Crédit Mutuel
Asset Management

Waste recovery as raw material or as fuel:

a promising solution to respond to the climate emergency ?

06/12/2022

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INTRODUCTION

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SMALL HISTORY OF WASTE

The appearance of waste as we know it today is relatively recent in the history of humanity.

Indeed, the abundance of waste and the problems that this poses are characteristic of modern man.

At the time when humans were still exclusively nomadic, the waste was only organic waste from leftovers of food, not posing environmental problems because of:

- The population still very low
- The very nature of this waste, which naturally breaks down into nature

From the birth of agriculture (around 7000 BC), marking the gradual transition from a nomadic to sedentary lifestyle to antiquity, the nature of waste does not change, still essentially organic and returned to nature by its degradation cycle.

Antiquity marks a first upheaval in our relationship to waste: Greek and Romans carry the waste produced in the cities outside them, most of the time in pits created for this purpose.

Around the year 1000, in the Middle Ages, more people live in cities and waste is, in fact, accumulated there. This period is marked by a significant lack of hygiene and the first street paving policies are carried out in order to limit odour pollution.

In the 17th century, the first 'recycles' appear, they are the rags. From the poor strata of the population, the rags recover old clothes, rags, animal bones, hair and any kind of objects that can be reused. At the same time, Louis XIV heavily taxes offenders who do not meet the time prescribed for the deposit of garbage in front of their door. In the nineteenth century, the industrial revolution led to the rapid development of cities. To preserve the health and hygiene of the population, a modern waste collection system is set up and companies specializing in sanitation and waste management are developing: SUEZ (1869) and Veolia (1853), then known as Compagnie Générale des Eaux. The first waste treatment centres were built in Saint Ouen in the late nineteenth century (1896). The waste is dumped in a large pit and is sorted: Rags collect paper, rags, bones, canned boxes, while other workers remove scrap, pottery, enamelled sheet in order to pass only the materials useful for agriculture to serve as fertilizer. The rest, that is to say, what cannot be sold to agriculture is destroyed in furnaces that give steam and electricity, is the energy recovery of waste.

At the beginning of the twentieth century, municipal collection of household waste was still limited to large municipalities and little developed in rural areas. It was only in 1975 that a first major law on municipal waste management was passed, obliging each municipality to collect and dispose of household waste.

But the vast majority of the waste collected is sent to landfill, representing a huge waste of raw materials and risks of pollution. In 1992, the government introduced the Royal Act obliging the recovery of household waste and prohibiting landfilling. Sorting bins are installed and people are starting to sort their waste: This is the beginning of modern recycling.

From the end of the twentieth century to the present, many global and national measures are being taken to combat global warming and waste management is an important part of this, with the dual objective of:

- **Reduce the volumes of waste produced by starting with the non recoverable portion**
- **Improve valuation**

Aware of the ongoing climate change and the scarcity of resources, our relationship with waste is changing. They are no longer seen as the waste of society but as the potential resources of tomorrow.

This change in valuation gives waste an economic value on which many sectors of activity such as construction and metallurgy are now built.

This study highlights these areas of activity by identifying the obstacles but also the levers conducive to their development.

SCOPE GIVEN TO THIS STUDY

Considering all waste streams and all sectors of activity would not make it possible to provide in this study a sufficiently precise light on the recovery channels as the stakes are different. For this reason, we will shed light on the flows of non organic residual household waste, those from construction and industrial waste.

We are therefore moving away:

- Organic waste, a source of biomethane production, which has already been addressed in a previous White Paper;
- Metals, because this flow alone can be the subject of a White Paper because the economic stakes and implications are so important;
- Plastic waste, because again the subject is vast and touches on other issues such as the threat they pose to biodiversity.

The scope thus defined covers 92% of waste generated annually in France.

UNSUSTAINABLE RESOURCE CONSUMPTION

RESOURCE CONSUMPTION UNSUSTAINABLE

The economy was built on the transformation of natural materials into everyday goods (food, buildings, furniture, clothing, etc.). From this observation, it is quite easy to highlight the link between GDP growth and consumption of natural materials.

Changes in the consumption of natural materials can be monitored using the ‘material footprint’ indicator. The material footprint corresponds to all the raw materials used to satisfy the final consumption of a country, including indirect flows such as raw materials used in production abroad, during transport, etc. This indicator makes it possible to observe the real impact of human activities on the consumption of natural resources.

On a global scale, the following are the superimposed developments of these two indicators:

Comparison of GDP evolution - Material footprint, adjusted for the effects of inflation

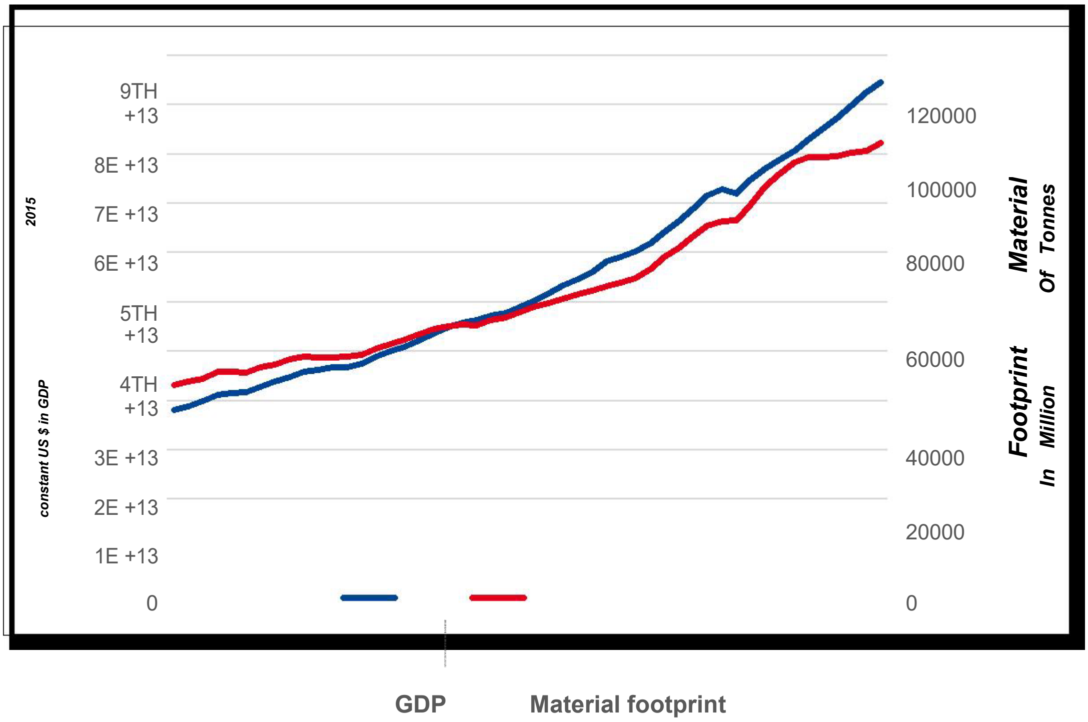


Figure 1.

Evolution of global GDP and global material footprint between 1970 and 2019 (GDP expressed in billions of constant dollars 2015 and material footprint in millions of tons)

Source: BL chart World Bank data evolution and Resource Panel

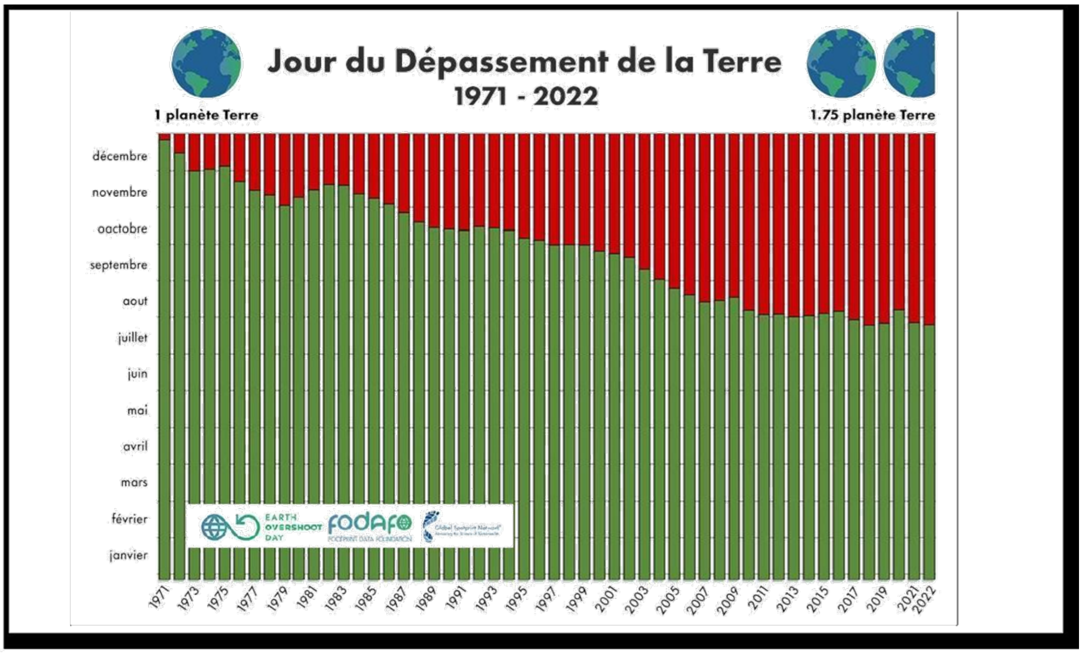
As the chart above illustrates, over the period 1970-2019, the global material footprint tracks GDP growth

From 1990 onwards, however, there has been a slight decoupling between the two indicators, due in particular to the increase in material productivity, an indicator expressing the economic value produced for one tonne of natural material consumed. Thus, in 50 years we have gone from the creation of $585/tonne of natural resources consumed in 1970 to just under $900/tonne in 2019, an increase of 54% in material productivity. However, this increase in productivity must be nuanced. Indeed, using fewer natural resources per dollar created is in the right direction but using less should be the real goal.

However, the global material footprint has grown almost linearly since 1970 without any slowdown: +212% between 1970 and 2019 (see Figure 1). At stake are our contemporary lifestyles, which lead to ever greater consumption of resources. However, the materials extracted are from natural processes over very long periods of time and in view of the current dynamics, these resources do not have the time to renew themselves: Global resource consumption is unsustainable.

This is reflected in the 'day of exceedance,' an indicator calculated each year by the Global Footprint Network, which marks the date on which humanity consumed all the resources that the Earth can generate in a year. After that date, humanity lives on credit, using resources that the planet is no longer able to produce. Since the 1970's: This date continues to move forward.

Evolution of the Earth overtaking day from 1971 to 2022



Source: National Footprint and Biocapacity Accounts, 2022 edition | data.footprintnetwork.org

Reducing the use of natural resources and thus avoiding the supply risks of certain materials requires that a dual objective be achieved:

- Aim for sobriety in our material consumption in order to reduce our material footprint
- Aim for efficiency in our material consumption: To this end, several technological solutions exist based on the principles of the circular economy, a model allowing us to further increase our material productivity.

