O	2.7 ± 0.9	5.3 ± 0.3	1.3 ± 0.2	
Cl^-	–	5.0 ± 0.5	0.01 ± 0.00	
Total metal (mg/kg)				
Cu	22.8 ± 1.2	1409.3 ± 89.1	1001.8 ± 0.2	
Zn	106.4 ± 0.6	7115.8 ± 163.2	2720.6 ± 6.5	
Pb	71.7 ± 0.30	1284.0 ± 14.8	520.2 ± 0.1	
Cr	56.1 ± 2.1	811.6 ± 24.6	590.6 ± 2.0	
Cd	0.7 ± 0.30	80.2 ± 1.7	2.3 ± 0.02	
Leaching concentration (mg/L)				
Cu	0.1 ± 0.2	0.6 ± 0.1	0.3 ± 0.1	15.0
Zn	0.9 ± 0.1	16.2 ± 0.1	9.1 ± 0.3	–
Pb	0.1 ± 0.1	0.7 ± 0.0	0.36 ± 0.1	5.0
Cr	ND[a]	4.3 ± 0.3	ND	5.0
Cd	ND[b]	1.8 ± 0.2	ND	1.0

Mean ± standard deviation ($n = 3$).
[a] Detection limits < 0.016 mg/L.
[b] Detection limits < 0.012 mg/L.

- Incineration slags economic value estimation (only Al2O3, Fe2O3 and Cu are considered in the calculation

Table 80: Incineration slags estimated economic value (Source: Strane)

Total Volume	12 378 933	t/y			
Composition	%	t	Prix		Prix total
Al2O3	0,165	2 042 524	488	€/t	996 751 644,90 €
Fe2O3	0,038	470 399	322,2	€/t	151 562 697,96 €
Cu	0,001	12 379	5772	€/t	71 451 198,39 €
Total price				€/y	1 219 765 541,25 €
Price per ton				€/t	98,54 €

<u>Table</u>

Table 81: Synergy 59 (Source: Strane)

Synergy 59	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	12 378 933
Substituted material equivalent price (€/Unit)	99
Final volume recovered (Unit/y)	2 525 302
Operational costs (€/y)	188 159 774
VA	60 672 396 €
VAT	13 020 296 €
Labour Share (€/y)	27 909 302 €

Direct jobs (€)	633
Indirect jobs (min)	317
Indirect jobs (max)	1913
Investment	
CAPEX	10 000* throughput^0,5
Total investment in EU	35 183 707 €
External impacts	
Climate change (kg. CO2-eq)	-33642159
Human health (DALY)	-30,109173
Ecosystem quality (PDF.m2.y)	-5836165,6
Use of resources (MJ)	-316450340
€ Climate change	2 691 373 €
€ DALY	2 228 079 €
€ Ecosystem quality	8 170 632 €
€ Use of resources	1 265 801 €
Sum of external economic impacts (€)	14 355 885 €
Carbon tax evolution (€/y)	-1 345 686 360 €
Waste tax	
Waste tax BaU (€/y)	480 550 160 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-480 550 160 €
Viability distance (100% of the resource price)	137
Viability distance (10% of resource price)	56
Waste treatment costs BaU (€/y)	2 475 786 500 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-2 475 786 500 €

Conclusion or comments

Incineration slag treatment and ferrous and non-ferrous metal content valorisation is much more valuable than for incineration ashes.

Nevertheless, this process is highly implemented in Europe and it is possible that the potential (60M€, 600 direct jobs, 2 000M€ of waste management costs savings, 480M€ of tax savings) is already well underway.

The viability distance to transport incineration slags is around 50 km.

5.58Synergy #60

Due to lack of data, this synergy is not modelled in this study.

5.59Synergy #61

Due to lack of data, this synergy is not modelled in this study.

5.60Synergy #62

Due to lack of data, this synergy is not modelled in this study.

5.61 Synergy #63

Due to lack of data, this synergy is not modelled in this study.

5.62 Synergy #64

Due to lack of data, this synergy is not modelled in this study.

5.63 Synergy #65

Due to lack of data, this synergy is not modelled in this study.

5.64 Synergy #66

Baseline business scenario

The BF slags are considered landfilled in the reference scenario.

Synergy

The aim of this synergy is to provide ceramic industries and replace clay components: Al203 (5-30%), CaO (0 – 26%), Fe2O3 (1-12%).

D3.2 findings:

- Steel slags could be potentially directly used as a raw material for the manufacture of ceramic bricks. However, slags from converter and linz-donalwitz process are more interesting because the most interest to analyse since the Blast Furnace slags already have a significant and extensive use in the production of cement and mineral wool industries. Therefore, it is meaningful to redirect steel slags to new uses.
- Feasibility depends on the incorporation percentage and for which application is the brick designed to.

Assumptions and calculation method

- The flow modelled is the receiving the receiving sector demand: Flow modelled: 19 250 000 t/y
- Slags granulated price: see Table 12 : Resources prices (Source: Strane)

Table

Table 82: Synergy 66 (Source: Strane)

Synergy 66	
Waste stream price in BaU scenario (€/Unit)	-
Waste stream volume (Unit/y)	46 314 324
Substituted material equivalent price (€/Unit)	16,5
Final volume recovered (Unit/y)	19 250 000
Operational costs (€/y)	
VA	317 625 000 €
VAT	68 162 325 €
Labour Share (€/y)	146 107 500 €
Direct jobs (€)	3315
Indirect jobs (min)	1658
Indirect jobs (max)	10012

Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment
External impacts	
Climate change (kg. CO2-eq)	-3902277400
Human health (DALY)	-1106,647
Ecosystem quality (PDF.m2.y)	-314565040
Use of resources (MJ)	-19913455000
€ Climate change	312 182 192 €
€ DALY	81 891 878 €
€ Ecosystem quality	440 391 056 €
€ Use of resources	79 653 820 €
Sum of external economic impacts (€)	914 118 946 €
Carbon tax evolution (€/y)	-156 091 096 000 €
Waste tax	
Waste tax BaU (€/y)	1 797 922 058 €
Waste tax Synergy (€/y)	1 050 637 058 €
Waste tax balance	-747 285 000 €
Viability distance (100% of the resource price)	94
Viability distance (10% of resource price)	9
Waste treatment costs BaU (€/y)	9 262 864 800 €
Waste treatment costs Synergy (€/y)	5 412 864 800 €
Waste treatment costs balance (€/y)	-3 850 000 000 €

Conclusion or comments

Whether the blast furnace slag or converter litter is considered, this synergy is viable. As converter slags have fewer outlets, the price is probably a little bit cheaper and will affect the value added (300 M€).

In any case, it is relevant to find news outlets for BF slags, BOF slags (and eventually EAF but a complementary study must be done to assess the compliance).

This synergy is referenced in a scientist paper but the use of steel slags in ceramic industries is not widely used at all [49] (Figure 15: Finale use of blast furnace slag in the EU (Source: BREF)). It is an innovative and promising valorisation route that could help reducing clay and other mineral addition extractions.

Nevertheless, the viability distance is low due to the cheap price of granulated slags.

As several synergies involve steel slags (BF slags and BOF slags), we had a special attention to avoid impacts double counting in the overall result.

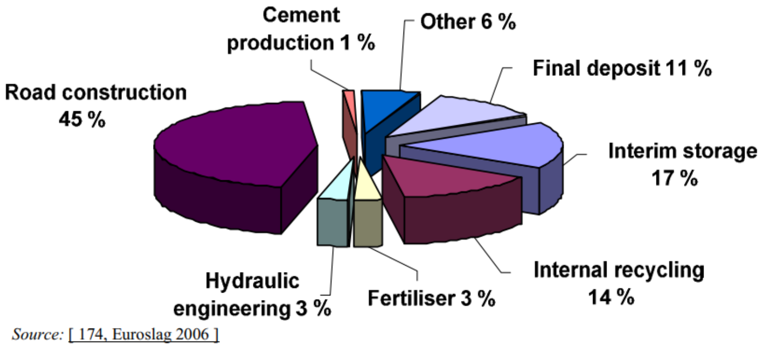


Figure 16: Use of steel slags in Europe (Source: Iron and steel BREF)

5.65 Synergy #67

Baseline business scenario

Refining mineral oil and gas plants usually waste the cooling water they have used.

Synergy

The aim of this synergy is to reuse refining mineral oil and gas plants cooling water to supply a combustion plant cooling system. This case is a Kalendborg industrial symbiosis existing solution. Used cooling water is a residue from Statoil, and is by origin surface water from Lake Tissø, that has been used for cooling in a closed pipe system at the refinery. The water has therefore not been polluted, and is send back to Ørsted for steam production at Asnæsværket. This means that the amount of water collected from Lake Tissø is reduced, and energy is saved because the used cooling water has a higher temperature that surface water from Lake Tissø, and is easier heated to steam.

Refining cooling systems are often closed pipe and supply all process which require cooling.

Assumptions and calculation method

- 0.23 m3 of cooling water is used to process one ton of crude oil [47].
- Calculations are based on a crude oil volume of 864 000 000 m3/year (760 320 000 t/an) [47].
- As there are no information on the volumes of this synergy in the previous deliverables, the calculation will not present environmental benefits and will not provide an estimation on the required investment.

