



EUROPEAN SUPPLIERS OF WASTE-TO-ENERGY TECHNOLOGY

ESWET Response to the European Commission Consultation on the Advanced Materials Act

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ESWET – the European Suppliers of Waste-to-Energy Technology represents companies that have built and supplied over 95% of the Waste-to-Energy (WtE) plants in operation in Europe. It seeks to promote the technologies which recover both energy and materials from non-recyclable waste that would otherwise end up in landfills.

ESWET welcomes the opportunity to contribute to the European Commission's consultation on **Advanced Materials**, which plays a key role in strengthening the EU's industrial competitiveness, strategic autonomy and sustainability objectives. Ensuring secure access to materials, improving circularity and reducing reliance on primary resources are central to the success of advanced material value chains.

In this context, the recovery of **metals and mineral fractions from incineration residues** represents an important contribution to Europe's material base. Metals recovered from bottom ash provide secondary sources of critical and strategic raw materials, which can be reintroduced into industrial processes and used as feedstock for the production of high-performance and advanced materials. At the same time, processed mineral fractions can substitute primary raw materials in construction and other applications, reducing environmental impacts and supporting resource efficiency.

WtE contributes to the circular economy by managing residual waste that cannot be prevented, reused or recycled. By safely treating these unavoidable fractions, WtE enables the recovery of materials and energy that would otherwise be lost, while preventing environmental and health risks associated with improper waste management.

Through the recovery and supply of secondary raw materials and mineral resources, WtE technologies can **support the development and scaling-up of advanced materials**, complementing recycling and contributing to resilient, circular and low-carbon industrial value chains in Europe.

This contribution outlines ESWET's perspective on the consultation and highlights how material recovery from WtE can support the objectives of the EU's advanced materials agenda, while remaining fully aligned with the waste hierarchy and Europe's broader circular economy goals.

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1. Waste-to-Energy in the circular economy

WtE facilities play a fundamental and irreplaceable role in the EU’s waste management system by providing an environmentally sound solution for residual waste that cannot be recycled, such as certain plastics, multi-material packaging, or residual biomass that has no viable recycling pathway.

Beyond their environmental function, WtE plants are also powerful contributors to Europe’s energy and resource resilience. The heat generated during treatment can be supplied to district heating and cooling networks, displacing fossil fuels and providing affordable, stable energy for households, hospitals, and industries. The electricity produced supports the European grid, helping to strengthen energy security at a time when diversification of supply is more important than ever.

In 2019, in Europe, WtE generated 43 billion kWh of electricity and 99 billion kWh of heat, which provided 20 million citizens with electricity and 17 million citizens with heat¹. Since the waste treated in WtE plants is mixed, with a majority of biogenic (biomass) content, over 50% of the energy produced is considered renewable². According to the IPCC guidelines³, biogenic CO₂ is considered carbon neutral and is therefore excluded from greenhouse gas (GHG) accounting.

¹ Confederation of European Waste-to-Energy Plants (CEWEP) (2022). *Waste-to-energy Climate Roadmap: The path to carbon negative*. At: <https://www.cewep.eu/wp-content/uploads/2022/06/CEWEP-WtE-Climate-Roadmap-2022.pdf>

² Giouse, F., Ravache, E. & Moutte, L. (2020). *Determination of the biogenic and fossil content of residual household waste and of an SRF, based on a ¹⁴C analysis of CO₂ from post-combustion gases*. ADEME – Cabinet Merlin – ENVEA. UIOM 14C Program – Measurement campaign on municipal solid waste incineration plants (UIOM) and SRF boiler. [in French]

³ Intergovernmental Panel on Climate Change (IPCC) (2006). *Guidelines for National Greenhouse Gas Inventories*. Geneva: IPCC. <https://www.ipcc-nggip.iges.or.jp/public/2006gl/>

In addition to that, WtE facilities also play a crucial role in material recovery. Through advanced treatment processes, valuable secondary raw materials (SRMs), metals such as aluminium, copper, zinc, and minerals can be extracted from incineration bottom ash and fly ash. These recovered materials reduce Europe’s dependence on imports and support the development of a more resilient industrial base.



Figure 1. *The role of Waste-to-Energy (WtE) in the circular economy, supporting pollution prevention, waste management, material recovery, and energy recovery to close resource loops. Source: ESWET.*

The climate contribution of WtE extends far beyond energy and material recovery. By diverting residual waste from landfills, WtE prevents the release of methane, a greenhouse gas over 80 times more potent than CO₂ over a 20-year period. Methane leakage from landfills remains one of the most underestimated and persistent sources of emissions in the waste sector. In contrast, WtE ensures that organic waste is safely oxidised and stabilised, avoiding long-term methane generation while recovering usable energy and materials. This landfill diversion effect alone makes WtE one of the most effective near-term mitigation levers in the waste chain.

Furthermore, modern WtE facilities act as advanced pollution prevention systems. Operating under the EU Industrial Emissions Directive (IED) and Best Available Techniques (BAT) standards, they safely destroy pathogens and hazardous organic compounds, including per- and polyfluoroalkyl substances (PFAS) and other persistent pollutants, while controlling acid gases, particulates, and heavy metals through sophisticated flue gas treatment. In doing so, WtE ensures that non-

recyclable, contaminated, or sanitary waste streams are managed in a way that protects both the environment and public health.