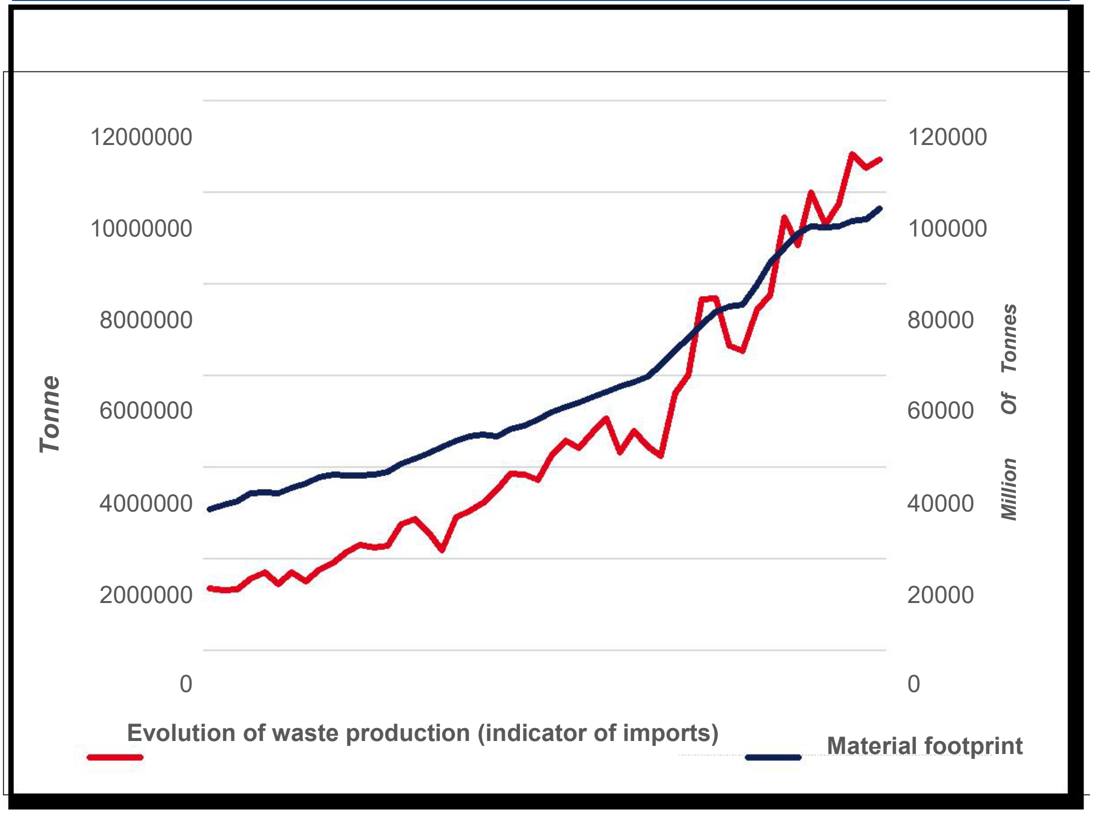
UNSUSTAINABLE WASTE PRODUCTION

RESULTING IN WASTE PRODUCTION UNSUSTAINABLE

Another causal link can be highlighted: It combines the consumption of materials and the production of waste.

Despite the difficulty of having complete data on the production of waste by our societies because the flows are numerous and diffuse (problem of traceability, waste lost in nature, in the oceans, etc.), we find that the evolution of the indicator (approximate) of the import of waste on a global scale is parallel to that of the evolution of the material footprint, here is what we obtain:

Evolution of waste production (indicator of imports) and the global material footprint between 1970 and 2019
(Waste production expressed in tonnes and material footprint in millions of tonnes)



Evolution of waste production (indicator of imports) and the global material footprint between 1970 and 2019 (waste production expressed in tonnes and material footprint in millions of tonnes)

Source: BL chart World Bank data evolution and Resource Panel

As a result, global waste production grows as we consume natural resources: This is called the linear economy.

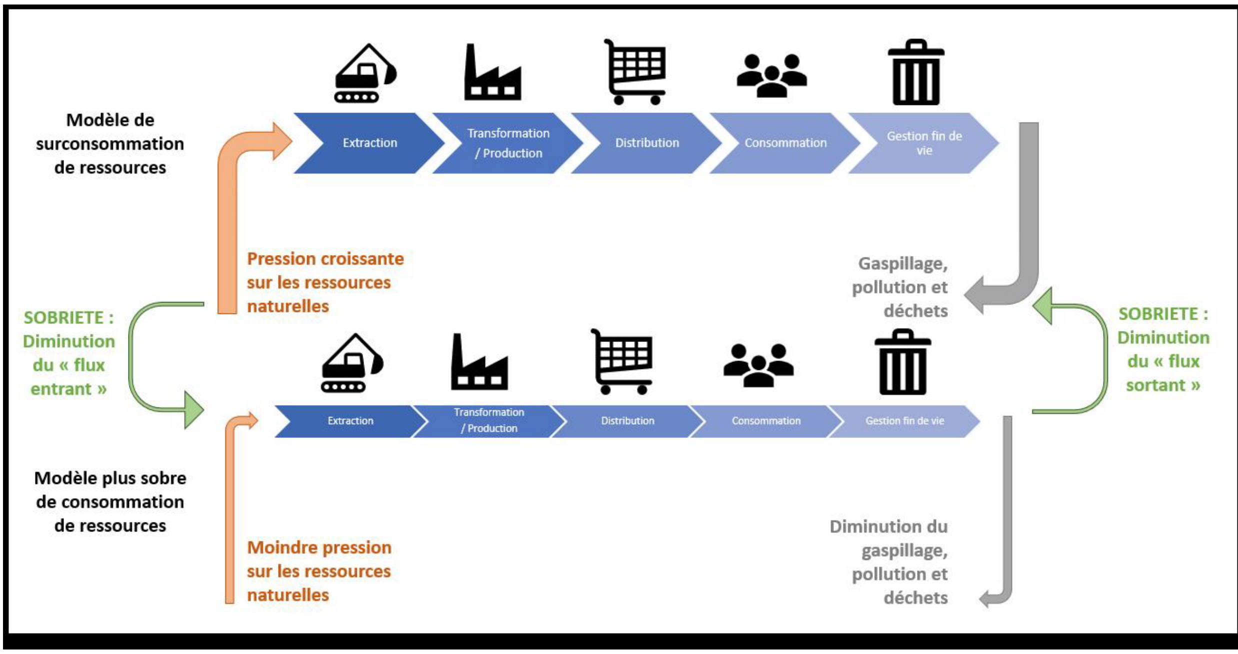
SOBRIETY

SOBRIETY

In general, 'sobriety' consists of consuming less but better. Thus, it is a very effective lever of action: By consuming less (effect on demand), we produce and extract less resources (effect on supply), which has the overall effect of reducing the material footprint.

Sobriety allows us to act upstream by reducing the incoming flow and thereby limiting the pressure that our consumption patterns impose on the Earth's natural resources, but also downstream, by reducing the outgoing flows, namely the waste generated.

Linear economy model and impact of sobriety



Source: BL Evolution

Thus, regardless of the model (overconsumption or sobriety), the volumes of waste produced correspond to the volume of materials extracted: The linear economy works on a system of 'communicating vessels.'

At a company level, sobriety can form the basis of a new business model by encouraging its customers not to consume ever more but to consume fewer products but better quality. This is proposed in particular by the '5R' approach to Reduce, Repair, Reuse, Recycle and Re imagine.

CIRCULAR ECONOMY

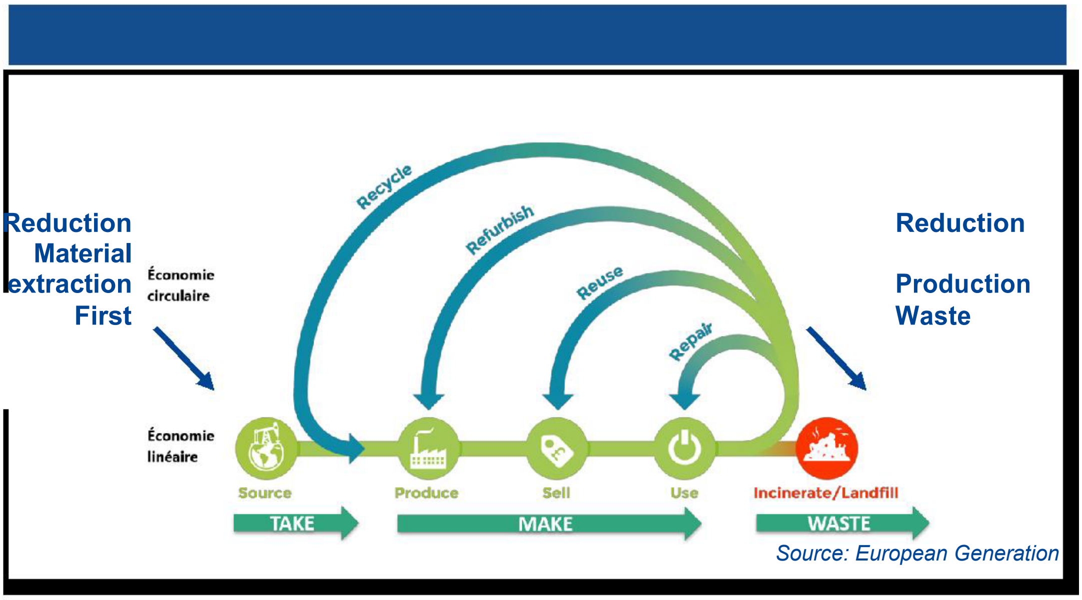
CIRCULAR ECONOMY

‘More efficient’ resource consumption would mean increasing material productivity even further, that is, using less material for a constant unit of production: This is what the circular economy allows.

INTRODUCTION TO THE CIRCULAR ECONOMY

‘The circular economy consists of producing goods and services in a sustainable manner by limiting the consumption and waste of resources and the production of waste’ defined by the Ministry of Ecological Transition and Territorial Cohesion in conjunction with the Ministry of Energy Transition.

The circular economy proposes to move from a completely disposable company (linear economy) to an economic model that recovers this waste by reintegrating it into manufacturing processes. There are different ways of using waste again as a raw material, these are so many ‘circular economy loops’:



Source: European Generation

This approach makes it possible to use resources already extracted again and limits the extraction of raw materials upstream as well as the production of waste downstream. The circular economy is one of the levers that explains the increase in material productivity observed since 1970.

Not all modes of recovery are equal from an environmental point of view. To illustrate this, the European Waste Directive (2008/98/EC) introduces a hierarchy of waste treatment methods. This is included in Article L.541-1 of the French Environment Code and prioritises prevention, followed by reuse, reuse, recycling, material recovery, energy recovery and disposal by landfill (see Appendices).