Table

Table 83: Synergy 67 (Source: Strane)

Synergy 67	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	0,9
Final volume recovered (Unit/y)	174873600
Operational costs (€/y)	
VA	157 386 240 €
VAT	33 775 087 €
Labour Share (€/y)	72 397 670 €
Direct jobs (€)	1643

Indirect jobs (min)	821
Indirect jobs (max)	4961
Investment	
CAPEX	
Total investment in EU	
Extrenal impacts	
Climate change (kg. CO2-eq)	
Human health (DALY)	
Ecosystem quality (PDF.m2.y)	
Use of resources (MJ)	
€ Climate change	
€ DALY	
€ Ecosystem quality	
€ Use of resources	
Sum of external economic impacts (€)	
Carbon tax evolution (€/y)	
Waste tax	
Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	
Viability distance (10% of the good transported price)	
Waste treatment costs BaU (€/y)	
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	

Conclusion or comments

The value added of the valorisation of the whole flow is around 157 M€/y, and the associated VAT is around 13 €. The expected job creation is around 1 643 throughout Europe.

A further study should be carried out to estimate the social and environmental benefits of this synergy.

However, it is very likely that this synergy will have a strong socio-economic benefit. Indeed, this solution would permit to take much less water from the environment, and would probably save on the price and taxes related to water withdrawal.

5.66Synergy #68

Baseline business scenario

Integrated gasification combined cycle combustion plants generate fly ash. Fly ash can be used as a Si, Al and Ca source in order to replace carbonates and silica sand glass manufacturing. The ash is usually landfilled.

Synergy

The aim of this synergy is to recover fly ash and provide glass manufacturing. Container glass manufacturing require 400 000 - 8 000 000 tons of silica sand, 800 000 - 13 200 000 tons of silica sand and 40 000 - 1 000 000 tons of mineral ingredients. The mineral demand which can be replaced by fly ash is 1 240 000 - 22 200 00 tons per year.

Assumptions and calculation method

- The study considers that the remaining ashes are landfilled.
- The ash volume retained is 1 730 000. This figure is most probably underestimated because it amounts to the volume of 5% of coal plants.
- The calcium, silicon and aluminium content of the ash is given in the following table [52].

Table 84 : Bulk chemical composition of CFA by region [52]

Component	Range (mass%)				
	Europe[a]	US[b]	China[c]	India[d]	Australia[e]
SiO_2	28.5–59.7	37.8–58.5	35.6–57.2	50.2–59.7	48.8–66.0
Al_2O_3	12.5–35.6	19.1–28.6	18.8–55.0	14.0–32.4	17.0–27.8
Fe_2O_3	2.6–21.2	6.8–25.5	2.3–19.3	2.7–14.4	1.1–13.9
CaO	0.5–28.9	1.4–22.4	1.1–7.0	0.6–2.6	2.9–5.3
MgO	0.6–3.8	0.7–4.8	0.7–4.8	0.1–2.1	0.3–2.0
Na_2O	0.1–1.9	0.3–1.8	0.6–1.3	0.5–1.2	0.2–1.3
K_2O	0.4–4	0.9–2.6	0.8–0.9	0.8–4.7	1.1–2.9
P_2O_5	0.1–1.7	0.1–0.3	1.1–1.5	0.1–0.6	0.2–3.9
TiO_2	0.5–2.6	1.1–1.6	0.2–0.7	1.0–2.7	1.3–3.7
MnO	0.03–0.2	nd	nd	0.5–1.4	nd
SO_3	0.1–12.7	0.1–2.1	1.0–2.9	nd	0.1–0.6
LOI	0.8–32.8	0.2–11.0	nd	0.5–5.0	nd

[a] Data from 41 CFAs reported in [19,20].
[b] Data from 38 CFAs reported in [21–23].
[c] Data from 8 CFAs reported in [24–26].
[d] Data from 7 CFAs reported in [27,28].
[e] Data from 4 CFAs reported in [29].

The values used will be 14.7% for calcium oxide, 44.1% for silicon and 24.05% for aluminium.

- The total calcium and aluminium volume is 1 433 305 t/y.
- The resale price of the ash is estimated using an average weighted by the calcium and aluminium composition: 930 €/t.
- The fly ash price founded in the literature is ~US$25 - $75/ton (Approximate range represents cement replacement quality fly ash) [50]. The final value selected for fly ash selling is 50 US$ or 45,11€ in
- For information, in 1985, fly ash prices range from $15 to $40 per ton [51].

Table

Table 85: Synergy 68 (Source: Strane)

Synergy 68	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	1730000
Substituted material equivalent price (€/Unit)	930
Final volume recovered (Unit/y)	1433305
Operational costs (€/y)	
VA	1 333 191 082 €
VAT	286 102 806 €
Labour Share (€/y)	613 267 898 €
Direct jobs (€)	13915

Indirect jobs (min)	6958
Indirect jobs (max)	42025
Investment	
CAPEX	
Total investment in EU	
Extrenal impacts	
Climate change (kg. CO2-eq)	-680707140
Human health (DALY)	-1019,4015
Ecosystem quality (PDF.m2.y)	-178148130
Use of resources (MJ)	-9870443200
€ Climate change	54 456 571 €
€ DALY	75 435 711 €
€ Ecosystem quality	249 407 382 000 €
€ Use of resources	39 481 773 €
Sum of external economic impacts (€)	249 576 756 055 €
Carbon tax evolution (€/y)	-27 228 285 600 €
Waste tax	
Waste tax BaU (€/y)	67 158 600 €
Waste tax Synergy (€/y)	11 517 700 €
Waste tax balance (€/y)	-55 640 900 €
Viability distance (100% of the resource price)	5315
Viability distance (10% of the good transported price)	532
Waste treatment costs BaU (€/y)	91 863 000 €
Waste treatment costs Synergy (€/y)	15 754 505 €
Waste treatment costs balance (€/y)	-76 108 496 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 1 333 M€/y, and the associated VAT is around 286 M€. The expected job creation is around 13 915 throughout Europe, high value characteristic of the lack of data. 76 million in taxes and landfill costs will be avoided.

The implementation of this synergy will generate a decrease of the carbon tax up than 27 228 M€. Environmental and human health impact would be significantly improved. Although, these results should be interpreted remembering that there are no data available on the investment and operating costs needed.

This synergy appears to be interesting, but calculation probably overestimates the value of this flow. Nevertheless, this synergy is very common and must be exploited to the maximum.

5.67Synergy #69

Baseline business scenario

950 coal combustion plants are referenced in European Union. These plants generate fly ash. Fly ash can be used as a Si, Al and Ca source in order to replace clay for bricks and roof tiles manufacturing. The ash is usually landfilled.

Synergy

The aim of this synergy is to recover fly ash and provide brick and roof tiles manufacturing. 1022 brick and roof tiles manufacturing are referenced in European Union. 55 000 000 tons of bricks and roof tiles are produced per year. It requires 350 kg of clay per ton of bricks and roof tiles produced. The annual clay demand is 19 250 000 tons per year (18 836 tons per site).

Assumptions and calculation method

- The study will consider that the remaining ashes are landfilled.
- The ash volume retained is 32 616 000.
- The calcium, silicon and aluminium content of the ash is given in the following table [52].

Table 86 : Bulk chemical composition of CFA by region [52]

Component	Range (mass%)				
	Europe[a]	US[b]	China[c]	India[d]	Australia[e]
SiO_2	28.5–59.7	37.8–58.5	35.6–57.2	50.2–59.7	48.8–66.0
Al_2O_3	12.5–35.6	19.1–28.6	18.8–55.0	14.0–32.4	17.0–27.8
Fe_2O_3	2.6–21.2	6.8–25.5	2.3–19.3	2.7–14.4	1.1–13.9
CaO	0.5–28.9	1.4–22.4	1.1–7.0	0.6–2.6	2.9–5.3
MgO	0.6–3.8	0.7–4.8	0.7–4.8	0.1–2.1	0.3–2.0
Na_2O	0.1–1.9	0.3–1.8	0.6–1.3	0.5–1.2	0.2–1.3
K_2O	0.4–4	0.9–2.6	0.8–0.9	0.8–4.7	1.1–2.9
P_2O_5	0.1–1.7	0.1–0.3	1.1–1.5	0.1–0.6	0.2–3.9
TiO_2	0.5–2.6	1.1–1.6	0.2–0.7	1.0–2.7	1.3–3.7
MnO	0.03–0.2	nd	nd	0.5–1.4	nd
SO_3	0.1–12.7	0.1–2.1	1.0–2.9	nd	0.1–0.6
LOI	0.8–32.8	0.2–11.0	nd	0.5–5.0	nd

[a] Data from 41 CFAs reported in [19,20].
[b] Data from 38 CFAs reported in [21–23].
[c] Data from 8 CFAs reported in [24–26].
[d] Data from 7 CFAs reported in [27,28].
[e] Data from 4 CFAs reported in [29].

The values used will be 14.7% for calcium oxide, 44.1% for silicon and 24.05% for aluminium.

- The total calcium and aluminium volume is 27 022 356 t/y.
- The resale price of the ash estimated using an average weighted by the calcium and aluminium composition is 930 €/t.
- The fly ash price founded in the literature is ~US$25 - $75/ton (Approximate range represents cement replacement quality fly ash) [50]. The final value selected for fly ash selling is 50 US$ or 45,11€.
- For information, in 1985, fly ash prices range from $15 to $40 per ton [51].