In addition, integrating carbon capture and storage (CCS) technologies with WtE plants offers a major opportunity to move the sector from carbon neutral to carbon negative, as approximately 60% of WtE emissions are biogenic. When this fraction is captured and permanently stored, WtE provides measurable and durable carbon removals (Bioenergy with CCS, BECCS) that can help the EU achieve its 2040 and 2050 climate targets.

Lastly, integrating carbon capture and utilisation (CCU) in WtE plants enables the sector to reach a new level of resource recovery through carbon circularity, by supplying captured CO₂ for reuse in industrial applications.

This role in the circular economy was already acknowledged by the European Commission in 2017 in a Communication⁴ and by the European Economic and Social Committee (EESC) in its Opinion⁵ in 2024. In the latter, the EESC recognises the untapped potential of WtE in advancing a more resource-efficient economy. It specifically notes that “both incinerator bottom ash and fly ash - residues from incineration - hold potential as sources of SRMs. It is essential to incentivise the recovery of metals, minerals, aggregates, potassium, sodium and calcium in salt form at EU level via appropriate legislation and by removing regulatory barriers [...]”. The EESC also recommends including WtE in the EU Taxonomy Delegated Acts, a proposal ESWET strongly supports, as it would provide long-overdue recognition of the sector’s environmental and economic value.

It is also worth noting that in July 2025, in the draft Implementing Regulation⁶ under Article 26 of the Critical Raw Materials Act (CRMA), **the European Commission explicitly recognised IBA from waste incineration as a waste stream with a high Critical Raw Material (CRM) recovery potential.**

The United Nations Economic Commission for Europe (UNECE) recognised WtE’s contributions in a 2022 report, describing WtE as “the most sustainable solution for non-recyclable waste as it recovers energy and materials while providing an alternative to highly polluting landfills and waste exports”⁷. Therefore, WtE is

⁴ European Commission. (2017). *The role of waste-to-energy in the circular economy*. COM(2017) 34 final. At: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017DC0034&from=en>

⁵ European Economic and Social Committee (EESC). (2024). *From waste plants to resource plants*. Opinion CCMI/228-EESC-2024. At: <https://www.eesc.europa.eu/en/our-work/opinions-information-reports/opinions/waste-plants-resource-plants>

⁶ European Commission. (2025). *Commission Implementing Regulation (EU) .../... listing the products, components and waste streams considered as having a relevant critical raw materials recovery potential under Regulation (EU) 2024/1252 (INTCOM Ares(2025)5155732)*. EUR-Lex. At: [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=intcom:Ares\(2025\)5155732](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=intcom:Ares(2025)5155732)

⁷ United Nations Economic Commission for Europe (UNECE) (2022). *Guidelines on Public-Private Partnerships for the Sustainable Development Goals in Waste-to-Energy Projects for Non-Recyclable*

regarded as a vital link in a comprehensive, circular, and climate-aligned waste management chain.

Despite this strong performance, the full contribution of WtE remains often overlooked in EU climate policy - even though its role spans landfill diversion, pollution prevention, renewable and local energy generation, material recovery, and an increasing potential for carbon capture. Taken together, these pillars make WtE one of Europe's most comprehensive tools for achieving both circularity and climate neutrality.

2. Unlocking WtE's potential to supply metals and minerals for the production of advanced materials

2.1. IBA as a source of materials

Advanced materials are engineered to have specific and tailored properties, such as mechanical properties, thermal stability, electrical conductivity, corrosion resistance, etc. They are increasingly recognised by the European Commission as a cornerstone of Europe's green and digital transitions, supporting industrial competitiveness, resource efficiency and climate objectives. In this context, WtE can play a key role by enabling the recovery of valuable materials from non-recyclable waste streams, transforming residues into secondary resources rather than losses.

Through advanced treatment processes, IBA enables both mineral and metal recovery, positioning WtE as a contributor to Europe's advanced materials agenda, circular economy goals and strategic autonomy in raw materials.

IBA is composed of 80 to 85% of minerals, 10 to 12% of ferrous metals (iron, steel), and 2 to 5% of non-ferrous metals (such as aluminium, copper, zinc, lead, silver, gold, and others) (Figures 2 and 3). In addition, Table 1 below exhibits the distribution of various elements in IBA from various incinerators for municipal solid waste (MSW) compared to the concentrations found in the lithosphere. As indicated, many of the minor and trace elements are significantly enriched in the IBA compared to the average composition of the lithosphere.

Waste: Pathways towards a Circular Economy. At: https://unece.org/sites/default/files/2022/10/ECE_CECI_WP_PPP_2022_03-en.pdf