A FAVOURABLE ENVIRONMENT FOR THE CIRCULAR ECONOMY

Favourable political environment

At the European level, the political context is favorable to the circular economy with in particular the action plan for a circular economy presented by the European Commission on 11 March 2020, within the framework of the Green Pact for Europe. While the 2015 circular economy package focused solely on recycling (municipal waste, packaging and waste collection), the 2020 action plan is more comprehensive and aims to ensure less waste, both by avoiding it and transforming it into high quality secondary resources.

At the French level, many pieces of legislation transpose European circular economy objectives. These include:

The Energy Transition for Green Growth Act (LTECV) of 18 August 2015, which aims in particular to:

- Reduce by 50% the amount of waste landfilled by 2025, i.e. the diversion of more than 50 Mt of waste from landfills
- Increase the quantity of waste recovered in the form of materials
- Gradually decouple economic growth and consumption of raw materials by targeting a 30% increase in material productivity between 2010 and 2030

The French Anti Waste and Circular Economy Act (AGEC) of 10 February 2020, which aims in particular to:

- The creation of an ELARGIE Producer Responsibility function (REP) covering construction products and materials in the building sector at 1 January 2022 (postponed to 1 January 2023)
- Deployment of bulk devices to limit packaging waste

As for investment firms, in France, the decree implementing Article 29 of the French Energy and Climate Act published on 27 May 2021 regulates the obligation to provide extra financial reporting. This involves communicating on the social, environmental, governance quality and means implemented to contribute to the energy, ecological and societal transition of its activities. Article 29 encourages the development of investment strategies aligned with the objectives of the Paris Agreement.

For listed companies, the 2021 Corporate Sustainable Reporting Directive (CSRD) reinforces the requirements of the 2014 NFRD (Non Financial Reporting Directive) to make companies more responsible by requiring them to disclose their impact on the planet. This is an additional lever, put in place by the EU as part of its climate plan, to accelerate the transition to a sustainable economy. (Reminder: For all companies fulfilling two of the following three criteria: 250 employees, €40M in turnover, or €20M in balance sheet, it will apply from 1 January 2025, and for SMEs listed between 10 and 250 employees from 1 January 2026).

Each company must submit, within a sustainability report to be audited: Its ESG strategy (business model, governance, analysis of the main impacts, risks and opportunities), its implementation (policies, objectives, actions, allocated resources) and its performance (indicators).

CIRCULAR ECONOMY & REPORTING GUIDELINES

The European Green Taxonomy sets criteria for selecting activities contributing to climate change mitigation and adaptation and **'Transition to a circular economy' appears as one of the 6 sustainability goals defined.**

The UN SDGs also provide a reporting framework. Extra financial rating agencies assess how companies contribute positively or negatively to sustainable development goals to refine their ESG rating. The circular economy is an integral part of SDG 12 'Responsible consumption and production'

FAVOURABLE ENVIRONMENTAL ENVIRONMENT

By reducing the pressure on natural resources, the circular economy helps to limit the consequences associated with their extraction:

- **The depletion of natural resources due to the continued growth of the material footprint;**
- **Biodiversity degradation: The extraction of natural resources requires heavy infrastructure and causes the displacement of large volumes of land that disrupt biodiversity. Dredging sand extraction from lagoons and rivers disrupts fauna and flora and degrades soils.**
- **The loss of vegetation promotes in particular:**
  - Soil leaching: When it rains, toxic products and polluting minerals are moved, contaminating streams and agricultural land
  - Erosion

By limiting waste production, the circular economy helps to limit the consequences of landfilling waste that is not recovered:

- **Olfactory and chemical pollution of the air: Landfills cause olfactory pollution by the foul smells they emit**
- **Soil and groundwater contamination: If landfills comply with standards requiring the impermeability of storage areas, the risk of soil and groundwater pollution remains present. When it rains, the water can import with it the toxic elements present in the waste and pollute the groundwater by infiltration into the soil.**
- **The risks of explosion or fire: Given the nature and materials they may contain, buried waste is fuel that, in the event of a fire, is likely to ignite.**
- **Greenhouse gas emissions: By decomposing, organic waste releases methane, a greenhouse gas with a global warming potential 23 times higher than CO2.**

Waste treatment is responsible for 3% of total greenhouse gas emissions in France and landfilling of unrecovered waste accounts for approximately 16% of methane emissions (Source: CNIID).

The circular economy is an important lever in the fight against global warming. Indeed, a study conducted by Goldman Sachs estimates that it could reduce global greenhouse gas emissions by 39% by reference to 2019 (see Appendices).

AN INCREASINGLY FAVOURABLE ECONOMIC ENVIRONMENT

By considering waste no longer as worthless waste but as new exploitable resources, the circular economy represents an opportunity for the creation of businesses and therefore jobs.

Until recently, the linear economy was still economically advantageous in most cases compared to the circular economy. Indeed, our economy having been established for centuries on the linear system of 'all waste,' it was advantageous: Relative low cost of energy and therefore transport in a globalised economy, relative low cost of resource extraction, optimisation of supply and manufacturing chain, economy of scale, etc.

However, the crises we are facing have revolutionised the cards:

- **The health crisis and the war in Ukraine are forcing us to rethink how we supply ourselves.**
- **Scarcity of natural resources leading to higher prices, and poor distribution of transport capacity increasing supply costs.**

The massive development of the circular economy would reduce waste management costs, develop more profitable recovery processes, create the necessary infrastructure in the territory for its proper development, and gradually balance the economic balance in its favor.

Finally, the regulatory tool could be an accelerator, taxing the most polluting activities and in fact favouring activities that are more environmentally friendly.

Thanks to these levers, the circular economy becomes a tool that allows a territory to generate value, savings and build resilience through a supply of locally available resources.

CIRCULAR ECONOMY AND EMPLOYMENT - KEY FIGURES

- For the same tonne of waste, incineration creates 3 FV-1 compared to 50 for reuse or reuse
- **800,000 FTEs: This is the number of jobs in the circular economy in France**
- **300,000 FTEs: This is the number of jobs that the government believes can be created in the circular economy sector**

Source: ADEME, France Strategy, Ministry of Ecology Transition and Territorial Cohesion

Most circular economy solutions generate cost savings on the raw material extraction plant because their processes consist of replacing a portion of virgin inputs with revalued material. However, the cost of supplying virgin natural materials is increasing, the interest
This improves the cost effectiveness of these solutions.

The current political, environmental and economic context is very favourable to the development of the circular economy. The challenge is therefore to:

- Consolidate existing valuation infrastructures
- Implement new ways to enhance value through innovative solutions, in particular

1 Fte: Equivalent Full Time

INTERVIEW

INTERVIEW WITH MAUDE SOUBEIRAN

Maude SOUBEIRAN
Regional Coordinator Hauts de France
Neo eco

What are the main challenges (technical economic, political) for the development of waste recovery channels in France and Europe?

- Regulatory aspect: The slow evolution of regulations limits the development of innovative channels - we must adapt the texts and thus create regulatory support facilitating the integration of recycled materials into new products;

- **Psychological aspect: Fear of integrating used materials into a 'new' product**

- **Technical aspect (related to psychological brake):**
  - The lack of knowledge associated with waste and its properties - > waste is not considered as materials when they may have properties relevant for recovery
  - Specific features of plastics/insulators: Composite materials, lightweight and diffuse flows make it difficult to set up sustainable sectors. Some of these materials are not recyclable because of their composition, others because technologies do not identify or separate them while maintaining profitability

- **Political aspect: Lack of investment in valuation channels**

- **General aspect: The lack of standards/demonstrators integrating eco products based on recycled material - > players have no feedback, which maintains a 'frivolous' climate around the integration of waste into new products**

In your opinion, what is the potential for the development of the recovery channels for the 3 waste streams mentioned in this study (construction, non organic household, industrial)?

Does one flow have greater potential than the others?

If so, why (technical feasibility, cost, accumulated delay, etc.)?

- BTP: With the upcoming PWR * PMCB and recent regulatory changes, the recovery potential of the BTP waste tends to increase. Companies are 'forced' to sort and recycle. Investments in the search for new outlets will increase, which will lead to new recovery channels. However, this evolution will remain slower for certain materials such as insulators and plastics due to the technical brakes presented above.

- Non organic household: Non organic household waste already has recycling channels - REP WEEE, waste collection, collection of recyclable household waste, etc. Packaging is still far from being fully recyclable and recycled, but many initiatives are underway by federations and eco organizations.

- Industrial waste: Industrial waste is of all kinds, it is complicated to make it a generality. Nevertheless, the advantage of this type of flow is recurrence and homogeneity. The development potential of these sectors is very high due to the diversity of deposits. This opportunity is also a brake because the recovery processes can not be 'simply' reproduced from industrialists to industrialists. A complete study of each waste must be carried out, which costs money and takes time. It is still a brake for some manufacturers who prefer to keep their current waste management circuits. Cement plants and metallurgy companies are the largest emitters of CO_2 in France, and are therefore strongly encouraged to reduce their emissions, in particular through the use of CSR as fuel for kilns. It is not a question of recycling, but this sector is likely to develop, from certain industrial waste streams.

* Producer's liability

For more than 10 years, you have been involved in the development of the waste recovery sector, what are the main changes you see?

- In the construction sector, regulatory changes have boosted the integration of the circular economy and therefore the optimization of waste management in practices. The implementation of the PMCB REP will require waste sorting and should allow for an increase in recovery rates.

- Attitudes are changing in general, with more and more external requests for research and the development of valuation channels. The increase in landfill costs is prompting manufacturers to ask us to optimise their management costs. This is mainly the case for mineral waste such as sediment, land and concrete. These deposits, being in large volumes, can have a big impact on the economic synthesis, so it is increasingly wise to value them. Regulations are moving in this direction to increasingly restrict solutions such as landfilling, cladding, etc.

- Local authorities are increasingly involved in the management and optimal recovery of waste, for economic reasons, but also probably to meet the expectations of the voters.

Today, what is the economic equation of waste recovery channels? (Economic equation of ‘circular’ versus ‘linear’)

On paper, recycling waste represents an additional cost in the value chain:

- **Linear model: Extraction > Production > Use > End of life**

- **Circular model: Extraction > Production > Usage > End of life > Recycling - Second life > Production > Usage > End of life > Recycling - New life > Production > Usage...**

The circular model requires an additional cost for recycling, however, it avoids new extraction costs and/or minimises them. He rethinks the model by including new lines, but removing others. In addition, some sectors have higher end of life management costs than recycling and reintegration costs. Gains are made on the resale of recycled material, which adds added value, but also on the purchase of recycled material compared to a raw material, which saves on supply.

However, it is also possible to note that integrating recycled material into the process costs more in terms of equipment and composition, the cost of resale of the recycled material must then be optimized. The economy is based on resources, which are no longer extracted, but some recycling processes still need to be improved to compete with the conventional linear circuit. Transport is often one of the important items for expenditure and environmental impact, so it is a key element for a relevant recycling channel.