Table

Table 87: Synergy 69 (Source: Strane)

Synergy 69	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	32 616 000
Substituted material equivalent price (€/Unit)	45,1
Final volume recovered (Unit/y)	27 022 356
Operational costs (€/y)	

VA	1 218 978 479 €
VAT	261 592 782 €
Labour Share (€/y)	560 730 100 €
Direct jobs (€)	12723
Indirect jobs (min)	6362
Indirect jobs (max)	38424
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	-12833494000
Human health (DALY)	-19218,96
Ecosystem quality (PDF.m2.y)	-3358658500
Use of resources (MJ)	-1,86089E+11
€ Climate change	1 026 679 520 €
€ DALY	1 422 203 040 €
€ Ecosystem quality	4 702 121 900 €
€ Use of resources	744 356 920 €
Sum of external economic impacts (€)	7 895 361 380 €
Carbon tax evolution (€/y)	-513 339 760 000 €
Waste tax	
Waste tax BaU (€/y)	1 266 153 120 €
Waste tax Synergy (€/y)	217 145 260 €
Waste tax balance (€/y)	-1 049 007 860 €
Viability distance (100% of the resource price)	258
Viability distance (10% of the good transported price)	26
Waste treatment costs BaU (€/y)	1 731 909 600 €
Waste treatment costs Synergy (€/y)	297 022 496 €
Waste treatment costs balance (€/y)	-1 434 887 104 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 1 218 M€/y, and the associated VAT is around 262 M€. The expected job creation is around 12 723throughout Europe, high value characteristic of the lack of data. 1 435 million in taxes and landfill costs will be avoided.

The implementation of this synergy will generate a decrease of the carbon tax up than 513 340 M€. Environmental and human health impact would be significantly improved. Although, these results should be interpreted remembering that there are no data available on the investment and operating costs needed.

This synergy appears to be interesting, but calculation probably overestimates the value of this flow.
Nevertheless, this synergy is very common and must be exploited to the maximum.

5.68 Synergy #70

Due to lack of data, this synergy is not modelled in this study.

5.69 Synergy #71

Due to lack of data, this synergy is not modelled in this study.

5.70 Synergy #72

Baseline business scenario

There are 192 pulp and paper production referenced installations in European Union which produce 41 800 000 t of pulp and paper /y. 77 kraft pulping process are referenced and produce 25 200 000 t of pulp/y.

A kraft pulping process generates between 10 and 20 kg of green liquor sludge / ADT Pulp or between 252 000 and 504 000 t of green liquor sludge per year. Green liquor sludges are composed by 75 - 85 mg of Cr/kg of green liquor sludge (and other several elements detailed in composition box) or 19 - 21 tons of Cr per year.

Usually, green liquor sludge is incinerated.

Synergy

The aim of this synergy is to recover Chrome from kraft pulping process in pulp and paper production sector and provide electrical arc furnaces for steel manufacturing.

Electrical arc furnace is direct smelting scrap steelmaking route. This technology is now widely used in European Union with 231 referenced installations. European annual EAF steel production is around 83 000 000 t/year. EAF use 23 - 363 kg of high alloy and stainless steel per ton of liquid steel produce or 1 909 000 - 30 129 000 tons of high alloy and stainless steel mainly made of Cr, Fe and Ni (Mo, Si, Mn, P and S traces).

The chrome is recovered and the rest of the sludge is incinerated.

Assumptions and calculation method

- The sludge is initially incinerated
- During the synergy, 377 980 tonnes of sludge per year are incinerated and 20 tonnes/year of chromium are recovered.

Table

Table 88: Synergy 72 (Source: Strane)

Synergy 72	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	378000
Substituted material equivalent price (€/Unit)	10018
Final volume recovered (Unit/y)	20
Operational costs (€/y)	
VA	200 360 €
VAT	42 997 €
Labour Share (€/y)	92 166 €
Direct jobs (€)	2

Indirect jobs (min)	1
Indirect jobs (max)	6
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	-43,227426
Human health (DALY)	0
Ecosystem quality (PDF.m2.y)	-20,329751
Use of resources (MJ)	-669,34867
€ Climate change	3 €
€ DALY	0 €
€ Ecosystem quality	28 462 €
€ Use of resources	3 €
Sum of external economic impacts (€)	28 468 €
Carbon tax evolution (€/y)	-1 729 €
Waste tax	
Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	57246
Viability distance (10% of the good transported price)	5725
Waste treatment costs BaU (€/y)	46 342 800 €
Waste treatment costs Synergy (€/y)	46 340 348 €
Waste treatment costs balance (€/y)	-2 452 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 200 360 €/y, and the associated VAT is around 43 000 €. The expected job creation is around 2 throughout Europe.

The implementation of this synergy will generate a decrease of the carbon tax up than 1 729 M€. Nevertheless, environmental and human health impact would not be significantly improved. Although, these results should be interpreted remembering that there are no data available on the investment needed.

Despite an expensive resource and a precious metal, the volume is not large enough and the environmental benefits not large enough for the synergy to be interesting.

5.71Synergy #73

Due to lack of data, this synergy is not modelled in this study.

5.72 Synergy #74

Due to lack of data, this synergy is not modelled in this study.

5.73 Synergy #75

Baseline business scenario

The selected baseline scenario for the solid particles in emissions is landfilled. We consider that they are not recovered, and they are finally landfilled with all dusts produce on the site.

Synergy

Antimony is a critical raw material which presents both a high supply risk and an economic importance, according to the 2017 European commission report *"Study on the review of the list of Critical Raw Materials"* [53]. The aim of this synergy is to recover Antimony particles from lime mixed feed shaft kiln air emissions and provide the market.

D3.2 findings:

- Traditional methods for metals recovery involve the use of Acid leaching and Precipitation processes.
- Recent advances involve the use of Acid leaching and Solvent extraction or Ion Exchange technologies.
- High operational costs due to acid prices and maintenance costs
- CAPEX relatively low but High for the IX technology

Assumptions and calculation method

- Antimony price: see Table 12 : Resources prices (Source: Strane)
- OPEX and CAPEX were not assessed due to the lack of data

Table

Table 89: Synergy 75 (Source: Strane)

Synergy 75	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	448
Substituted material equivalent price (€/Unit)	6868,9
Final volume recovered (Unit/y)	448
Operational costs (€/y)	No data available
VA	3 077 267 €
VAT	660 382 €
Labour Share (€/y)	1 415 543 €
Direct jobs (€)	32
Indirect jobs (min)	16
Indirect jobs (max)	97
Investment	
CAPEX	No data
Total investment in EU	No data for calculation
External impacts	
Climate change (kg. CO2-eq)	-0,6232203
Human health (DALY)	-1,573E-05

Ecosystem quality (PDF.m2.y)	-5,7062876
Use of resources (MJ)	-7,2343777
€ Climate change	0 €
€ DALY	1 €
€ Ecosystem quality	8 €
€ Use of resources	0 €
Sum of external economic impacts (€)	9 €
Carbon tax evolution (€/y)	-25 €
Waste tax	
Waste tax BaU (€/y)	17 391 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-17 391 €
Viability distance (100% of the resource price)	39251
Viability distance (10% of resource price)	3925
Waste treatment costs BaU (€/y)	89 600 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-89 600 €

Conclusion or comments

This synergy as a real economic potential with 3M€ of value added with only 448 t of recoverable antimony in lime kiln through Europe. Nevertheless, the environmental impact is very low or non-existent, probably due to the low Antimony quantities considered.

Potentially, 32 jobs could be created for sites equipped with lime mixed feed shaft kiln (1 job per 3 sites). This solution could be scaled up to other ceramic sites with other types of equipment.

Moreover, as this resource is presenting a high supply risk [53], Antimony's market price could grow quickly and make the synergy become even more viable.

5.74Synergy #76

Baseline business scenario

The BOF slags are considered landfilled in the reference scenario.

Synergy

The aim of this synergy is to provide alumina content from BOF slag to aluminium production in non-ferrous metals industries.

D3.2 findings:

- Same technologies as Synergies #31 & 32
- A full salt slag process recycling is required
- 0,46 – 0,68 tons of aluminium oxides per ton of salt slag processed
- Recovery rate: 100%
- Electricity demand 1 900 – 3845 MJ per tonne of salt slag
- OPEX and CAPEX are expensive, but the payback period is less than two years
- Treatment costs are like disposal costs

Assumptions and calculation method

- Slags granulated price: see Table 12 : Resources prices (Source: Strane)
- Electricity costs: average 2 872,5MJ is equivalent to 798 kWh per ton of salt slag. That corresponds to 392 179 760 €/y.
- Two assessments are provided: one with the price of aluminium oxide price and the other one with the granulated slag price.

Table

Table 90: Synergy 76 (Source: Strane)

Synergy 76	With aluminium oxide price	With granulated slag price
Waste stream price in BaU scenario (€/Unit)	-	-
Waste stream volume (Unit/y)	1 426 966	1 426 966
Substituted material equivalent price (€/Unit)	16,5	341,1
Final volume recovered (Unit/y)	85 618	85 618
Operational costs (€/y)	392 179 760	392 179 760
VA	-390 767 064 €	-362 975 474 €
VAT	-83 858 612 €	-77 894 537 €
Labour Share (€/y)	-179 752 849 €	-166 968 718 €
Direct jobs (€)	-4079	-3789
Indirect jobs (min)	-2039	-1894
Indirect jobs (max)	-12318	-11442
Investment		
CAPEX	No data	No data
Total investment in EU	No data for calculation	No data for calculation
External impacts		
Climate change (kg. CO2-eq)	-147424950	-147424950
Human health (DALY)	-228,63802	-228,63802
Ecosystem quality (PDF.m2.y)	-59606340	-59606340
Use of resources (MJ)	-2323529900	-2323529900
€ Climate change	11 793 996 €	11 793 996 €
€ DALY	16 919 213 €	16 919 213 €
€ Ecosystem quality	83 448 876 €	83 448 876 €
€ Use of resources	9 294 120 €	9 294 120 €
Sum of external economic impacts (€)	121 456 205 €	121 456 205 €
Carbon tax evolution (€/y)	-5 896 998 000 €	-5 896 998 000 €
Waste tax		
Waste tax BaU (€/y)	55 394 820 €	55 394 820 €
Waste tax Synergy (€/y)	52 071 131 €	52 071 131 €
Waste tax balance	-3 323 689 €	-3 323 689 €
Viability distance (100% of the resource price)	0	0
Viability distance (10% of resource price)	9	195
Waste treatment costs BaU (€/y)	285 393 200 €	285 393 200 €
Waste treatment costs Synergy (€/y)	268 269 608 €	268 269 608 €
Waste treatment costs balance (€/y)	-17 123 592 €	-17 123 592 €

Conclusion or comments

This synergy appears not viable according to D3.2 outcomes. Our economic assessment confirms the non-viability of this synergy. Indeed, the only alumina content is not enough to compensate, operational costs and remaining material landfilling costs.