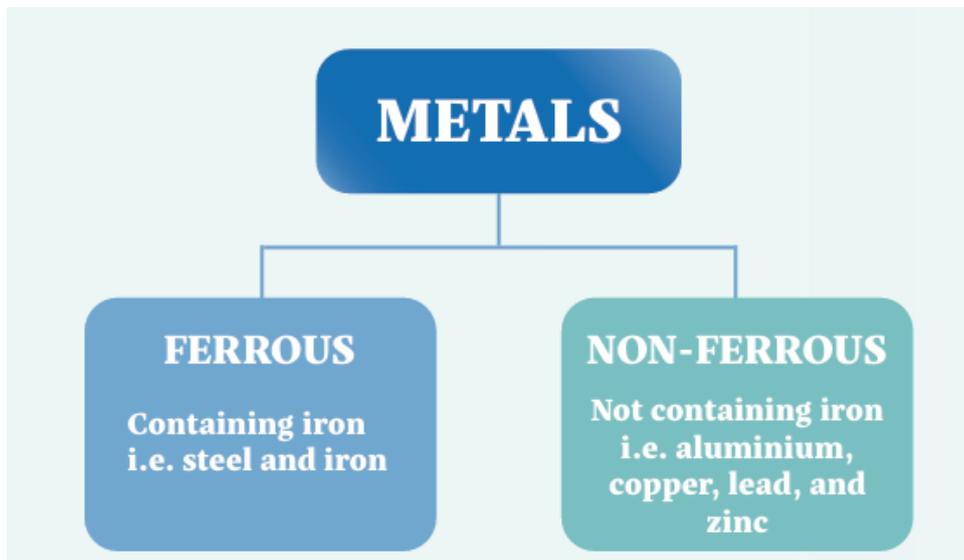
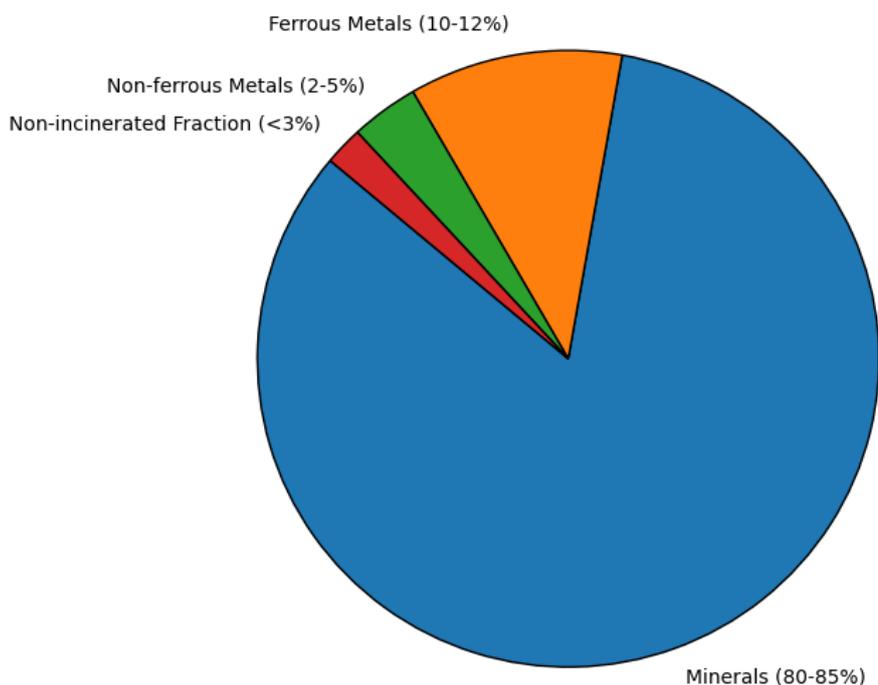


Figure 2. Classification of metals into ferrous and non-ferrous. Source: ESWET⁸.



⁸ ESWET (2023). *Integrated Resources Recovery Facility*. At: <https://eswet.eu/documents/recovering-the-non-recyclable-the-integrated-resource-recovery-facility/>.

Figure 3. Composition of raw IBA. Source: ESWET based on data from Neuwahl et al. (2019)⁹.

Table 1. Composition of MSW IBA (in mg/kg) and the lithosphere based on total analysis. Source: Hjelmar et al. (2011)¹⁰.

Element	MSW IBA		Lithosphere
	Min	Max	
Si	91,000	310,000	276,000
Ca	60,000	120,000	36,000
Fe	4,100	150,000	51,000
Al	22,000	73,000	81,000
Na	2,900	42,000	28,000
K	800	16,000	26,000
C	10,000	60,000	950
Mg	400	26,000	21,000
S	1,000	5,000	600
Ti	2,600	9,500	6,000
Cu	190	8,200	70
Zn	610	7,800	80
Cl	800	4,200	500
Pb	98	14,000	16
Ba	400	3,000	430
Mn	83	2,400	900
Ag	0.3	37	0.007
As	0.12	190	5
B	38	510	10
Br	1.4	150	2.5
Cd	0.3	71	0.2
Co	6	350	40
Cr	23	3,200	200
Cs	1	2	3.2
Fe	200	1,100	625
Hg	0.02	7.8	0.1
I	2	10	0.3
Mo	2.5	280	2.3
Ni	7	4,300	100
Sb	10	430	-

⁹ ESWET (2023). same source as above; Neuwahl, F., Cusano, G., Benavides, J. G., Holbrook, S. & Roudier, S. (2019). Best Available Techniques (BAT) Reference Document for Waste Incineration. Seville: Joint Research Center.

¹⁰ Hjelmar, O., Johnson, A. & Comans, R. (2011). Incineration : Solid Residues. In Th. H. Christensen (ed.), Solid Waste Technology & Management (pp. 430-462). Hoboken, NJ : John Wiley & Sons.

Se	0.05	10	0.09
Sn	2	380	40
Sr	85	1,000	150
V	20	120	150

2.2. Metals

Currently, IBA is increasingly viewed as a significant source of metals, as it **contains significant quantities of both CRM (e.g., aluminum and copper) and non-CRM yet strategic metals, which can be recovered through advanced treatment processes**. CRMs are essential for Europe's green and digital transition, powering technologies including electric vehicles, batteries, renewable energy systems, high-voltage cables, semiconductors, and data infrastructure. As several CRMs are imported from geopolitically unstable regions, strengthening domestic sources has become a strategic priority under the EU CRMA. WtE contributes directly to this objective: this makes IBA one of Europe's most accessible and underexploited secondary CRM sources. In recognition of this opportunity, as previously written, in July 2025, the Commission explicitly recognised IBA from waste incineration as a waste stream with a **high CRM recovery potential** in its draft Implementing Regulation under Article 26 of the CRMA.