Why and how should the world of finance be involved in the development of innovative waste recovery channels in France and Europe?

Investment in research and development projects for new value chains boosts the sector and leads to more sustainable solutions. Involving the financial sector also means changing the focus on waste and recovery, reconciling economy, circularity and the environment. Financing from major banking groups is rarely used for research into waste recovery. Funding legislation could force banks to finance more sustainable projects.

VALORISATION DES DÉCHETS - ÉTUDE PAR FLUX DE DÉCHETS

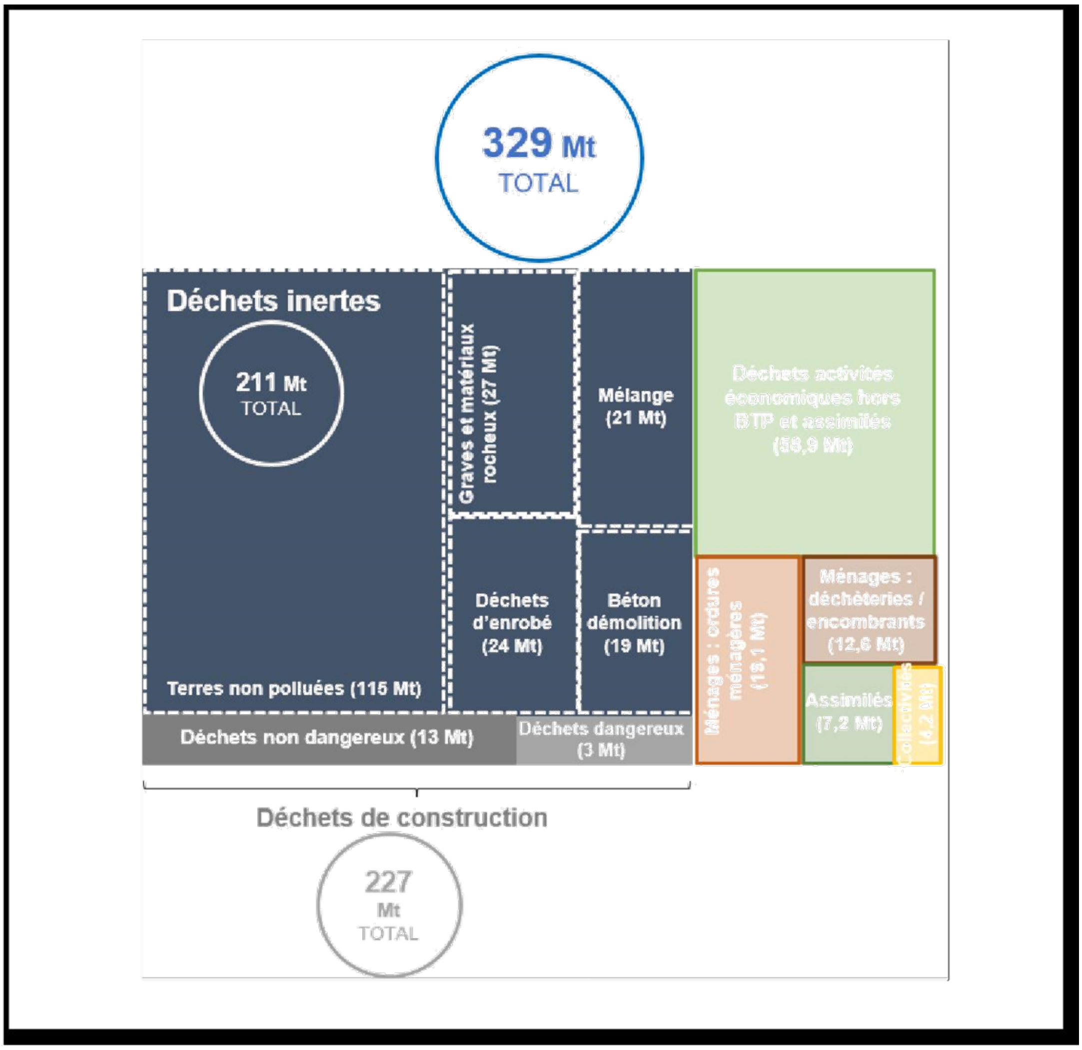
WASTE RECOVERY - STUDY BY WASTE STREAM

CONSTRUCTION WASTE

Field characterisation

In 2017, France produced 329 million tonnes (Mt) of waste across all sectors, including 227 Mt from the construction industry, or nearly
70% of waste produced.

Share of different sectors in waste production in France



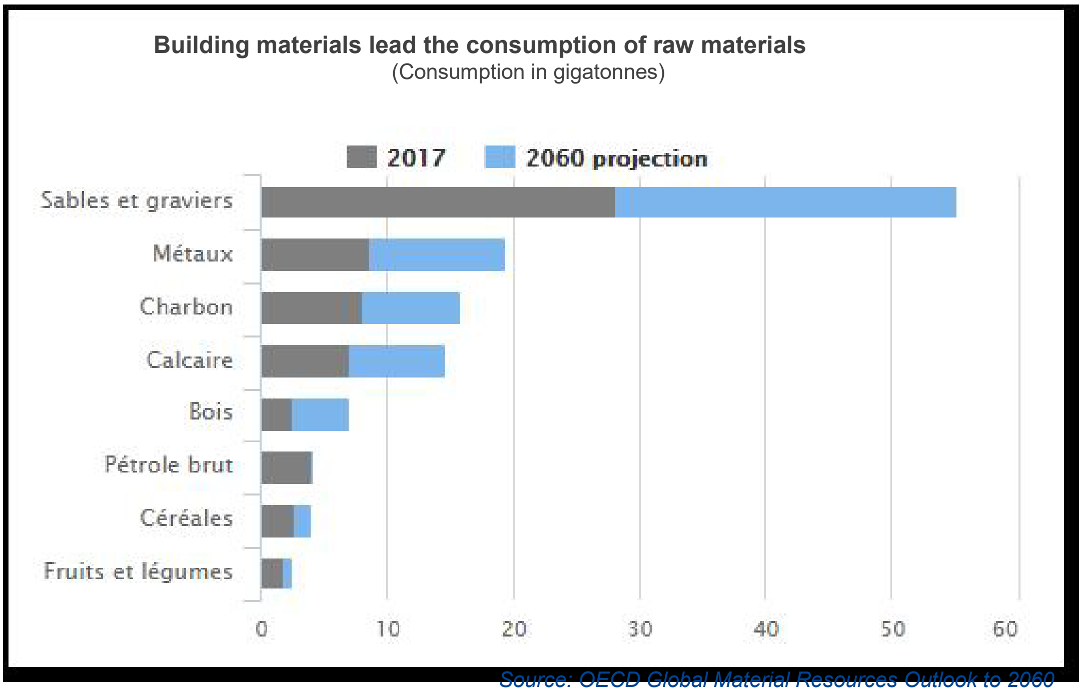
BL chart evolution based on the following sources:
RSD 2016, ADEME - Collective Survey 2017, estimations IN numeri, Unicem

Applied to the domestic production of building materials, with a volume of 383 Mt in 2018, the circular economy would cover a significant part of the demand for materials.

Inert waste does not decompose, burn or produce any physical or chemical reaction. They represent a considerable weight of 211 Mt, or 93% of the sector's waste. In decreasing order of importance, the majority flows consist of: Unpolluted land (55%), serious and rocky materials (13%), asphalt mix waste (11%) and demolition concrete (9%).

The OECD's Global Material Resource Outlook to 2060 project a shift from the global use of materials from 96 gigatonnes in 2019 to 167 gigatonnes in 2060. The construction sector has been identified as having a major impact, with a doubling of volumes extracted from sand and gravel:

2060 forecasts of consumption of various resources worldwide



Source: OECD Global Material Resources Outlook to 2060

Valuation today

FOCUS ON CURRENT WASTE RECOVERY CONSTRUCTION IN FRANCE IN 2014

- **69% valuation of construction sector flows (all modes combined)**
- **69% are treated by material recovery (without knowing exactly the detail between reuse, recycling and material recovery in quarries fill or road underlayer)**
- **16% are stored in dedicated facilities**
- **15% have an unknown outlet**

The 69% material recovery rate is boosted by the significant proportion of inert waste among the waste in the sector (93%), a waste family that usually recovers into quarries and road underlayer.

Innovative and potential recovery solutions in the circular economy

The solutions for the treatment of the largest waste streams in the sector, which have the greatest potential for development and environmental impact, are those of the recycling of excavated land, demolition concrete and asphalt waste.

Recycling of excavated land for ground construction

Unpolluted land accounts for about half of the sector's waste streams, or 115 Mt

Usually resulting from excavations related to earthworks, the land is generally used in situ for backfilling or levelling purposes, for example.

It has many ecological and social virtues:
- It has a very low carbon balance
- It is totally reusable as a raw material if it is not stabilized
- It is 100% healthy and without VOCs - Volatile Organic Compounds - considered as the main source of pollution of inhabited spaces
- It is perspious and operates as a natural hygrometric regulator

This deposit therefore represents a considerable volume of resources that can potentially be mobilised for purposes other than backfilling.

It was on the basis of this observation that the Cycle Terre (93) project was born to launch a production chain of building materials from excavated soils in the Île de France to allow the production of significant volumes and promote the return of a productive activity in the city.

Three production lines are currently in operation, each corresponding to a material made from soil waste: A ‘compression’ line producing Compressed Earth Locks (BTC); a ‘coated’ line producing finishing or laying mortars; an ‘extrusion’ line producing clay panels dubbing in raw earth.

Their areas of application are multiple:

- Non bearable walls in frame filling
- Inner lining and lining
- Carrying walls (R +1 maximum)
- Heavy bulkhead

A SECTOR THAT IS STILL LOOKING FOR ITS BUSINESS MODEL

The use of raw land can generate significant additional costs compared to more industrialised techniques:

- A need for a skilled workforce
- Additional studies for material formulation or architectural prototyping
- A lack of technical standards that generate additional costs related to insurance prices

However, these additional costs depend on the use of raw land: For example, ground coatings, facade filling or separation partitions in BTC have a relatively limited additional cost compared to industrial equivalents, but make savings.

- Energy because it consumes little grey energy - see Glossary
- As a highly insulating material, it reduces energy consumption related to air conditioning and heating of buildings.