5.75 Synergy #77

To avoid a double counting of the BOF slags valorisation, please refer to the Synergy #6 that involve the same resource.

5.76 Synergy #78

Baseline business scenario

From the organic chemical sector, tar is landfilled by utilities. Then, waste taxes and charges are paid by the industrial site in the baseline business scenario.

Synergy

The aim of this synergy is to recover tars from hydrogen peroxide manufacturing and provide waste co-incineration.

There are 23 hydrogen peroxide production referenced installations in European Union. European annual hydrogen peroxide production is 1 423 000 t/y or 61 869 t/y/site. It generates between 0,78 and 2,4 kg of tars per ton of hydrogen peroxide produce. The associated annual tars production is equivalent to 1 110 - 3 415 t/y (48 - 98 t /site)

In European Union, waste co-incineration uses 0,1 - 10 % of waste complement. Tars are fuel used as waste complement.

Assumptions and calculation method

- The minimum tar production volume (1 110 t/y) was used for the calculation.
- The PCI of the tar used is 25 Mj/t.

Tab

Table 91: Synergy 78 (Source: Strane)

Synergy 78	
Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	1 110
Substituted material equivalent price (€/t)	234,7512617
Final volume recovered (t/y)	1 110
Operational costs (€/y)	
VA	260 574 €
VAT	55 919 €
Labour Share (€/y)	119 864 €
Direct jobs	3
Indirect jobs (min)	1
Indirect jobs (max)	8
Investment	
CAPEX	
Total investment in EU	

External impacts	
Climate change (kg. CO2-eq)	-1659704,7
Human health (DALY)	-1,6552327
Ecosystem quality (PDF.m2.y)	-325321,45
Use of resources (MJ)	-86941270
€ Climate change	132 776 €
€ DALY	122 487 €
€ Ecosystem quality	455 450 030 €
€ Use of resources	347 765 €
Sum of external economic impacts (€)	456 053 059 €
Carbon tax evolution (€/y)	-66 388 188 €
Waste tax	
Waste tax BaU (€/y)	43 090
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	1341
Viability distance (10% of the good transported price)	134
Waste treatment costs BaU (€/y)	58 941
Waste treatment costs Synergy (€/y)	NA
Waste treatment costs balance (€/y)	NA

Conclusion or comments

The value added of the valorisation of the whole flow is around 260,5 k€/y, and the associated VAT is around 55,9 k€. 5 jobs can be created directly because of the value added that is quite low compare with other synergies.

The investment is low and the charges of the industrial site can be externalised. The distance is enough to reach the receiving sector in several case. This synergy is easy to implement but is not the most ecologic one as the change is to incinerate the waste and not landfill it.

5.77Synergy #79

Baseline business scenario

From the organic chemical sector, tar is landfilled by utilities. Then, waste taxes and charges are paid by the industrial site in the baseline business scenario.

Synergy

The aim of this synergy is to recover tars from styrene manufacturing by hydrogenation and provide cement and clinker kiln for burning.

There are 11 styrene production referenced installations in European Union. European annual styrene production is 5 284 000 t/y or 480 450 t/y/site. It generates between 453,9 kg of tars per ton of styrene produce. The associated annual tars production is equivalent to 2 400 000 t/y (218 126t /site)

There are 268 cement plants in Europe Union which produce 118 Mt/y of clinker and 157 mT/y of grey cement. Carbon waste are used in clinker and cement kiln. Tars are a significant part of carbon waste used in cement industries.

Assumptions and calculation method

- The minimum tar production volume (327 200 t/y) was used for the calculation.
- The PCI of the tar used is 28 Mj/t.

Tab

Table 92: Synergy 79 (Source: Strane)

Synergy 79	
Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	327 200
Substituted material equivalent price (€/t)	262,9214131
Final volume recovered (t/y)	327 200
Operational costs (€/y)	NA
VA	86 027 886 €
VAT	18 461 584 €
Labour Share (€/y)	39 572 828 €
Direct jobs	898
Indirect jobs (min)	449
Indirect jobs (max)	2712
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-240077530
Human health (DALY)	-239,43065
Ecosystem quality (PDF.m2.y)	-47057992
Use of resources (MJ)	-12576120000
€ Climate change	19 206 202 €
€ DALY	17 717 868 €
€ Ecosystem quality	65 881 188 800 €
€ Use of resources	50 304 480 €
Sum of external economic impacts (€)	65 968 417 351 €
Carbon tax evolution (€/y)	-9 603 101 200 €
Waste tax	
Waste tax BaU (€/y)	12 701 904
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	1502
Viability distance (10% of the good transported price)	150

Waste treatment costs BaU (€/y)	17 374 320
Waste treatment costs Synergy (€/y)	NA
Waste treatment costs balance (€/y)	NA

Conclusion or comments

The value added of the valorisation of the whole flow is around 86 M€/y, and the associated VAT is around 55,9 k€. 898 direct jobs can be created thanks to this synergy.

The investment is low and the charges of the industrial site can be externalised. The distance is enough to reach the receiving sector in several case. This synergy is easy to implement but is not the most ecologic one as the change is to incinerate the waste and not landfill it.

5.78Synergy #80

Baseline business scenario

The spent solvent from the organic chemical sector is incinerated by utilities. Then, waste charges are paid by the industrial site in the baseline business scenario.

Synergy

The aim of this synergy is to recover spent solvents from styrene production and provide cement and clinker kiln for burning.

The spent solvent is collected in the last steps of styrene production by ethylbenzene dehydrogenation and then need to be treated before going to cement sector. The spent solvent has to be homogenised first passing through a fluidification process. A stirring propeller or a recirculation system is used in order to keep the wastes homogeneous. Before loading, the liquid is filtered.

There are 7 styrene production referenced installations in European Union. European annual styrene production is 3 130 000 t/y or 447 142 t/y/site. It generates between 1,5 and 6 kg of spent solvent per ton of styrene produce. The associated annual spent solvent production is equivalent to 4 695 - 18 780 t/y (426 - 1 707 t /site)

There are 268 cement plants in Europe Union which produce 118 Mt/y of clinker and 157 mT/y of grey cement. Solvent and related waste are used for burning in clinker and cement kiln. There are 268 cement plants in Europe Union which produce 118 Mt/y of clinker and 157 mT/y of grey cement. Carbon waste are used in clinker and cement kiln. Tars are a significant part of carbon waste used in cement industries.

Assumptions and calculation method

- The average of spent solvent production volume (8 998 t/y) was used for the calculation.
- The PCI of the tar used is 28 Mj/t.

Tab

Table 93: Synergy 80 (Source: Strane)

Synergy 80	
Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	8 998
Substituted material equivalent price (€/t)	286,3965393
Final volume recovered (t/y)	8 998
Operational costs (€/y)	
VA	2 576 996 €

VAT	553 023 €
Labour Share (€/y)	1 185 418 €
Direct jobs	27
Indirect jobs (min)	13
Indirect jobs (max)	81
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-4594285,1
Human health (DALY)	-1,0336318
Ecosystem quality (PDF.m2.y)	-656495,13
Use of resources (MJ)	-268674970
€ Climate change	367 543 €
€ DALY	76 489 €
€ Ecosystem quality	919 093 182 €
€ Use of resources	1 074 700 €
Sum of external economic impacts (€)	920 611 913 €
Carbon tax evolution (€/y)	-183 771 404 €
Waste tax	
Waste tax BaU (€/y)	NA
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	1637
Viability distance (10% of the good transported price)	164
Waste treatment costs BaU (€/y)	1 103 155
Waste treatment costs Synergy (€/y)	NA
Waste treatment costs balance (€/y)	NA

Conclusion or comments

The value added of the valorisation of the whole flow is around 2,5 M€/y, and the associated VAT is around 553 k€. 27 jobs can be created directly because of the value added that is quite low compare with other synergies.

The investment is low and the charges of the industrial site can be externalised. The distance is enough to reach the receiving sector in several case. Then, this synergy is easy to implement.

5.79Synergy #81

Baseline business scenario

The crude oil generated by refineries is treated in WWTP.

Synergy

The aim of this synergy is to recover oil from crude atmospheric distillation wastewater and provide blast furnaces in steel industries.

110 crude atmospheric distillation are referenced in European Union. They produce 864 000 0000 m3 of petroleum products / per year (7 854 543 m3/site). These processes generate 0,08 - 0, 75 m3 of wastewater per ton of final product. Waste water from crude atmospheric distillation is composed by five fractions: phenol, mercaptans, chlorides, H2S and oil.

Blast furnace is a widely used steelmaking process with 86 installations in European Union. Blast furnaces annual production is 116 280 000 t/y of hot metal (1 352 093 t/site). It require 30,1 kg of oil per ton of hot metal produced. The associated oil demand is 3 500 028 t/y.

Assumptions and calculation method

- The average of spent solvent production volume (327 200 t/y) was used for the calculation.
- The PCI of the tar used is 30,5 MJ/t.