It must be noted that materials such as aluminium alloys, copper alloys, steel alloys, and others can be applied as advanced materials that are specifically engineered to offer enhanced properties compared to pure metals or traditional materials. These alloys are of vital importance in various high-performance applications where their specific characteristics like strength, lightweight, corrosion resistance, and heat tolerance are crucial. For example, aluminium alloys are widely used in the aerospace sector due to their lightweight and strength properties, while nickel alloys are ideal for applications that require high temperature resistance (e.g., turbine blades, jet engines and heat exchangers in industries). By using these materials, industries are able to meet increasingly demanding requirements in fields like aerospace, automotive, electronics, energy systems and construction, sectors that are regarded as vital for the European economy.

Moreover, IBA can contain **rare earth elements**, which, due to their distinctive optical and magnetic characteristics, are essential for a variety of advanced technologies, such as electronics, hybrid and electric vehicles, wind turbines, photovoltaics, as well as defense applications like missile guidance systems and satellites. As mining activities are almost inevitably associated with serious environmental pollution and corresponding human health risks and social

resistance, recovering rare earths from alternative sources, such as IBA, has attracted the interest of the scientific literature¹¹.

While there are metals recovered from IBA not classified as CRM, such as gold and silver, they are still essential in achieving the energy and digital transition. Precious metals including the ones just mentioned and strategic materials such as copper and nickel are key elements in the manufacturing of batteries - valuable for the energy storage of renewable energy, solar power and thermal panels, or wind turbine blades. While their concentration in IBA is smaller than the more conventional metals, they can also be recovered from WtE in state-of-the-art treatment plants.

IBA represents a consistent and highly enriched secondary source of precious metals, with concentrations several orders of magnitude higher than natural ores. In addition, their recovery requires far less energy and environmental impact compared with conventional mining and refining.

The study by Chuchro et al. (2025)¹² found average contents of 6,973 ppb silver, 314 ppb gold, 41 ppb palladium, and 14 ppb platinum, corresponding to 930, 7,800, 27, and 275 times their average levels in the Earth's crust. Notably, silver concentrations exceed those reported in the benchmark Swiss Hinwil plant (5,300 ppb) and are comparable to high-performing Italian facilities, confirming Europe-wide recoverability potential. The results demonstrate that these metals occur without seasonal or trend variability, ensuring **stable recovery yields throughout the year**, while 14–20% of samples showed outlier concentrations, pointing to particularly rich fractions that could significantly increase profitability when targeted with advanced separation methods. Figure 4 highlights this steady occurrence and the presence of numerous high-value outliers, demonstrating the consistency and profitability potential of IBA-based recovery.

¹¹ Wen, Y., Hu, L., Boxleiter, A., et al. (2023). Rare Earth Elements Recovery and Waste Management of Municipal Solid Waste Incineration Ash. *ACS Sustainable Resource Management*, 1(1), 17-27.

¹² Chuchro, M., Jędrusiak, R., & Bielowicz, B. (2025). Statistical analyses of precious metal contents in waste incineration bottom ashes. *Scientific Reports*, 15, 8149. At: <https://doi.org/10.1038/s41598-025-91855-7>