To maintain profitability conditions, transport distances must be limited

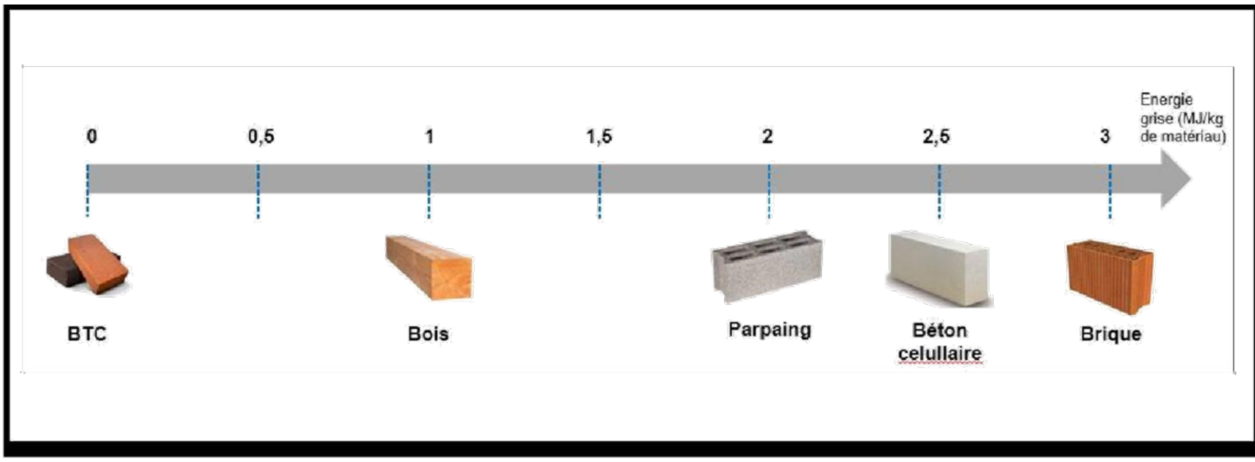
Source: Earth Cycle

Although the economic interest of the construction of raw land is still fragile, from an environmental point of view, this sector responds to the challenges concerning the treatment of large volumes of excavated land by the works of the Grand Paris Express; volumes estimated at 43 Mt.

Thus, the Cycle Terre project will not be able to absorb the volumes of waste from locally excavated land alone (target of 8000 tonnes in the demonstration phase) but the objective is to initiate the process and serve as a reference for other sectors. And this will be made possible by the various missions that the project has set itself, such as:

- Produce technical references for raw earth construction: Today 3 technical certifications (bricks, clay panels and mortar)
- **Develop with real estate developers and architects the use of materials to test the value of the process**
- Offer construction materials with a very low environmental impact

Comparison of grey energy consumption by type of material



Source: BL chart evolution on Anco data

Unlike terracotta, raw earth is the subject of natural drying, which makes the manufacturing process less impacting: At equivalent volume, raw earth emits 2.5 times GHG than cooked earth and about 2 times less than concrete blocks.

Recycling of demolition concrete

Demolition concrete represents 19 Mt waste/year or 8% of the waste in the construction sector in France, making it one of the main deposits. Today, widely used in quarry filling or in road underlayer application (80%), this waste stream is one of the best recovered in the sector.

However, considering that the remaining 20% is stored in specialised facilities, the share of demolition concrete recycled in new concrete represents a very marginal part (less than 1%), which is a challenge in view of the strong impact of this product on natural resources.

Sand and granulate used in the composition of concrete account for approximately 80% of its volume (rate dependent on concrete uses). Each year, between 35 and 39 million cubic metres of ready mix concrete are produced in France2, or between 28 and 31 million cubic metres of sand and aggregates required.

Thus, the valuations made of demolition concrete today do not make it possible to substitute the volumes of sand and aggregates extracted annually for the construction of new concrete. The application of a circular economy loop through recycling would meet this challenge.

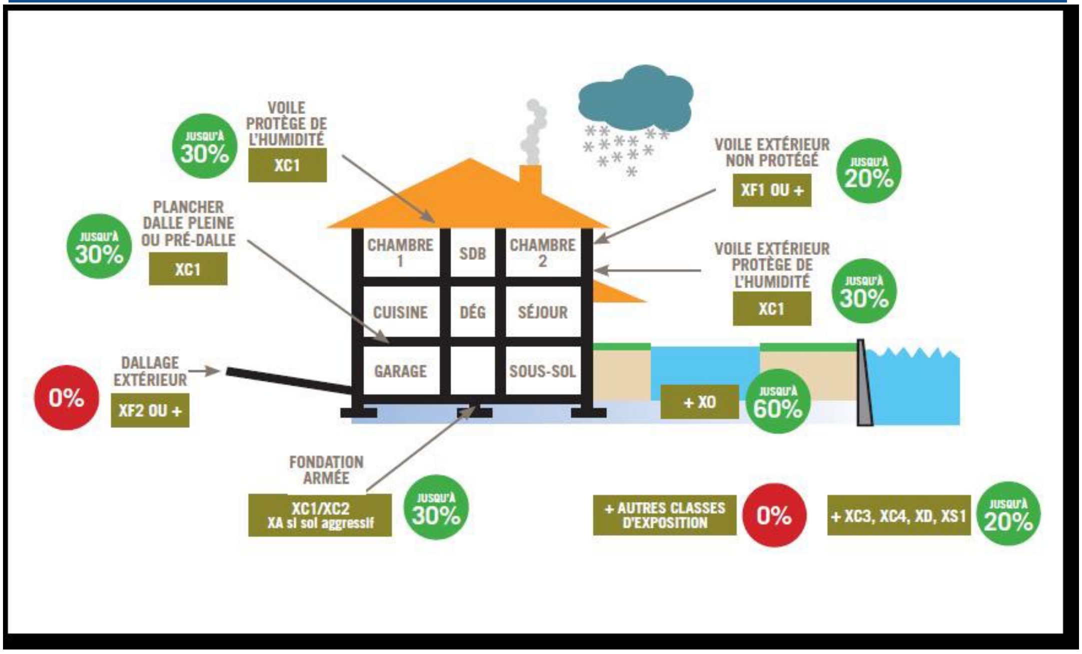
And recycling concrete into concrete is technically possible. To do this, it is necessary to prepare the demolished concrete upstream:

- A site sorting step is required to separate demolition concrete from other mixed waste streams on site, including metal frames (reinforced concrete)
- A second stage of crushing, the reduction of the material in small fragments
- It is then screened, it is a sorting according to their particle size
- Finally, we perform the dust removal

2 Source: Statista in 2013 and 2019

At the end of this preparation process, we obtain Recycled Cetons Granulates that can be incorporated into the development of new concrete. Incorporation rates are governed by standards and vary between 0 and 60% of the total mass of aggregates in concrete:

Maximum rate of incorporation of GBR into the construction of new concrete according to the class of exposure



Source: Aggneo Bâtiment

The recycling of demolition concrete has many advantages, such as:

- Its environmental interest: Related to the impacts of resource extraction such as sand in the seabed
- Its ability to technically meet construction requirements

From an economic point of view, the constraint on the availability of aggregates (permission to operate new quarries) and the fact that decommissioning materials must be treated or landfilled with increasing costs, make the recovery of demolition concrete economically attractive.

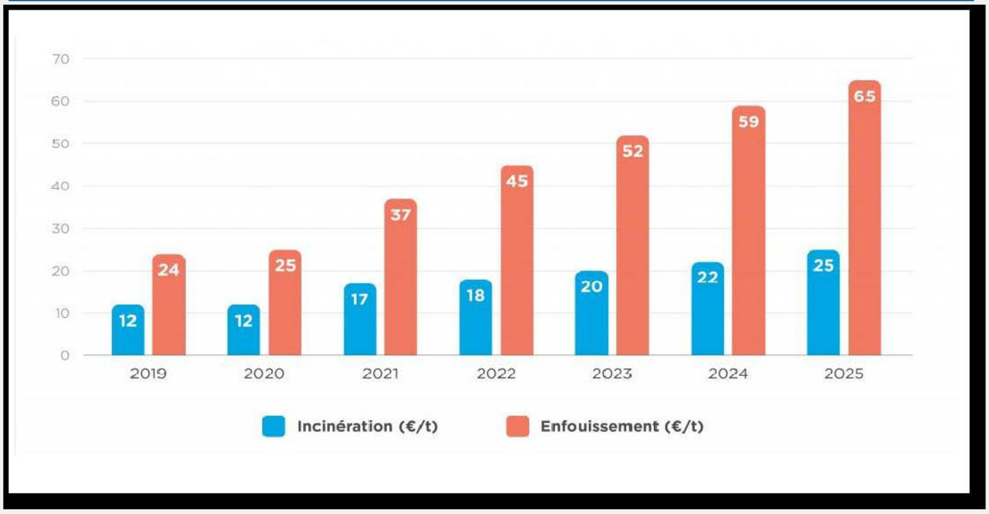
FOCUS ON TGAP EVOLUTION
General tax on polluting activities

The government has put in place financial incentives to direct professional waste streams to modes with the lowest environmental impacts. The General Tax on Polluting Activities - created in 1999 on the 'polluter pays' principle applies to 'final' waste, ie non recoverable waste intended for either landfilling or incineration.

This tax changes each year on January 1, increasing the cost of waste treatment for professionals

And the pace of TGAP growth is accelerating: Landfill TGAP is expected to increase from €25/tonne in 2020 to €65/tonne in 2025, while incineration TGAP is expected to increase from €12/tonne in 2020 to €25/tonne in 2025, or double in 5 years.

Change in TGAP cost for landfill and incineration (€/t) in 2019 and 2025
Infographic: Phenix



Source: 2019 Finance Act No. 2018-1317 of 28 December 2018, article 24

The increase in waste treatment costs through incineration and landfilling makes circular waste recovery increasingly attractive.

NON ORGANIC HOUSEHOLD WASTE AND INDUSTRIAL WASTE

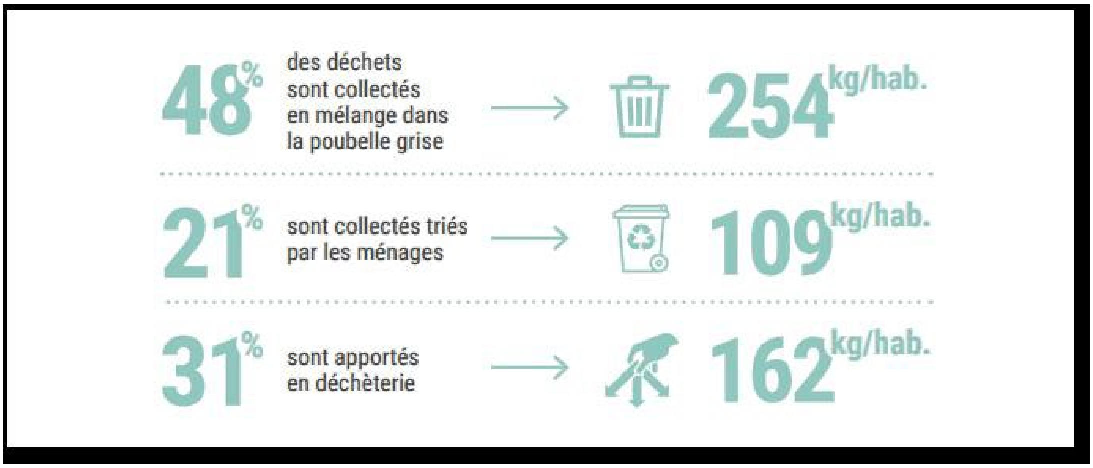
Field characterisation

Household waste

In 2018, household waste accounted for nearly 30 Mt in France3, including 10 Mt in France of non organic residual household order4.