Table

Table 94: Synergy 81 (Source: Strane)

Synergy 81	
Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	327 200
Substituted material equivalent price (€/t)	286,3965393
Final volume recovered (t/y)	327 200
Operational costs (€/y)	
VA	93 708 948 €
VAT	20 109 940 €
Labour Share (€/y)	43 106 116 €
Direct jobs	978
Indirect jobs (min)	489
Indirect jobs (max)	2954
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-155645560
Human health (DALY)	-202,18037
Ecosystem quality (PDF.m2.y)	-86813580
Use of resources (MJ)	-18344617000
€ Climate change	12 451 645 €
€ DALY	14 961 347 €
€ Ecosystem quality	121 539 012 000 €
€ Use of resources	73 378 468 €
Sum of external economic impacts (€)	121 639 803 460 €
Carbon tax evolution (€/y)	-6 225 822 400 €
Waste tax	

Waste tax BaU (€/y)	NA
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	1637
Viability distance (10% of the good transported price)	164
Waste treatment costs BaU (€/y)	NA
Waste treatment costs Synergy (€/y)	NA
Waste treatment costs balance (€/y)	NA

Conclusion or comments

The value added of the valorisation of the whole flow is around 93,7 M€/y, and the associated VAT is around 20 M€. 978 direct jobs can be created and it is not sure that this synergy is well-known. But, it is important to consider that the investment and the operational cost are highly variable. Only obtainable through contact with manufacturer. These parameters have a significant impact on the viability and have to be studied in detail.

The distance is enough to reach the receiving sector in several case.

5.80Synergy #82

Baseline business scenario

The wood from pulp and paper sector is incinerated by utilities. Synergies of the same type are already implemented and operational.

Synergy

The aim of this synergy is to recover waste wood from pulp and paper production sector, and provide combustion plants. The use of wood waste of this sector in another sector is a quite common synergy.

Wood waste refers to barks, sawdust and other wood waste.

There are 16 sulphite pulping process referenced installations in European Union which produce 2 200 000 t of pulp /y. This process generates 198 000 tons of bark and 66 000 - 110 000 tons of sawdust per year. There are rejects from coarse screening.

There are 77 Kraft pulping processes referenced installations in European Union which produce 25 200 000 t of pulp /y. This process generates 151 200 tons of wood waste per year.

Integrated gasification combined cycle processes use biomass complements like wood waste.

Assumptions and calculation method

- The minimum of wood waste production volume (5 350 400 t/y) was used for the calculation.
- The PCI of the wood used is 16,8 MJ/kg.
- The worst case is considered here, when no synergy is implemented and the material is incinerated by utilities in the baseline scenario.

Table

Table 95: Synergy 82 (Source: Strane)

Synergy 82	
Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	5 350 400
Substituted material equivalent price (€/t)	23,55652174
Final volume recovered (t/y)	5 350 400
Operational costs (€/y)	
VA	126 036 814 €
VAT	27 047 500 €
Labour Share (€/y)	57 976 934 €
Direct jobs	1316
Indirect jobs (min)	658
Indirect jobs (max)	3973
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-972684440
Human health (DALY)	-2233,3659
Ecosystem quality (PDF.m2.y)	-1847710400
Use of resources (MJ)	-18170066000
€ Climate change	77 814 755 €
€ DALY	165 269 077 €
€ Ecosystem quality	2 586 794 560 000 €
€ Use of resources	72 680 264 €
Sum of external economic impacts (€)	2 587 110 324 096 €
Carbon tax evolution (€/y)	-38 907 377 600 €
Waste tax	
Waste tax BaU (€/y)	NA
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	135
Viability distance (10% of the good transported price)	13
Waste treatment costs BaU (€/y)	655959040
Waste treatment costs Synergy (€/y)	NA
Waste treatment costs balance (€/y)	NA

Conclusion or comments

The value added of the valorisation of the whole flow is around 126 M€/y, and the associated VAT is around 27 M€. 1 316 direct jobs can be created. As mentioned before, this synergy is quite common and is also well-known for other receiving sectors.

The investment is low and the charges of the industrial site can be externalised. The distance is enough to reach the receiving sector in several case even if the material has a low price. Then, this synergy is easy to implement.

5.81Synergy #83

Baseline business scenario

The sludge from sugar beet production process is incinerated by utilities, or, sometimes, in other industrial sector with a synergy already implemented.

Synergy

The aim of this synergy is to recover sludge from sugar beet production process to provide cement raw material preparation.

129 plants produce sugar from beet. The annual associated sugar production is around 16 700 000 t/y (129 457 t/site). Sugar beet industries generate 230 kg of soil and green waste / t of sugar which is equivalent to 3 841 000 t of soil and green waste per year (29 775 par facility).

Soil and green wastes are composed by sludges, beet soil, beet tails, leaves.

The aim of this synergy is to separate beet residues and leaves from sludge, then valorise green waste to agricultural sector and send sludge as a waste co-incineration product.

In European Union, waste co-incineration uses 0,1 - 10 % of waste complement. Sludges are waste complement for combustion.

Assumptions and calculation method

- The average of sludge production volume (3 841 t/y) was used for the calculation (230 kg/t of sugar beet production).
- The PCI of the wood used is 11 MJ/kg.
- The worst case is considered here, when no synergy is implemented and the material is incinerated by utilities in the baseline scenario.

Tab

Table 96: Synergy 83 (Source: Strane)

Synergy 83	
Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	3841
Substituted material equivalent price (€/t)	15,42391304
Final volume recovered (t/y)	3841
Operational costs (€/y)	NA
VA	59 243 €
VAT	12 714 €
Labour Share (€/y)	27 252 €
Direct jobs	1
Indirect jobs (min)	0
Indirect jobs (max)	2
Investment	
CAPEX	NA
Total investment in EU	NA

External impacts	
Climate change (kg. CO2-eq)	-107372510
Human health (DALY)	-109,3612
Ecosystem quality (PDF.m2.y)	-17870066
Use of resources (MJ)	-39056128000
€ Climate change	8 589 801 €
€ DALY	8 092 729 €
€ Ecosystem quality	25 018 092 400 €
€ Use of resources	156 224 512 €
Sum of external economic impacts (€)	25 190 999 442 €
Carbon tax evolution (€/y)	-4 294 900 400 €
Waste tax	
Waste tax BaU (€/y)	NA
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	88
Viability distance (10% of the good transported price)	9
Waste treatment costs BaU (€/y)	470907
Waste treatment costs Synergy (€/y)	NA
Waste treatment costs balance (€/y)	NA

Conclusion or comments

The value added of the valorisation of the whole flow is around 59,2 k€/y, and the associated VAT is around 12,7 k€. Only 1 direct job can be created because of the value added that is quite low compare with other synergies.

The worst case was considered here, when no synergy is implemented and the material is incinerated by utilities in the baseline scenario.

The investment is low (direct synergy) and the charges of the industrial site can be externalised. The distance of viability is really limited. But this synergy is still easy to implement.

5.82 Synergy #84

Baseline business scenario

The sludge from vinyl chloride monomer manufacturing is incinerated by utilities, or, sometimes, in other industrial sector with a synergy already implemented.

Synergy

The aim of this synergy is to recover sludges from vinyl chloride monomer manufacturing and provide waste co-incineration.

There are 26 vinyl chloride monomer manufacturing referenced installations in European Union. European annual vinyl chloride monomer production is 8 293 000 tons per year or 318 961 tons per year and per site. It generates between 0,07 - 2,1 kg/t of sludges per ton of vinyl chloride monomer. The associated annual sludges production is equivalent to 580 - 17 415 t/y (22 - 669 t /site)

In European Union, waste co-incineration uses 0,1 - 10 % of waste complement. Sludges are waste complement for combustion.

Assumptions and calculation method

- The average of sludge from waste water pre-treatment volume (8 898 t/y) was used for the calculation (0.07–2.1 kg/t of VCM).
- The PCI of the wood used is 11 MJ/kg.
- The worst case is considered here, when no synergy is implemented and the material is incinerated by utilities in the baseline scenario.

Tab

Table 97: Synergy 84 (Source: Strane)

Synergy 84	
Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	8898
Substituted material equivalent price (€/t)	15,42391304
Final volume recovered (t/y)	8898
Operational costs (€/y)	
VA	137 242 €
VAT	29 452 €
Labour Share (€/y)	63 131 €
Direct jobs	1
Indirect jobs (min)	1
Indirect jobs (max)	4
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-9536,0081
Human health (DALY)	-0,00571671
Ecosystem quality (PDF.m2.y)	-1134,6132
Use of resources (MJ)	-144907,78
€ Climate change	763 €
€ DALY	423 €
€ Ecosystem quality	1 588 458 €
€ Use of resources	580 €
Sum of external economic impacts (€)	1 590 224 €
Carbon tax evolution (€/y)	-381 440 €
Waste tax	
Waste tax BaU (€/y)	NA
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	88

Viability distance (10% of the good transported price)	9
Waste treatment costs BaU (€/y)	1090895
Waste treatment costs Synergy (€/y)	NA
Waste treatment costs balance (€/y)	NA

Conclusion or comments

The value added of the valorisation of the whole flow is around 137,2 k€/y, and the associated VAT is around 29,4 k€. Only 1 direct job can be created because of the value added which is quite low compare with other synergies.

The worst case was considered here, when no synergy is implemented and the material is incinerated by utilities in the baseline scenario.

The investment is low (direct synergy) and the charges of the industrial site can be externalised. The distance is enough to reach the receiving sector in several case. Then, this synergy is easy to implement.

5.83Synergy #85

Baseline business scenario

The oil from visbreaking operation wastewater is treated by WWTP

Synergy

The aim of this synergy is to recover oil from visbreaking operation wastewater and provide wales kiln operation in zinc and cadmium industries.