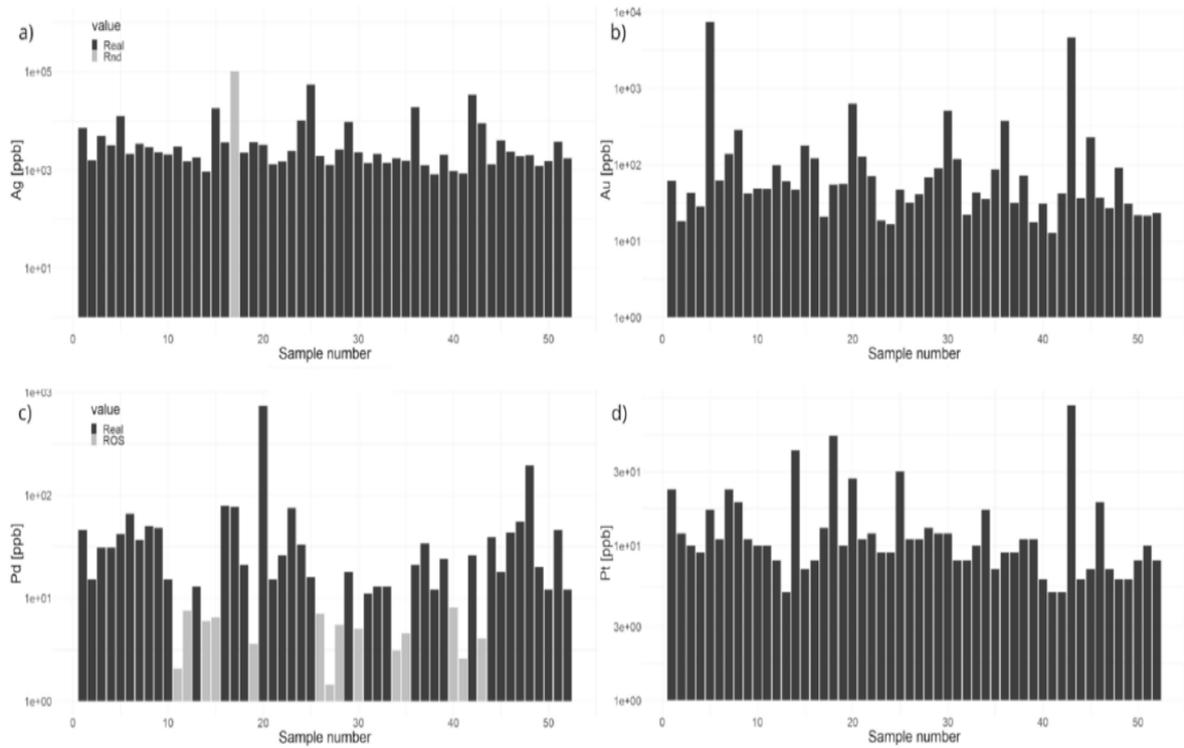


Figure 4. Concentrations of precious metals (Ag, Au, Pd, Pt) in weekly IBA samples from the Krakow Thermal Waste Treatment Plant, showing stable recoverability and numerous high-value outliers. Source: Chuchro et al., 2025.

Although the standalone Internal Rate of Return (IRR) for precious metals recovery was calculated at 4.4 %, comprehensive recovery of both precious and non-ferrous metals - as already implemented in several European facilities - **can raise returns well above 20%, underlining IBA’s strategic importance in securing Europe’s access to critical and high-value raw materials**, as illustrated in Figure 5.

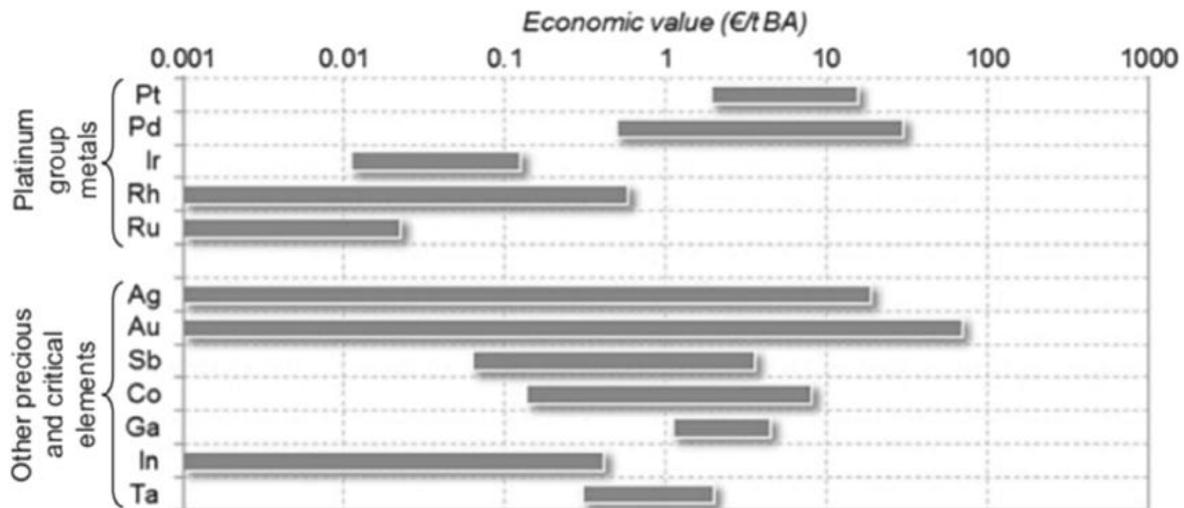


Figure 5. Estimated total economic value of precious metals (Ag, Au, Pd, Pt) contained in IBA, illustrating the financial and material potential of Waste-to-Energy residues as a secondary raw materials source. Source: Adapted from Chuchro et al. (2025), based on Astrup et al. (2016)¹³.

With approximately 500 WtE facilities operating in Europe, producing more than **20 million tonnes of IBA annually**¹⁴, the metal recovery potential is significant, but only **one-third of the non-ferrous metals it contains are currently recycled**¹⁵. Advanced technologies, such as dry extraction systems, could enable the recovery of up to **0.7 million tonnes of aluminium - equivalent to 11% of EU imports**¹⁶. **In 2021, the market potential of fully recovered metals from IBA was estimated at €2 billion**¹⁷, while **reducing the extraction of virgin materials and avoiding up to 14.5 million tonnes of CO₂ emissions**¹⁸. Redirecting just 300,000 tonnes of aluminium, copper, zinc, and lead currently lost

¹³ Astrup, T., Rosenblad, C., & Sloop, H. A. van der. (2016). Treatment and reuse of incineration bottom ash. In R. D. Billings & E. E. Park (Eds.), *Environmental materials and waste: Resource recovery and pollution prevention* (pp. 607–645). Elsevier. At: <https://doi.org/10.1016/B978-0-12-803837-6.00024-X>

¹⁴ TU Delft. (n.d.). *Incinerator bottom ash recycling* [Research & Innovation, Recycling Technologies]. At: <https://www.tudelft.nl/en/ceg/about-faculty/departments/engineering-structures/sections-labs/resources-recycling/research-innovation/recycling-technologies/incinerator-bottom-ash-recycling/>

¹⁵ ESWET. (2023). *Integrated Resources Recovery Facility*. At: <https://eswet.eu/documents/recovering-the-non-recyclable-the-integrated-resource-recovery-facility/>.