During a waste assessment campaign carried out in 2017, it was observed that the annual average production of non-organic household waste (OMR) was down sharply: -31% between 1993 and 2017, from 365 kg of OMR/hab./year to 254 kg of OMR/hab./year; although the share of OMR in household waste remains high (48% in 2017):

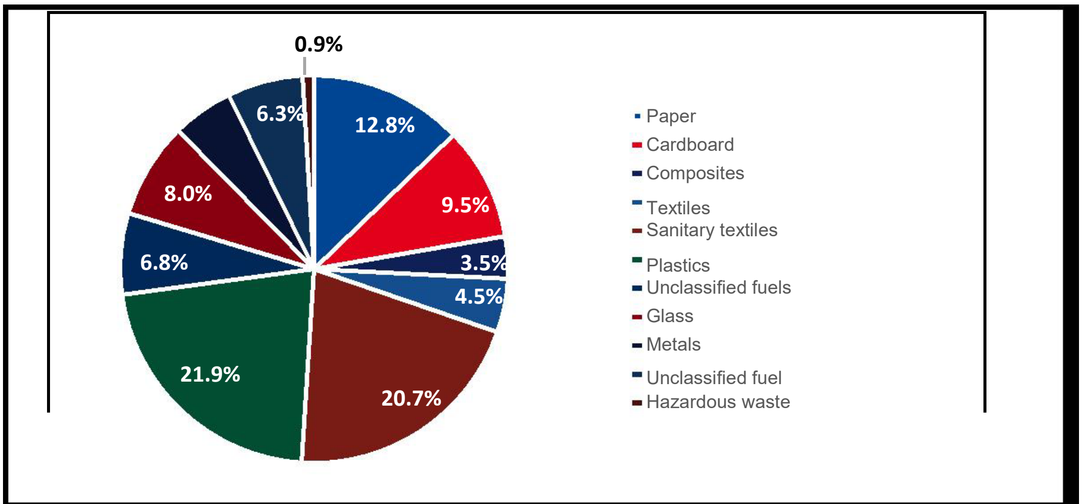
Breakdown of household waste between OMR, selective



Source: ADEME -2017 Collection Survey

The second observation is that the composition of the OMR has not changed over the last 10 years. Limited to non organic OMR, the results from MODECOM 2017 are as follows:

Characterisation of non organic OMR waste in France in 2017



Industrial waste

Industrial waste (or waste from economic activities excluding construction and similar) represents a deposit of approximately 66 Mt per year in France, i.e. 20% of total waste production.

The characterisation of industrial waste is more complex than that of household waste. It represents a flow nearly 2 times larger, more diffuse and of a wide variety (metals, paper and cardboard, glass, plastic, rubber, wood, textile and leather, mixed waste, etc.)

Valuation today

Household waste

The content of grey garbage cans (organic and non organic OMR) is mainly recovered for energy purposes: 68% goes to energy recovery or incineration, 24% to landfills and 8% to composting or anaerobic digestion (mainly for organic waste).

Industrial waste

72% of manufacturing waste is directly recovered, including 57% recycling, 3% organic recovery, and 12% incineration with heat recovery.

Innovative and potential recovery solutions in the circular economy

In order to comply with the Law on Energy Transition for Green Growth, it is necessary to accelerate the recycling of waste to find new solutions; such as the one developed by Neolithe of fossilization of waste.

Accelerated fossilization of waste - Experience of Neolithe

A French company created in 2019, Néolithe has developed a patented process of fossilization unique in the world, allowing non recyclable, non inert and non hazardous waste to be transformed into mineral aggregates.

This process addresses a dual environmental challenge:

- **Reducing the volume of non recyclable waste by offering a more virtuous alternative than current recovery methods**
- **To meet the high demand for aggregates (the most consumed raw material in France) for construction needs**

This process is thus part of a circular economy approach whose constituent stages are as follows:

- Collection of non recyclable waste (refusal of sorting)
- Waste shredding
- Fossil fuels of waste without pollutant emissions
- New crushing of the outgoing material (waste powder)
- Mixture of this powder with binder and water in the following proportions: 80% waste powder/20% low carbon/water binder (Stone Pasta)
- Shaping aggregates

The waste entering the fossil fuel process can be made up of household waste, as well as mixed ordinary industrial waste such as plastic, wood, textiles, plaster or insulation.

The aggregates thus created can be recovered as a road underlayer or directly for the manufacture of concrete.

From an economic point of view, the fossil fuel price is equivalent to the price of the landfill service (including transport and TGAP). This price is therefore variable depending on the region in which the Fossiliser is located. In the medium term, fossilization will be cheaper than landfilling, at an equivalent price in all regions, as the landfill price will have continued to rise.

Following the Neolithe process, Anthropocite's metric ton of aggregates is now sold at the same price as recycled or new aggregates, i.e. 5 to €15/t.

INTERVIEW

Nicolas Cruaud,
Chairman of
Neolithe

INTERVIEW WITH **NICOLAS CRUAUD**

As a first step, we would like to characterise precisely the waste used as inputs in your fossil fuel process.

Indeed, it is indicated on your website that the waste used results from the refusal to sort both household and industrial waste and can be composed of plastic, wood or even organic materials. Could you detail the characterisation of incoming waste?

The waste we treat is mixed waste. They contain everything that sorting players do not consider recyclable or not economically profitable to recycle. Without being exhaustive, one can find in a refusal to sort DIB: Plastics in mixtures, wood, paper, cardboard, textiles, mineral wool, plasters, foams, etc.

Once the mineral granulate is obtained from the process, the recovery panel is wide (integration into concrete, road sublayer, quarry embankment, etc.).

Where are your aggregates used today? Who are the players taking over aggregates (large construction companies, local construction SMEs, etc.)? Does the regulatory framework in place force you into the possible valuations of your aggregates?

The first certified application we have obtained is integration into non structural concrete. It already makes it possible to consume a very large amount of material. The second in the process of certification is the application in road technology, particularly in severe bitumen and underlayer. We are also working on integration into structural concrete. The regulatory framework in place, and in particular the granulate standard, does not allow us to identify with recycled granulate, or even artificial granulate, because the definitions do not stick. This prevents us, for example, from reaching normalised concrete.

The fossil fuel process that you have put in place is a circular economy solution that has the particularity (and interest) of responding to two major problems:

That of reducing waste and its overall impact and that of replacing it with aggregates that can be used for the uses of BTP, an overexploited natural resource whose extraction has a significant impact.

Also, we would like to know the economic balance of your solution:

- **At what price do you take back the ton of waste by entering? Is this price variable according to its composition? Its provenance?**

  In the short term, the price of fossil fuels is equivalent to the price of the landfill service (including transport, including TGAP). This price is therefore variable depending on the region in which the Fossiliser is located. In the medium term, fossilization will be cheaper than landfilling, at an equivalent price in all regions, as the landfill price will continue to rise

- **At what price do you sell the tonne of granulate obtained? What is the cost compared to the ton of 'new' aggregates?**

  One tonne of Anthropocite aggregates is now sold at the price of recycled or new aggregates, i.e. between 5 and €15/t. In the medium term, this price may have to rise, when the CO_2 sequestration potential of the granulate will be well perceived by customers as an asset of decarbonisation of the construction.

- **In general, what are the costs in the equation?**

  The main fossil fuel costs are Fossilizer depreciation, maintenance and wear parts, binders, and electricity.

More generally, while there is no shortage of circular economy solutions, fewer have a positive economic balance or are able to compete economically with similar linear solutions.

What is your view of the cost equation for waste recovery companies? (Economic equation of 'circular' versus 'linear')

Except in rare and temporary cases of very high prices of raw materials, and therefore recycled materials, circular economy economic models such as mine can only be competitive thanks to taxation and the constraint applied to existing linear processes. For example, the cost of landfilling in France in 2023 was around €150/t. By way of comparison, in the United States, where the environmental constraint on waste management is much lower, the landfill cost is around €35/t. The sustainability of this type of model is therefore strongly correlated with the political will of the country.

Finally, in your opinion, why and how should the world of finance be involved in the development of innovative waste recovery channels in France and Europe?

In my opinion, the greatest risk for the world of finance in terms of waste recovery is to seek to finance large energy recovery assets for non recyclable waste (excluding biomass). These assets (incinerators and boilers at CSR) are now the reference solution to compensate for the lack of landfill capacity (decided by the State). They also seem all the more relevant today, in the midst of an energy crisis, because they provide some additional production capacity.

However, the energy recovery of non recyclable waste (excluding biomass) inevitably implies the production of very carbon energy, in particular because of the combustion of fossil materials present in waste (plastics in particular).

To give an order of magnitude, the electricity generated by an incinerator emits as much fossil CO2 per electric MWh as a coal fired power plant, and the heat generated emits more fossil CO2 per thermal MWh than a fuel oil boiler.

These investments, which have a depreciation period of decades, are therefore obviously incompatible with the zero carbon trajectory of the EU, and in particular that of France, which already produces its energy in a rather low carbon way. The risk is therefore to finance an asset that will be considered worthless in 5 or 10 years, as constraints on CO2 emissions will have grown dramatically. The first example of this is the vote in the European Parliament on the inclusion of incinerators in the ETS carbon quota market, implying an increase in incineration costs of around 50% in 2026.

Finally, these infrastructures have strong economies of scale, which leads manufacturers to oversize furnaces. This means, as of today, that in some cities there is a need to import waste to be incinerated so as not to create an oven vacuum, which would damage the plant prematurely. This also implies that incinerators are in constant opposition and confrontation with all the advances in waste reduction and upstream recycling, as this strongly impacts their available deposit.