52 visbreaking process are referenced in European Union. They produce 23 400 000 m3 of petroleum products / per year (450 000 m3/site). These processes generate 0,08 - 0, 75 m3 of wastewater per ton of final product. Wastewater from crude atmospheric distillation is composed by five fractions: phenol, COD, HCN, NH3, H2S and oil. The aim of this synergy is to separate fractions and recover

Waelz kiln operation is a zinc recovery route. 15 processes are referenced in European Union. They produce 2160 000 t/y (144 000 t/site) and require 0,001 m3 per ton of final product or 2 160 m3 per year.

Conclusion and comments

There is not enough data to study this synergy.

5.84Synergy #86

Baseline business scenario

The carcases from slaughterhouses and animal industry are incinerated by utilities, or, sometimes, in other industrial sector with a synergy already implemented.

Synergy

The aim of this synergy is to recover carcase from slaughterhouses and provide burning operation in cement industries. This synergy refers to poultry carcase valorisation but can be applied for others animals' carcases.

Around 191 poultry slaughterhouses are refenced in European Union. visbreaking process are referenced in European Union. They produce 3 906 900 tons of poultry carcase (20 455 tons per site). By products of slaughterhouses are carcase, blood, bones and fat.

There are 268 cement plants in Europe Union which produce 118 Mt/y of clinker and 157 MT/y of grey cement. Carcase can be use in clinker kiln for burning.

Assumptions and calculation method

- The average of carcases volume (3 906 899 t/y) was used for the calculation.
- The PCI of the wood used is 17,5 MJ/kg.
- The worst case is considered here, when no synergy is implemented and the material is incinerated by utilities in the baseline scenario.

Table

Table 98: Synergy 86 (Source: Strane)

Synergy 86	
Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	3 906 899
Substituted material equivalent price (€/t)	24,53804348
Final volume recovered (t/y)	3 906 899
Operational costs (€/y)	NA
VA	95 867 658 €
VAT	20 573 199 €
Labour Share (€/y)	44 099 122 €
Direct jobs	1001
Indirect jobs (min)	500
Indirect jobs (max)	3022
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-640694670
Human health (DALY)	-1543,9923
Ecosystem quality (PDF.m2.y)	-1271831800
Use of resources (MJ)	-11743284000
€ Climate change	51 255 574 €
€ DALY	114 255 430 €
€ Ecosystem quality	1 780 564 520 000 €
€ Use of resources	46 973 136 €
Sum of external economic impacts (€)	1 780 777 004 140 €
Carbon tax evolution (€/y)	-25 627 786 800 €
Waste tax	
Waste tax BaU (€/y)	NA
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA

Viability distance (100% of the resource price)	140
Viability distance (10% of the good transported price)	14
Waste treatment costs BaU (€/y)	478985817
Waste treatment costs Synergy (€/y)	NA
Waste treatment costs balance (€/y)	NA

Conclusion or comments

The value added of the valorisation of the whole flow is around 95,8 M€/y, and the associated VAT is around 20,5 M€. 1001 direct jobs can be created. However, the worst case has been considered here, when no synergy is implemented and the material is incinerated by utilities in the baseline scenario. Then, in the real case, this synergy is already well-known and done in several sectors.

The investment is low (direct synergy) and the charges of the industrial site can be externalised. Then, this synergy is easy to implement.

5.85Synergy #87

Baseline business scenario

The wood from pulp and paper sector is incinerated by utilities. Or, synergies of the same type are already implemented and operational.

Synergy

The aim of this synergy is to recover waste wood from pulp and paper production sector, and provide combustion plants (similar than the synergy 82). The use of wood waste of this sector in another sector is a quite common synergy.

Wood waste refers to barks, sawdust and other wood waste.

There are 16 sulphite pulping process referenced installations in European Union which produce 2 200 000 t of pulp /y. This process generates 198 000 tons of bark and 66 000 - 110 000 tons of sawdust per year.

There are 77 kraft pulping processes referenced installations in European Union which produce 25 200 000 t of pulp /y. This process generates 151 200 tons of wood waste per year.

Long rotary kiln in lime manufacturing sector are wood consumers for combustion.

Assumptions and calculation method

- The minimum of wood waste production volume (5 350 400 t/y) was used for the calculation.
- The PCI of the wood used is 16,8 MJ/kg.
- The worst case is considered here, when no synergy is implemented and the material is incinerated by utilities in the baseline scenario.

Table

Table 99: Synergy 87 (Source: Strane)

Synergy 87

Waste stream price in BaU scenario (€/t)	0
Waste stream volume (t/y)	5 350 400
Substituted material equivalent price (€/t)	23,55652174
Final volume recovered (t/y)	5 350 400
Operational costs (€/y)	
VA	126 036 814 €
VAT	27 047 500 €
Labour Share (€/y)	57 976 934 €
Direct jobs	1316
Indirect jobs (min)	658
Indirect jobs (max)	3973
Investment	
CAPEX	NA
Total investment in EU	NA
External impacts	
Climate change (kg. CO2-eq)	-873509180
Human health (DALY)	-1958,5002
Ecosystem quality (PDF.m2.y)	-1769317200
Use of resources (MJ)	-17025142000
€ Climate change	69 880 734 €
€ DALY	144 929 015 €
€ Ecosystem quality	2 477 044 080 000 €
€ Use of resources	68 100 568 €
Sum of external economic impacts (€)	2 477 326 990 317 €
Carbon tax evolution (€/y)	-34 940 367 200 €
Waste tax	
Waste tax BaU (€/y)	NA
Waste tax Synergy (€/y)	NA
Waste tax balance (€/y)	NA
Viability distance (100% of the resource price)	135
Viability distance (10% of the good transported price)	13
Waste treatment costs BaU (€/y)	655959040
Waste treatment costs Synergy (€/y)	NA
Waste treatment costs balance (€/y)	NA

Conclusion or comments

The value added of the valorisation of the whole flow is around 126 M€/y, and the associated VAT is around 27 M€. 1 316 direct jobs can be created. As mentioned before, this synergy is quite common and is also well-known for other receiving sectors.

The investment is low and the charges of the industrial site can be externalised. The distance is enough to reach the receiving sector in several case even if the material has a low price. Then, this synergy is easy to implement.

5.86Synergy #88

Baseline business scenario

The crude oil generated by refineries is treated in WWTP.

Synergy

The aim of this synergy is to recover oil from crude atmospheric distillation wastewater and provide furnace black process in inorganic chemicals.

110 crude atmospheric distillation processes are referenced in European Union. They produce 864 000 0000 m3 of petroleum products / per year (7 854 543 m3/site). These processes generate 0,08 - 0, 75 m3 of wastewater per ton of final product. Wastewater from crude atmospheric distillation is composed by five fractions: phenol, mercaptans, chlorides, H2S and oil.

There are 24 furnace black processes in European Union which produce 1 745 000 tons of carbon black (72 708 tons per site) and require 2 800 000 tons of oil per year.

Conclusion

Please refer to the synergy 80 and 81.

5.87Synergies #89 & 90

Baseline business scenario

Pulp and paper plants usually waste the cooling water they have used. 72 mechanical pulping and chemical pulping processes are referenced in European Union. The annual pulp production is 13 600 000 tons per year (188 888 tons per site).

Synergy

The aim of this synergy is to reuse production of pulp and paper plants cooling water to supply fertilisers industries or refining industries cooling systems.

Assumptions and calculation method

- According to deliverable 3.1, 20 m3 of cooling water is used to process one ton of pulp produce.
- As there are no information on the volumes of this synergy in the previous deliverables, the calculation will not present environmental benefits and will not provide an estimation on the required investment.

Table

Table 100: Synergy 89 - 90 (Source: Strane)

Synergy 89-90	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	1,26
Final volume recovered (Unit/y)	272000000
Operational costs (€/y)	
VA	342 720 000 €
VAT	73 547 712 €
Labour Share (€/y)	157 651 200 €

Direct jobs (€)	3577
Indirect jobs (min)	1789
Indirect jobs (max)	10803
Investment	
CAPEX	
Total investment in EU	
Extrenal impacts	
Climate change (kg. CO2-eq)	
Human health (DALY)	
Ecosystem quality (PDF.m2.y)	
Use of resources (MJ)	
€ Climate change	
€ DALY	
€ Ecosystem quality	
€ Use of resources	
Sum of external economic impacts (€)	
Carbon tax evolution (€/y)	
Waste tax	
Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	7
Viability distance (10% of the good transported price)	1
Waste treatment costs BaU (€/y)	
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	

Conclusion or comments

The value added of the valorisation of the whole flow is around 343 M€/y, and the associated VAT is around 74 €. The expected job creation is around 3 577 throughout Europe.

A further study should be carried out to estimate the social and environmental benefits of this synergy.

However, it is very likely that this synergy will have a strong socio-economic benefit. Indeed, this solution would permit to take much less water from the environment, and would probably save on the price and taxes related to water withdrawal.

5.88Synergies #91 & #92

As in the LCA and the D3.3, synergies 91 and 92 are modelled together.

Baseline business scenario

Heat is not recovered in the process

Synergy

Waste heat is recovered in the process and avoid energy production through fuel burning with boilers.