¹⁶ ESWET. (2023). *Integrated Resources Recovery Facility*. At: <https://eswet.eu/documents/recovering-the-non-recyclable-the-integrated-resource-recovery-facility/>. For reference, a tonne of aluminium is worth about 2,209 € (February 2023).

¹⁷ Blasenbauer, D., Huber, F., Lederer, J., et al. (2020). Legal situation and current practices of waste incineration bottom ash utilisation in Europe. *Waste Management*, 102, 868-883. At: <https://hal.science/hal-02472497>.

¹⁸ From internal calculations based on figures from Geschäftsbericht der ZAV Recycling AG (2020).

to landfilling or downcycling¹⁹ into true recycling could significantly improve the EU's raw material resilience and contribute to circular economy goals.

It should also be mentioned that, while IBA treatment has historically been organised through centralised facilities in order to secure sufficient volumes and achieve economic viability, recent technological developments have broadened the range of possible treatment configurations. Depending on local conditions, these may include centralised, regional, or plant-adjacent solutions, where such options are justified from a case-by-case techno-economic perspective. This flexibility can, in certain contexts, simplify the integration of material recovery into existing WtE infrastructure, without implying a one-size-fits-all approach.

Moreover, based on internal industry analysis, the addition of IBA treatment capacity, where deemed appropriate, is estimated to represent less than approximately 5% of the total investment cost of a WtE plant, making it a relatively limited incremental cost. However, the actual environmental and economic benefits depend strongly on the chosen processing concept, local market conditions, logistics, and regulatory frameworks.

In any case, the utilisation of IBA still varies widely across Member States reflecting differences in regulatory requirements, availability of primary raw materials, and public acceptance. Nevertheless, the recovery of metals from IBA represents not only an economic opportunity but also a climate and resource-efficiency imperative. **As decarbonisation pressures intensify, Europe cannot afford to overlook domestic sources of secondary raw materials that can strengthen the circular economy, particularly where these materials can contribute to the production of advanced and strategic applications.**

2.3. Minerals

The mineral fraction remaining after metal recovery can be used in various applications, connected to the production of advanced materials, each at different stages of development and acceptance by authorities and the public. These applications offer varying potentials for managing the bulk of IBA, with differing costs and environmental impacts²⁰.

The mineral fraction of IBA contains a variety of components such as silica (SiO_2), alumina (Al_2O_3), lime (CaO), magnesia (MgO) and other oxides, which are key constituents in the **production of glass and glass-ceramics**. When processed,

¹⁹ TU Delft. (n.d.). *Incinerator bottom ash recycling* [Research & Innovation, Recycling Technologies]. At: <https://www.tudelft.nl/en/ceg/about-faculty/departments/engineering-structures/sections-labs/resources-recycling/research-innovation/recycling-technologies/incinerator-bottom-ash-recycling/>

²⁰ Syc, M., Simon, F. G., Hykš, J., et al. (2020). Metal recovery from incineration bottom ash: State-of-the-art and recent developments. *Journal of Hazardous Materials*, 393, 122433.

these minerals can be combined with other materials (such as sodium carbonate or boron compounds) to produce glass, which can then be crystallised into glass-ceramics under controlled heating. Glass-ceramics produced from IBA may potentially exhibit desirable thermal stability, high mechanical strength, and wear resistance, which are essential for applications in electrical components, and engineered materials. Certain glass-ceramics, like bioactive glass-ceramics, may be used in medical applications, such as bone implants. Studies have demonstrated the technical feasibility of producing glass-ceramics from IBA, confirming that usable glass phases can be derived from its mineral fraction, but, however, these remain largely experimental and not widely implemented commercially²¹. Therefore, this potential remains largely unexploited. Careful sorting and processing of the mineral fraction would be needed to ensure uniformity and consistency in the final product, while extensive testing and compliance with safety standards would be necessary before widespread commercial use.

Moreover, minerals from IBA can substitute primary aggregates in construction²² applications such as road foundations²³, concrete products, and engineered fill. Using these secondary minerals reduces pressure on virgin extraction, lowers lifecycle emissions, and supports circular construction. Despite these clear environmental and economic benefits, the utilisation of the mineral fraction of IBA is not yet classified as “recycling”²⁴ at EU level, even though its performance and utility are well demonstrated across many Member States. The recovery of materials from IBA, therefore, represents a major yet largely untapped opportunity to strengthen Europe’s domestic raw-material supply. Encouragingly, positive examples already exist: in the Netherlands, a national “Green Deal on Bottom Ash”²⁵ has been in place since 2020, where all operators committed - through a public-private partnership - to full mineral recovery, demonstrating both feasibility and high added value.

²¹ Monteiro, R. C. C., Figueiredo, C. F., Alendouro, M. S., et al. (2008). Characterization of MSWI bottom ashes towards utilization as glass raw material. *Waste Management*, 28(7), 1119-1125.

²² Blasenbauer, D., Huber, F., Lederer, J., et al. (2020). Legal situation and current practices of waste incineration bottom ash utilisation in Europe. *Waste Management*, 102, 868-883. At: <https://hal.science/hal-02472497>

²³ In Denmark, for instance, after the recovery of recyclable metals, almost 99% of the bottom ash is used for construction: See *Factsheet from the Danish Ministry of Environment*. At: <https://cirkulaer.dk/files/media/document/MSWI%20Bottom%20ash%20in%20Denmark%20-%20In%20English.pdf?>

²⁴ EC Implementing Decisions 2019/1004, WFD, metals separated and recycled after incineration are considered as recycled.