Valuation for CSR production - Environmental and economic impact study

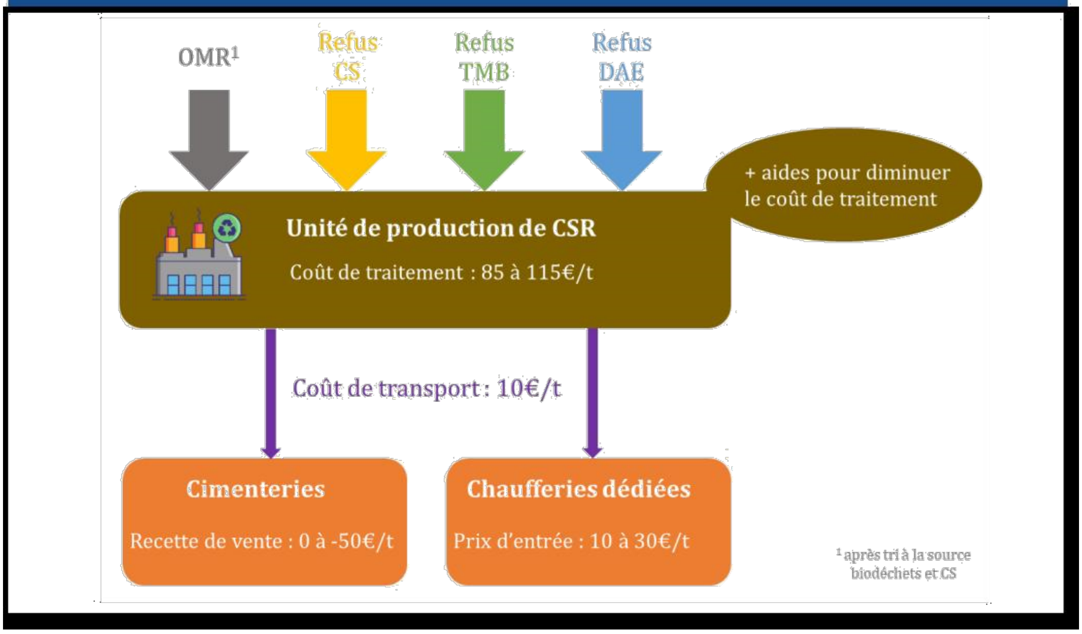
CSR results from the refusal to sort waste from economic activities, selective collection of packaging, bulky waste (dry waste and rich in plastic residues, wood, paper, etc., which cannot be recycled under current conditions). Non hazardous solid waste, They may represent between 15 and 90% of the incoming stream, depending on their nature, the type of sorting and the quality sought for the stream intended for material recycling. The production of CSR from household waste is an efficient energy recovery route in terms of heat and/or electricity, generally as a substitute for fossil energy.

We distinguish:

- **High quality CSR (PCI - Lower Calorific Power > 18 MJ/kg and chlorine content < 0.5%), mainly used in cement plants in France: It is estimated that cement manufacturers could consume 1 million tonnes by 2025, compared with less than 400,000 tonnes today.**
- Good quality CSR (PCI between 12 and 18 MJ chlorine < 1.5% which will be intended for dedicated CSR boilers.

In economic terms, the CSR sector must be supported by public financial aid in order to make this method of valuation more profitable. Indeed, as the chart below illustrates, the production cost of CSR remains well above the landfill cost (€85/t currently 5) even taking into account the increase in TGAP.

Synopsis of the route followed by different waste streams in the case of CSR and energy recovery



Source: Neci Normandie

As a result, compensation is set up to encourage boilers to use CSR in their processes, these aids, between 10 and €30/t, are necessary to achieve a competitive energy production cost.

5 Source: FNADE

From an environmental point of view, the CSR function is very interesting compared to the fossil fuels it replaces. Indeed, if CSR emits almost as much CO2 as coal and 50% more than natural gas with equal energy production, the real climate interest of CSR is that it contains a so called biogenic share of CO2.

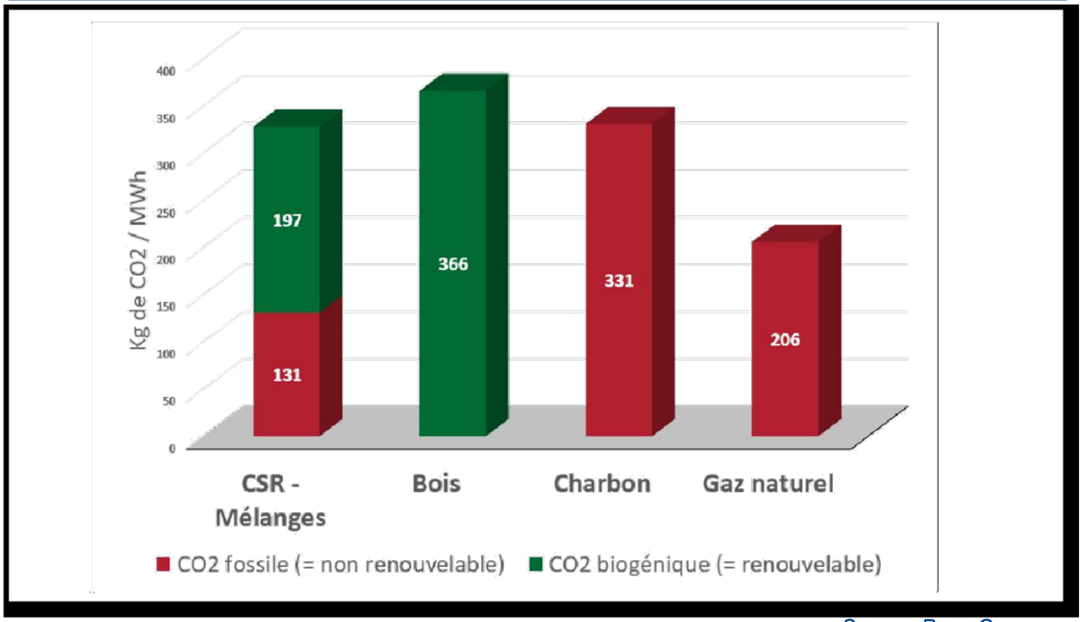
BIOGENIC CO2 FOCUS

Biogenic carbon is the carbon contained in the biomass of agricultural or forestry origin, emitted during its combustion or degradation, as well as that contained in the organic matter of the soil. Regardless of its origin, biogenic or fossil, a CO2 molecule acts in the same way on the greenhouse effect. However, unlike fossil fuels, biomass can be renewed on a human scale, with more or less long cycles (annual crops, forests).

Thus, the biogenic part of the GHG emitted by the combustion of CSR was absorbed by the materials recovered throughout their lifetime.

Pena Groupe (revenue of 80 million euros in 2021) is specialised in the sorting waste recovery sector and a pioneer in CSR recovery. A study by PENA Groupe reveals that the average share of biogenic CO2 contained in CSR is 65% and that this rate allows for a much lower fossil CO2 emission (non renewable) than for coal and natural gas:

Comparison of direct CO2 emissions by fuel



Source: Pena Groupe

CSR emits 60% less CO2 fossil equivalent than coal and 36% less than natural gas.

CONCLUSION

CONCLUSION

This study highlighted the environmental impact of waste and the economic limits of our current production methods that are still largely based on a ‘linear’ approach to resource use.

However, waste poses a problem for our current societies both in terms of the volume generated (production that has been growing steadily and has increased sharply since the pre industrial era) and in terms of pollution caused (pollution of air, water impacting biodiversity as a whole).

Thus, in line with the international climate objectives set, the waste component is therefore one of the pillars on which action is urgently needed and the circular economy, through waste recovery, a real opportunity.

To respond to this urgency, solutions exist and are already in place, other more innovative, are still at the stage of industrialization and development and are promising avenues in this fight against time.

With regard to the various non financial obligations of companies and green investment guidelines, the world of finance is experiencing a turning point and investing in these sectors of the future would accelerate their development.
In this way, finance could play a leading role in the ongoing ecological transition of our societies.

LEXICON

LEXICON

GREY ENERGY

Grey energy is the sum of the energies needed for an object's life cycle. It is long, it starts from the extraction of the raw material that allows the manufacture. Grey energy includes all those spent and consumed to create the product, pack it, transport it to distribution sites, store it, distribute it, sell it, use it, maintain it, and then recycle it when it is at the end of its life.

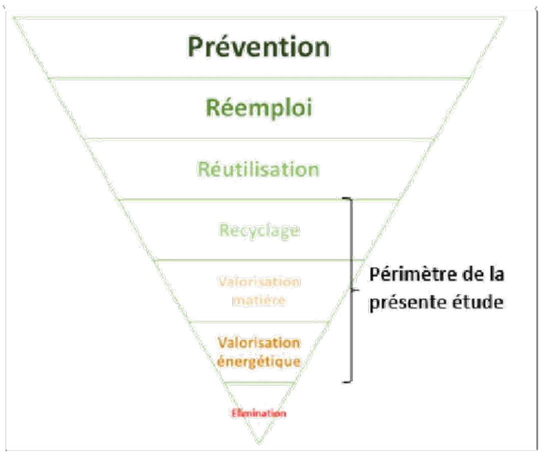
GASIFICATION

Gasification (or pyrogasification) of waste consists of heating it at temperatures generally between 900 and 1,200, in the presence of a small amount of oxygen (which can be brought by air, air enriched with O2, pure dioxygen (O2), carbon dioxide [CO2] or water vapour). Apart from the mineral fraction of the waste and a small amount of unconverted fixed carbon that constitutes the solid residue, the entire waste is thus converted into a gas called synthetic gas (also referred to as syngas or syngas). When the gasification reaction is carried out at atmospheric pressure, the synthetic gas is generally composed mainly of CO and H2 and a few percent of CH4. According to the processes, it also contains a greater or lesser proportion of carbon dioxide (CO2) and nitrogen (N2).

PRIORITISATION OF WASTE TREATMENT METHODS

Illustration of the hierarchy of waste recovery methods as introduced by the 2008 European Framework Directive on Waste and included in the French Environment Code:

Prioritisation of waste treatment methods and scope of this study



Source: BL Evolution

INCINERATION

Incineration is a mode of oxidation that uses oxygen as an oxidising agent. It is a waste treatment method based on the combustion of waste and the treatment of effluents. Effluents are potentially harmful fumes (heavy metals, dioxins and furans, dust, CO, HCI, HF, SO2, NO, NO2, etc.) that should be treated before they are released into the atmosphere; their treatment leads to the production of solid waste (smoke purification residues). Other solid effluents are made up of masterpieces (which can be recovered from building materials, for example). The heat produced can be recovered directly in the form of heat and/or can be used to generate electricity (cogeneration is used).

PYROLYSIS

Pyrolysis and gasification applied to waste are means of converting it into liquid and combustible gas, which opens up a very wide range of possibilities for their efficient recovery. Pyrolysis of waste is to heat it to temperatures generally between 350 and 650, in the absence of oxygen (or in the presence of a very small amount of oxygen or air, intended to bring, by very partial combustion, the energy necessary for the pyrolysis process). This results in the production of a combustible gas, a liquid (oil or mixture of hydrocarbons), and a by product (often referred to as 'coke' or 'char' or 'biochar' if the waste is biomass) that contains the mineral fraction of the incoming waste, as well as 'fixed carbon,' ie the carbon present in the waste that has not been transformed into gas or liquid.

RECYCLING

Recycling is defined as 'any waste recovery operation, including organic waste, restated for substances, materials or products for their initial function or for other purposes' (Article L. 541-1-1 of the French Environment Code)

REUSE

Operation that allows goods that are not waste to be used again without changing their initial use.

REUSE

Operation that allows a waste to be used again by possibly diverting its initial use.