Assumptions and calculation method

- Waste heat data were gathered for several sectors, see Table 101: Heat recovery potential for some EU sites (Source: Strane)
- Price of energy produced by natural combustion in boilers, see Table 102: MWh price produced by natural gas combustion with boilers (Source: Strane)

Table 101: Heat recovery potential for some EU sites (Source: Strane)

SECTOR	PROCESS	PROCESSES IN EU	KWh/y	GJ/y
INORGANIC CHEMICALS	PYROGENIC SILICA MANUFACTURING	6	120 000 960	432 000
FOOD DRINK AND MILK INDUSTRIES	SALAMI AND SAUSAGE PRODUTION	200	16 383 600 000	58 980 960
SLAUGHTERHOUSES	CATTLE SLAUGHTER PROCESS	2420	227 578 590	819 283
SLAUGHTERHOUSES	PIG SLAUGHTER PROCESS	576	1 508 238 375	5 429 658
SLAUGHTERHOUSES	POULTRY SLAUGHTER PROCESS	191	429 759 000	1 547 132
PRODUCTION OF PULP PAPER AND BOARD	MECHANICAL PULPING AND CHEMIMECHANICAL PULPING	72	37 620 000 000	135 432 000
WASTE INCINERATION	RECOVERY OF ENERGY NH	467	87 485 292 050	314 947 051
ORGANIC CHEMICALS	EHTYLBENZENE MANUFACTURING	10	18 707 700 000	67 347 720
ORGANIC CHEMICALS	STYRENE MANUFACTURING BY DEHYDROGENATION	7	5 952 450 000	21 428 820
ORGANIC CHEMICALS	STYRENE CO-PRODUCTION WITH PROPYLENE OXIDE	4	3 401 400 000	12 245 040
ORGANIC CHEMICALS	HYDROGEN PEROXIDE MANUFACTURING	23	1 147 231 400	4 130 000
		Total number of processes	Total KWh/y	Total GJ/y
		3976	172 983 250 375	622 739 665

Table 102: MWh price produced by natural gas combustion with boilers (Source: Strane)

T (°C)	Cost_MWh_th €/MWh
70	26,057
80	26,147
90	26,239
100	26,330
110	26,451
120	26,571
130	26,692
140	26,814
150	26,937
160	27,061
170	27,187
180	27,313
190	27,441
200	27,570
210	27,700
220	27,831
230	27,964
240	28,098
250	28,233
260	28,369
270	28,507
280	28,646
290	28,787
300	28,928
310	29,072
320	29,216
330	29,363
340	29,510
350	29,659
360	29,810
370	29,962
380	30,116
390	30,271
400	30,428

410	30,587	**580**	33,560	**750**	37,173	**920**	41,658
420	30,747	**590**	33,753	**760**	37,410	**930**	41,955
430	30,909	**600**	33,948	**770**	37,650	**940**	42,257
440	31,072	**610**	34,145	**780**	37,893	**950**	42,564
450	31,238	**620**	34,345	**790**	38,139	**960**	42,875
460	31,405	**630**	34,547	**800**	38,388	**970**	43,190
470	31,574	**640**	34,752	**810**	38,641	**980**	43,510
480	31,745	**650**	34,959	**820**	38,897	**990**	43,835
490	31,917	**660**	35,168	**830**	39,157	**1000**	44,165
500	32,092	**670**	35,380	**840**	39,420	**1010**	44,500
510	32,268	**680**	35,595	**850**	39,686	**1020**	44,840
520	32,446	**690**	35,812	**860**	39,956	**1027**	45,081
530	32,627	**700**	36,032	**870**	40,230	Average	33,850
540	32,809	**710**	36,254	**880**	40,508		
550	32,994	**720**	36,480	**890**	40,789		
560	33,180	**730**	36,708	**900**	41,075		
570	33,369	**740**	36,939	**910**	41,364		

Table

Table 103: Synergies 91 & 92 (Source: Strane)

Synergy 91 & 92	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	33,85
Final volume recovered (Unit/y)	172 983 250
Operational costs (€/y)	
VA	5 855 483 025 €
VAT	1 256 586 657 €
Labour Share (€/y)	2 693 522 192 €
Direct jobs (€)	61118
Indirect jobs (min)	30559
Indirect jobs (max)	184576
Investment	
CAPEX	A lot of technologies are required
Total investment in EU	N.F.
External impacts	
Climate change (kg. CO2-eq)	-59997681148
Human health (DALY)	-35967,81583
Ecosystem quality (PDF.m2.y)	-7138642883
Use of resources (MJ)	-9,11716E+11
€ Climate change	4 799 814 492 €
€ DALY	2 661 618 372 €
€ Ecosystem quality	9 994 100 037 €
€ Use of resources	3 646 863 864 €
Sum of external economic impacts (€)	21 102 396 764 €
Carbon tax evolution (€/y)	-2 399 907 245 931 €

Waste tax	
Waste tax BaU (€/y)	0 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	0 €
Viability distance (100% of the resource price)	NA
Viability distance (10% of resource price)	NA
Waste treatment costs BaU (€/y)	0 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	0 €

Socio-economic assessment for 1kWh of heat recovered

Table 104: Socio-economic assessment for 1kWh of heat recovered (Source: Strane)

Generic waste heat recovery (per GJ)	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	**33,85**
Final volume recovered (Unit/y)	**277,78**
Operational costs (€/y)	
VA	**9 403 €**
VAT	**2 018 €**
Labour Share (€/y)	**4 325 €**
Direct jobs (€)	**0,0981**
Indirect jobs (min)	**0,0491**
Indirect jobs (max)	**0,2964**
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	**-96,344724**
Human health (DALY)	**-5,77574E-05**
Ecosystem quality (PDF.m2.y)	**-11,463286**
Use of resources (MJ)	**-1464,0403**
€ Climate change	**8 €**
€ DALY	**4 €**
€ Ecosystem quality	**16 €**
€ Use of resources	**6 €**
Sum of external economic impacts (€)	**34 €**
Carbon tax evolution (€/y)	
Waste tax	
Waste tax BaU (€/y)	**0 €**
Waste tax Synergy (€/y)	**0 €**
Waste tax balance	**0 €**
Viability distance (100% of the resource price)	**NA**
Viability distance (10% of resource price)	**NA**
Waste treatment costs BaU (€/y)	**0 €**
Waste treatment costs Synergy (€/y)	**0 €**
Waste treatment costs balance (€/y)	**0 €**

Conclusion or comments

The heat recovery potential on selected industries in enormous. This synergy is widely used but there are plenty of sites which do not practice heat recovery despite a significant deposit. A lot of sites are currently working heat recovery implementation for internal use or external suppling (industries and district heating).

The total potential for selected is:

- 5000 M€ of value added
- 1 200M€ of VAT
- 61 000 job created (probably overestimated)
- A major decrease of environmental impact particularly on eco-systems quality and climate change.

Apply heat recovery on all industrial sites in EU would be a major challenge with enormous benefits for sites and community.

The heat recovery socio-economic assessment per GJ is presented in the table below.

Table 105: Socio-economic assessment for 1GJ of heat recovered (Source: Strane)

Generic waste heat recovery (per GJ)	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	33,85
Final volume recovered (Unit/y)	277,78
Operational costs (€/y)	
VA	9 403 €
VAT	2 018 €
Labour Share (€/y)	4 325 €
Direct jobs (€)	0,0981
Indirect jobs (min)	0,0491
Indirect jobs (max)	0,2964
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	-96,344724
Human health (DALY)	-5,77574E-05
Ecosystem quality (PDF.m2.y)	-11,463286
Use of resources (MJ)	-1464,0403
€ Climate change	8 €
€ DALY	4 €
€ Ecosystem quality	16 €
€ Use of resources	6 €
Sum of external economic impacts (€)	34 €
Carbon tax evolution (€/y)	
Waste tax	
Waste tax BaU (€/y)	0 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	0 €
Viability distance (100% of the resource price)	NA
Viability distance (10% of resource price)	NA
Waste treatment costs BaU (€/y)	0 €
Waste treatment costs Synergy (€/y)	0 €

Waste treatment costs balance (€/y)	0 €

A GJ of heat recovered generate around 9 000€ of value added and 34€ of external costs benefits (environmental and social impacts).

5.89Synergies #93 & #94

As in the LCA and the D3.3, synergies 93 and 94 are modelled together.

Baseline business scenario

Steam is not recovered in the process.

Synergy

Waste steam is recovered in the process to produce heat or electricity and avoid energy production through fuel burning with boilers.

Assumptions and calculation method

- Waste steam data were gathered for several sectors, see Table 106: Steam recovery potential for some processes in EU (source: Strane)
- Price of energy produced by natural combustion in boilers, see Table 102: MWh price produced by natural gas combustion with boilers (Source: Strane)
- One steam ton energy content is around 750 kWh (average) [54]

Table 106: Steam recovery potential for some processes in EU (source: Strane)

SECTOR	PROCESS	NUMBER OF PROCE IN EU	KWh/y	GJ/y
SLAUGHTERHOUSES	INCINERATION MEAT AND BONE MEAL	12	1 319 268 750	432 000
REFINING MINERAL OIL AND GAS	CATALYTIC CRACKING FCC PROCESS	61	8 688 871 875	31 279 939
STEEL	BASIC OXYGEN STEELMAKING AND CASTING MANUFACTURING	101	2 200 610 873	28 292 760
		Total number of processes	**Total KWh/y**	**Total GJ/y**
		174	**20 897 623 373**	**91 284 638**

Table

Table 107: Synergies 93 & 94 (Source: Strane)

Synergy 93 & 94	
Waste stream price in BaU scenario (€/Unit)	0
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	34
Final volume recovered (Unit/y)	20 897 623
Operational costs (€/y)	
VA	707 384 551 €
VAT	151 804 725 €
Labour Share (€/y)	325 396 894 €
Direct jobs (€)	7383,4697

Indirect jobs (min)	3691,7349
Indirect jobs (max)	22298,0785
Investment	
CAPEX	Many technologies allow to recover heat
Total investment in EU	N.F.
External impacts	
Climate change (kg. CO2-eq)	-9433668510
Human health (DALY)	-2856,308007
Ecosystem quality (PDF.m2.y)	-859416185,1
Use of resources (MJ)	-1,43116E+11
€ Climate change	754 693 481 €
€ DALY	211 366 793 €
€ Ecosystem quality	1 203 182 659 €
€ Use of resources	572 463 017 €
Sum of external economic impacts (€)	2 741 705 949 €
Carbon tax evolution (€/y)	-377 346 740 403 €
Waste tax	
Waste tax BaU (€/y)	0 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	0 €
Viability distance (100% of the resource price)	NA
Viability distance (10% of resource price)	NA
Waste treatment costs BaU (€/y)	0 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	0 €

Conclusion or comments

The steam exploitation potential to produce energy on the selected industries in enormous. This synergy is widely used but there are plenty of sites which do not practice steam valorisation despite a significant deposit. A lot of sites are currently working on steam recovery technologies implementation.