²⁵ Born, J.-P. (nd). *Dutch Green Deal Bottom Ash (IBA) – Status 2016*. Dutch Waste Management Association (DWMA). At: <https://ygoforum.fi/wp-content/uploads/2019/11/Born Bottom Ash GreenDeal.pdf>

The construction sector has been identified as one of the priority areas in the Commission's 2024 Communication on Advanced Materials²⁶, which highlights the growing need for materials that improve energy efficiency, structural performance, circularity and environmental outcomes. It is important to note that one category that relates to the characterisation of materials as "advanced" for construction applications in the above Communication is **circularity** ("Materials to improve circularity and address environmental performance"). In general, according to the Communication, "the inherent qualities of advanced materials make it indeed possible for them to drive innovation characterized by the principles of: **Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Renew and Recover**". Mineral fraction recovered from IBA directly responds to these objectives, offering a secondary construction material with proven technical performance and significantly lower environmental impacts compared to primary raw materials.

To illustrate this, Figure 6 below compares the environmental performance of conventional raw materials with that of minerals and metals recovered from IBA, based on Life Cycle Assessment (LCA) results from TU Delft. The results clearly show that the recovery and reuse of materials from IBA significantly reduce environmental impacts across all impact categories, including global warming, human toxicity, ecotoxicity, acidification, eutrophication, and resource depletion. The conventional scenario (in red) consistently exhibits the highest environmental impact levels, while all three recovery scenarios show substantial environmental gains. Among these, the cement scenario demonstrates the greatest overall environmental benefit, achieving reductions of up to around 60-90% compared to the baseline. These results confirm that integrating SRMs from (treated) IBA into industrial processes (such as metal recovery, concrete production, and cement manufacturing) can deliver systemic reductions in life-cycle impacts, supporting both resource efficiency and climate objectives. The environmental benefits arise mainly from the avoidance of primary raw material extraction, reduced energy consumption, and lower greenhouse gas emissions associated with virgin production.

²⁶ European Commission (2024), Advanced Materials for Industrial Leadership. At: [Advanced Materials for Industrial Leadership - Research and innovation](#)

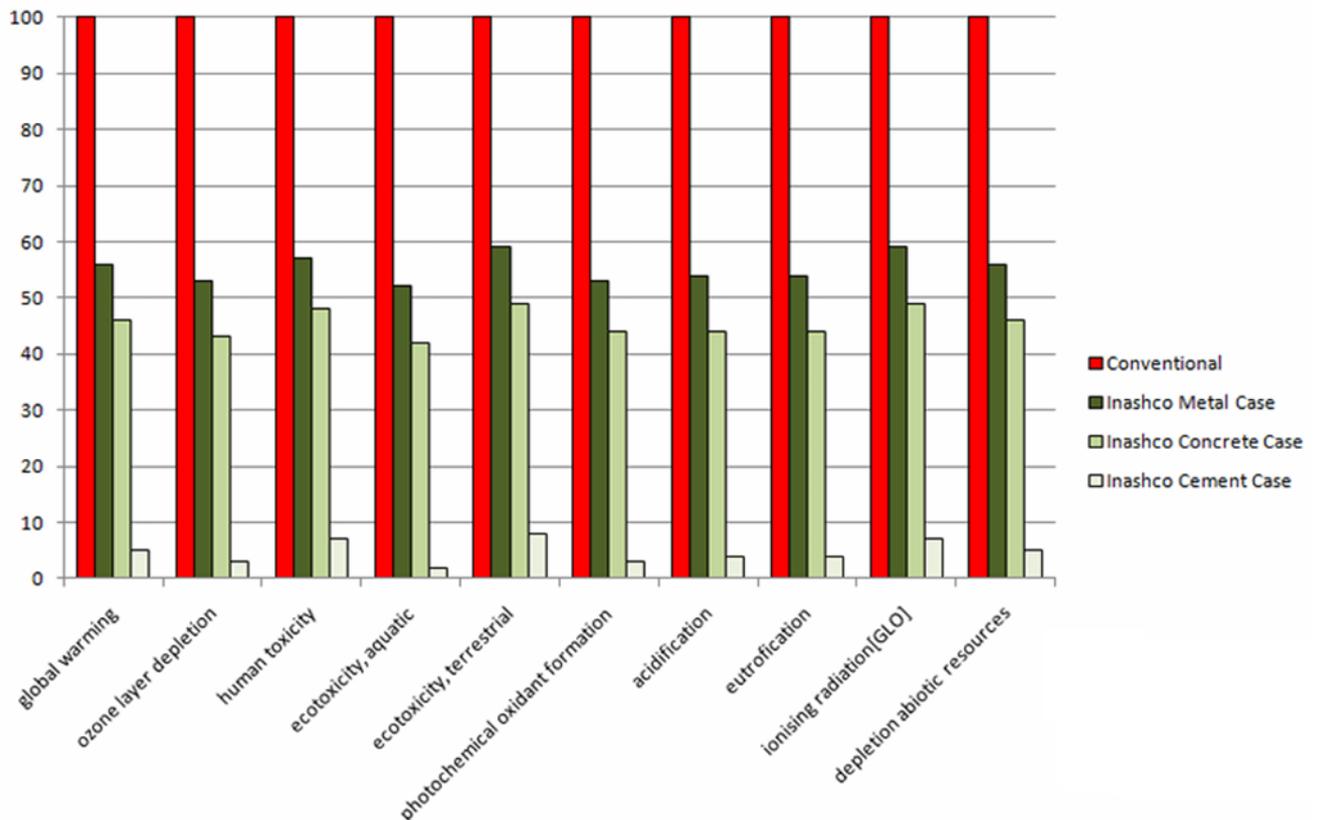


Figure 6. Environmental benefits of substituting conventional raw materials with minerals and metals recovered from IBA in metal, concrete, and cement applications. Source: TU Delft²⁷.