ENERGY RECOVERY

Energy recovery allows, in accordance with the waste management hierarchy, to use waste that could not be recycled or recovered in material form as a renewable energy source. The processes implemented are either total oxidation processes (combustion, incineration or wet oxidation - definitions in the Lexic), or processes for decomposition and/or thermochemical transformation (pyrolysis or gasification), imposing different methods of recovery/recovery of the calorific energy released, or processes for recovery of Solid Fuels for Recovery (CSR).

MATERIAL VALUATION

Material recovery of waste includes all recovery operations other than those that produce energy (energy recovery). There are two main material valuation transactions within the scope under review: Recycling and material recovery of waste from the construction sector.

MATERIAL RECOVERY OF WASTE FROM THE CONSTRUCTION SECTOR

Applied to waste from the construction sector, material recovery consists of recovering waste for use in backfilling quarries or underlayer roads. Unlike recycling, recovered waste does not include a complex industrial process. The circular logic of these recovery methods is also part of the fact that these operations are generally carried out in situ or close to the site of origin of the waste (short circuits). On the other hand, in the case of serious concrete in particular, these operations can be assimilated to decycling (or downcycling in English) since the waste is 'transformed' into material of lower value: Concrete that has very interesting technical characteristics is therefore only used to 'fill holes.'

REP PMCB

ELARGIE responsibility of Producers for Building Products and Materials. Extended producer responsibility (REP) channels are specific systems for organising waste prevention and management, which concern certain types of products. The EPR of building products and materials is above all a 'Waste' subject before being a 'Building' subject, and thus appeals to professionals of end of life management of products (eco organizations, collectors and recyclers of waste).

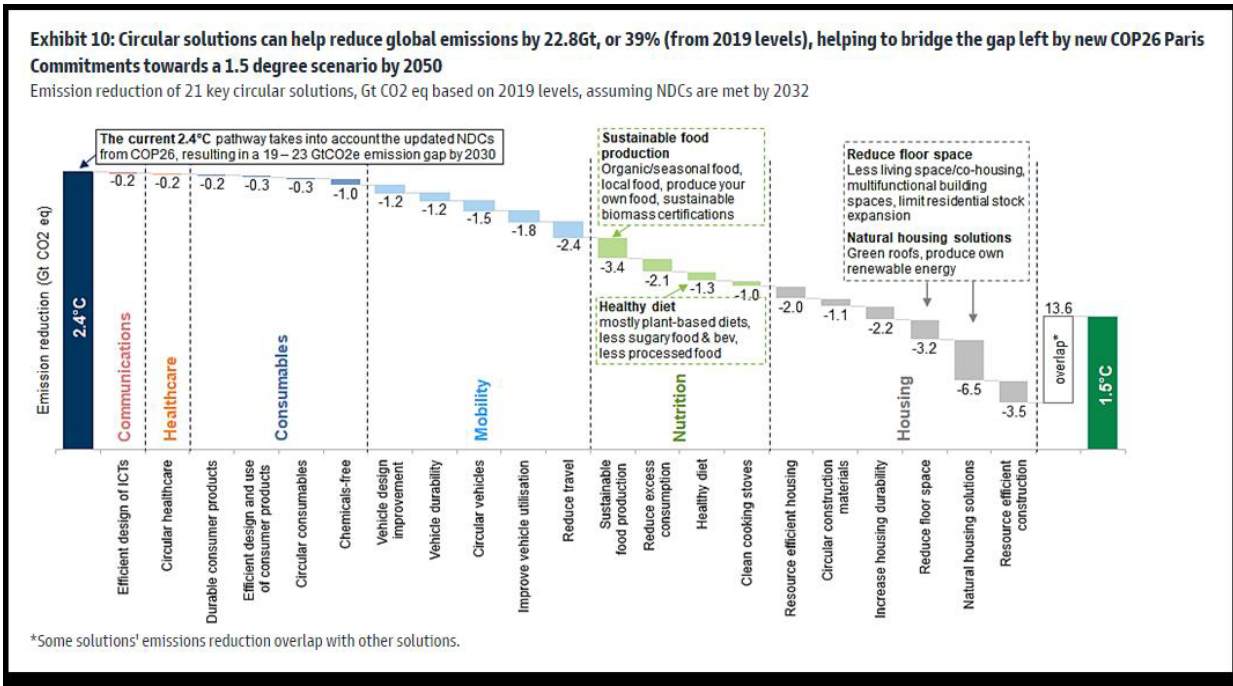
ANNEXES

APPENDICES

CIRCULAR ECONOMY CONTRIBUTION TO GHG REDUCTION

A study conducted by Goldman Sachs focused on quantifying the contribution of the circular economy to the reduction of greenhouse gases in alignment with the objectives of the Paris Agreement:

Forecast to reduce global greenhouse gas emissions through the circular economy

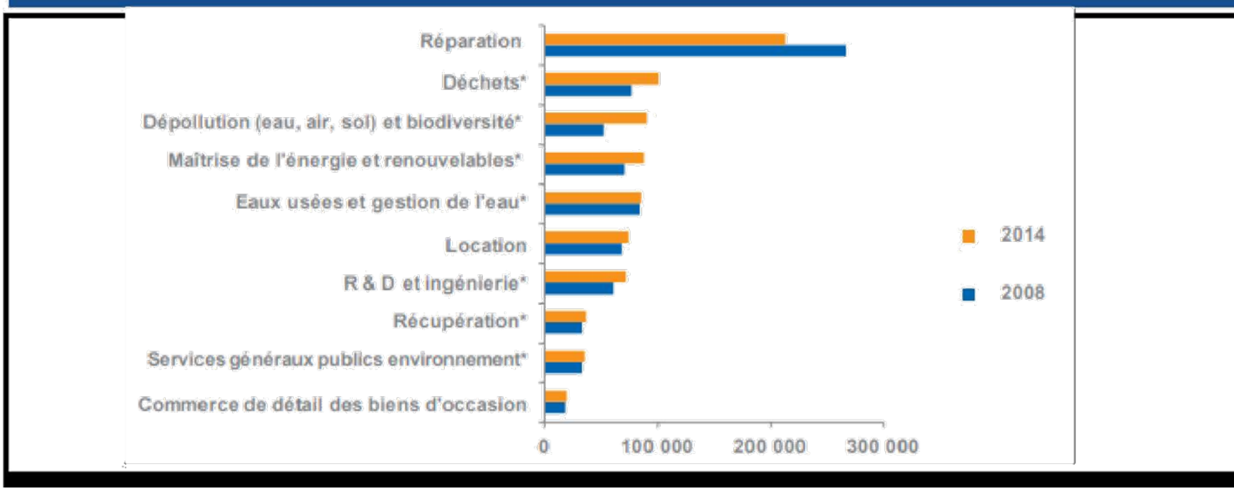


Source: Goldman Sachs

EMPLOYMENT TRENDS IN THE CIRCULAR ECONOMY APPLIED TO DIFFERENT SECTORS

In a study, France Stratégie quantified employment trends in the circular economy by detailing by business sector, highlighting employment growth in the circular economy:

Employment in the circular economy, in thousands of full time equivalent, 2008-2014



Source: France Strategy 49

COMPANIES CONCERNED BY THE REPORTING OBLIGATION NON FINANCIAL COMPANIES

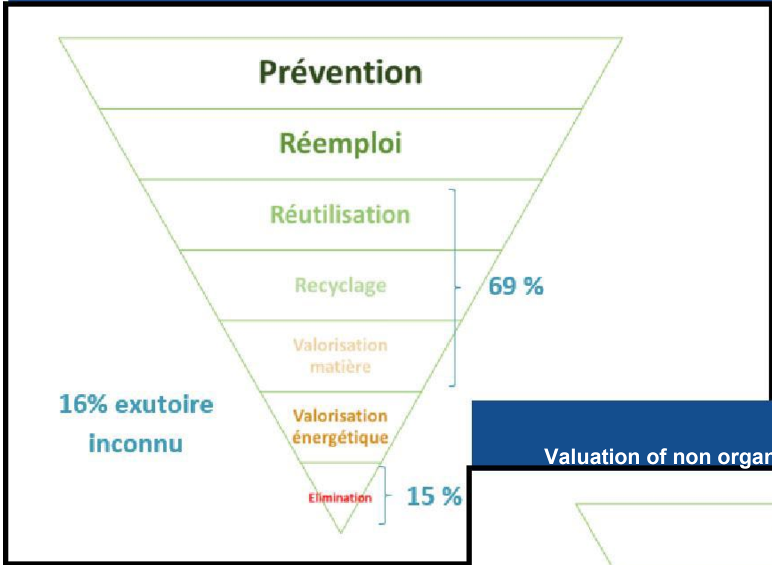
In accordance with Article R. 225-104 and R. 22-10-29 of the French Commercial Code, a non financial performance statement must be prepared by a company when its balance sheet total or turnover and number of employees exceed the following thresholds:

- For any listed company: 20 million euros for the total balance sheet or 40 million euros for the net amount of revenue and 500 for the average number of employees during the year.
- For any unlisted company: 100 million euros for total assets or net sales and 500 for the average number of employees.

The number of companies affected by these reporting obligations would be around 3800.

CURRENT RECOVERY OF THE VARIOUS WASTE STREAMS WITH THE PRIORITISATION OF PROCESSING METHODS

Recovery of BTP waste by type of treatment

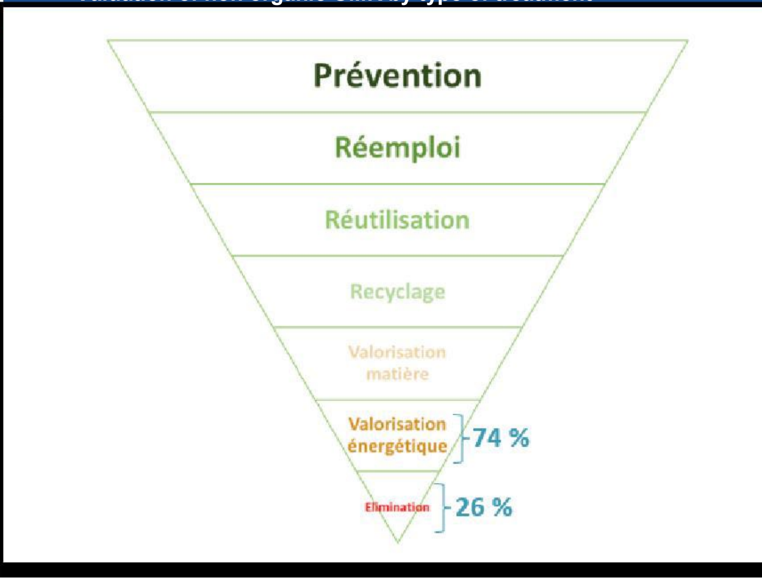


Source

The recycling of waste produced by the construction business in 2014 carried out by the

Ministry of Ecological Transition. BL evolution chart

Valuation of non organic OMR by type of treatment



Source

The recycling of waste produced by the construction business in 2014 carried out by the

Crédit Mutuel Asset Management