The total potential for selected is:

- 707 M€ of value added
- 151 M€ of VAT
- 7 000 job in Europe (probably overestimated)
- A major decrease of environmental impact particularly on eco-systems quality and climate change due to fossil energy use saving.

Apply heat recovery on all industrial sites I EU would be a major challenge with enormous benefits for sites and community.

The waste heat recovery from steam socio-economic assessment per GJ is presented in the table below.

Table 108: Waste heat recovery from steam socio-economic assessment per GJ (Source: Strane)

Generic waste heat recovery from steam (per GJ)	
Waste stream price in BaU scenario (€/Unit)	
Waste stream volume (Unit/y)	
Substituted material equivalent price (€/Unit)	33,85
Final volume recovered (Unit/y)	277,78
Operational costs (€/y)	

VA	9 403 €
VAT	2 018 €
Labour Share (€/y)	4 325 €
Direct jobs (€)	0,0981
Indirect jobs (min)	0,0491
Indirect jobs (max)	0,2964
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	-103,34344
Human health (DALY)	-3,12901E-05
Ecosystem quality (PDF.m2.y)	-9,4146858
Use of resources (MJ)	-1567,7967
€ Climate change	8 €
€ DALY	2 €
€ Ecosystem quality	13 €
€ Use of resources	6 €
Sum of external economic impacts (€)	30 €
Carbon tax evolution (€/y)	
Waste tax	
Waste tax BaU (€/y)	0 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	0 €
Viability distance (100% of the resource price)	NA
Viability distance (10% of resource price)	NA
Waste treatment costs BaU (€/y)	0 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	0 €

A GJ of heat recovered generate around 9 000€ of value added and 30€ of external costs benefits (environmental and social impacts).

5.90 Synergies #95, #96, #97, #98, #99 & #100

Baseline business scenario

All types of solid and liquid combustible wastes are sent to waste treatment plants to be incinerated.

Synergy

The purpose of synergies 95 and 96 is to recover all types of solid and liquid combustibles waste and send it to waste treatment industries to produce conventional fuels, and the goal of synergies 97 to 100 is to provide industries with fuels from industrial wastes rather than using traditional fuels. In European Union, 266 facilities are referenced as waste treatment plants aimed to produce material used as fuel. They treat 5 297 000 tons of wastes per year (19913 per site) in order to produce various solid and liquid fuels.

The resource obtained with synergy 97 is oil, the one obtained with synergy 98 is bitumen, the one obtained with synergy 99 is methanol and the one obtained with synergy 100 is gas oil.

Assumptions and calculation method

- Synergies 95 to 100 are modelled within the same calculation for 5 297 000 tons of waste per year. The final volume recovered is the sum of the volumes described in synergies 97 to 100 (oil 4 475 965 t/y – bitumen 201 286 t/y – methanol 270 147 t/y – gas oil 3 739 682 t/y). The price of this volume was determined using a weighted average based on the LHVs of the various resources produced. The price used for the business as usual waste is coal price.
- Operational costs were determined according to data from the technology database (D3.2). The average OPEX is 23.3 €/t, the average water demand is 248.5 L/t, the average electricity demand is 49.5 kWh/t and the average heat demand is 3 000 MWh/y.

Table

Table 109: Synergies 95, 96, 97, 98, 99 & 100 (Source: Strane)

Synergy 95-100	
Waste stream price in BaU scenario (€/Unit)	29,44
Waste stream volume (Unit/y)	5297000
Substituted material equivalent price (€/Unit)	384
Final volume recovered (Unit/y)	8687080
Operational costs (€/y)	143040820
VA	3 036 854 220 €
VAT	651 708 916 €
Labour Share (€/y)	1 396 952 941 €
Direct jobs (€)	31698
Indirect jobs (min)	15849
Indirect jobs (max)	95727
Investment	
CAPEX	
Total investment in EU	
External impacts	
Climate change (kg. CO2-eq)	-34453053651
Human health (DALY)	-34737,97715
Ecosystem quality (PDF.m2.y)	-3980258963
Use of resources (MJ)	-5,3182E+11
€ Climate change	2 756 244 292 €
€ DALY	2 570 610 309 €
€ Ecosystem quality	5 572 362 548 525 €
€ Use of resources	2 127 281 601 €
Sum of external economic impacts (€)	5 579 816 684 726 €
Carbon tax evolution (€/y)	-1 378 122 146 034 €
Waste tax	
Waste tax BaU (€/y)	
Waste tax Synergy (€/y)	
Waste tax balance (€/y)	
Viability distance (100% of the resource price)	1998
Viability distance (10% of the good transported price)	219

Waste treatment costs BaU (€/y)	649 412 200 €
Waste treatment costs Synergy (€/y)	
Waste treatment costs balance (€/y)	-649 412 200 €

Conclusion or comments

The value added of the valorisation of the whole flow is around 508 000 €/y, and the associated VAT is around 652 €. The expected job creation is around 31 700 throughout Europe.

The implementation of this synergy will generate a decrease of the carbon tax up than 1 378 122 M€. Environmental and human health impact would be significantly improved. The distance is enough to reach the receiving sector in several case.

These results should be interpreted remembering that there are no data available on the investment needed. This synergy seems promising, but the socio-environmental study should be repeated more precisely. In addition, many approximations have been made. To improve the accuracy of the results, the calculations for each sector should be repeated independently.

6. Conclusions and perspectives

Performing a socio-economic assessment of 100 synergy types is a new activity that has never been carried out. No methodology was available. Therefore, it was necessary to develop a specific methodology.

Data availability was one of the main challenges of this work. Despite an in-depth and extensive search for data, the screening socio-economic assessment (T3.5) allowed to model 81 synergy types over 100. The 19 remaining synergy types could not be evaluated due to a lack of data specifically needed from a socio-economic assessment perspective. Industrial data are required to perform a full and valid socio-economic study.

The socio-economic assessment of the 100 synergy types lead to quantify the industrial symbiosis potential in EU according to specific indicators defined by the methodology:

- A 33 500 M€ added value thorough Europe
- A 7 000 M€ VAT
- 15 500 M€ of labour share
- 350 000 direct jobs created
- 175 000 to 1 000 000 induced indirect jobs
- The economic equivalence of the environmental impacts is about 100 000 M€, probably over estimated due to the high uncertainty of the data provided for the LCA T3.4
- A 7 500 000M€ carbon tax decrease (probably overestimate since calculation is based on the climate change LCA indicator)
- A 2 200 000M€ waste tax decrease
- 41 000M€ of waste management costs avoided

A second more sensitive assessment, considering the 15 most profitable synergy types' implementation level, lead to refine the results and characterise the remaining industrial symbiosis potential in:

- **A 12 500 M€/y added value** compare to the initial use of the waste stream
- **6 000 M€/y of labour share**
- **130 000 direct jobs created** and between 66 000 and 400 000 indirect jobs generated

Studying waste streams usable both as combustible and raw material (with a high LHV e.g. hydrogen, methanol, benzene, etc.) highlights one major key learning: unfortunately, the material exchange is not economically relevant instead of a direct incineration on site. However, considering the economic benefits of the avoided environmental impacts makes it possible to turn the synergy viable and give an additional life to these reused wastes.

In case of non-profitable synergy (economically), the use of avoided environmental economic values allows to turn the synergy viable. This argument can motivate especially local authorities to support the synergies implementation, for example with long-term profitable subsidies.

The final methodology chosen focuses on the resource intrinsic value improvement by the synergy implementation and do not consider some important value in a socio-economic analysis perspective (raw material provider and waste management companies' financial losses). When a market price is not available, the resource price estimation is a key challenge that could conduct to overestimate the financial benefits.

The use of LCA indicators which were calculated from wide range and uncertain data probably overestimate the equivalent economic values of avoiding environmental impacts.

This deliverable is a screening work providing inputs for the task 3.6 and the final industrial symbiosis potential assessment.

Next steps are the integration of industrial sites geolocated data to identify couples of sites, mutualisation options and perform a statistical analysis on the European industrial symbiosis potential.

The integration of geolocated data will allow to control the viability distances for each synergy types with various transportation options (in particular for gaseous stream transportation by pipeline, not including in this deliverable).

The T3.6 work will lead to identify all mutualisation opportunities for unviable synergies or for synergy types involving weak volumes.

The screening socio-economic assessment performed in T3.5 will be updated and improved to obtain more accurate results with geolocated data.

These work and deliverable constitute a relevant and innovative step forward to assess the socio-economic impact of a 100 synergy types sample. The main advantage of this work is to make synergies implementation comparison easier and to quantify order of magnitude of economic benefits and associated jobs creation.

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