While the technical feasibility and environmental benefits of recovering minerals from IBA are increasingly well documented, their large-scale deployment ultimately depends on market acceptance and regulatory certainty. As with other construction materials, the transition from pilot applications to widespread use requires well-defined performance criteria, harmonised standards and recognised certification schemes to build confidence among authorities, industry and end users.

In this respect, one of the main obstacles remains the lack of clear end-of-waste (EoW) criteria. Fragmented national approaches create legal uncertainty, administrative complexity and reduced trust in secondary materials, particularly when they are traded across borders. This also hampers economies of scale, discourages investment in recovery technologies and leads to inefficiencies in the

²⁷ TU Delft. (2013). *Recycling of Incinerator Bottom Ash: A study on the recycling potential of incinerator bottom ash in the Netherlands*. At: <https://filelist.tudelft.nl/CiTG/Over%20faculteit/Afdelingen/Engineering%20Structures/Resources%20%26%20Recycling/Incinerator%20Bottom%20Ash/recyclingiba1.pdf>

functioning of the Single Market. These challenges are particularly acute for materials derived from incineration residues which can substitute primary construction aggregates but whose treatment and valorisation still vary widely across Member States in the absence of clear (EU-level) EoW criteria.

Addressing these barriers requires the same enabling conditions identified by the Commission for advanced materials more broadly. In particular, clear standards, robust testing and certification frameworks, together with targeted public procurement, are essential to build trust and support market uptake. ESWET fully agrees with this approach and considers it directly applicable to the use of IBA-derived minerals in construction, where robust regulatory frameworks and procurement signals can accelerate deployment and market acceptance.

2.4. Fly ash

Aside from IBA, essential materials can also be recovered from another residue of combustion: fly ash. Fly ash is classified as hazardous in the majority of EU countries and represent a smaller amount compared to IBA, but several state-of-the-art treatment plants are able to recover materials from it such as heavy metals. Thanks to advanced acidic washing technologies, facilities in Denmark, Sweden, and Switzerland can recover zinc, lead, copper and cadmium.²⁸

As explored in ESWET's *Integrated Resource Recovery Facility* report²⁹, beyond metal recovery, fly ash can also be valorised as a secondary construction material. Accelerated Carbonation Technology (ACT), for example, combines captured CO₂ with thermal residues, including fly ash, to produce carbon-negative aggregates for the construction sector. As previously mentioned, an end-of-waste status has already been granted to such aggregates in the UK³⁰, enabling its use as a marketable construction product.

The above recovery processes are not yet commonly applied in the European WtE sector. Their wider deployment would depend on the development of stable markets for secondary raw materials, supported by clear regulatory frameworks and demand from downstream users. As a result, despite these promising developments, material recovery from fly ash remains limited across the EU.

Both IBA and fly ash illustrate the **untapped potential of secondary raw materials recovered from WtE residues**, provided that appropriate regulatory and market conditions are in place. Harnessing this potential will be indispensable

²⁸ See for instance, the SwissZinc project at <https://swisszinc.ch/index.html>.

²⁹ ESWET. (2023). *Integrated Resources Recovery Facility*. At: <https://eswet.eu/documents/recovering-the-non-recyclable-the-integrated-resource-recovery-facility/>.

³⁰ Gunning P., Hills C.D. and Carey P.J. (2013), Commercial application of accelerated carbonation: Looking back at the first year, ACEME.

for achieving the objectives of the EU Green Deal, the Clean Industrial Deal, the CRMA and the Advanced Materials agenda.

In this context, the Commission has indicated that funding instruments such as the Innovation Fund may support activities related to the recycling and re-use of critical materials for clean-technology value chains, with the current call allocating €4 billion for net-zero technologies³¹. **IBA and fly ash treatment and recovery technologies should therefore be explicitly taken into account within these funding frameworks.**

A coherent EU policy framework should recognise and support the recovery of minerals and metals from both IBA and fly ash as an integral component of Europe's advanced materials and circular-economy strategy, enabling scale-up, investment and cross-border deployment of these solutions.

3. Calculating the environmental, climate, and strategic benefits of material recovery from Waste-to-Energy

Across the EU, moving residual waste up the hierarchy from landfilling to recycling and WtE has already driven more than a 40% cut in waste-sector emissions since 1990. The climate value of WtE comes from three integrated effects: landfill diversion that avoids methane emissions, fossil energy substitution via reliable baseload electricity and heat, and material recovery from IBA.

According to CEWEP³², the diversion of non-recyclable waste from landfills to WtE results in **avoiding the emission of more than 600 kg of CO₂ per tonne of waste treated** in a 100-year time perspective. In other words, WtE plants prevent the formation of landfill gas by treating the organic methane-producing compounds in MSW, therefore decreasing their net emissions. Additionally, the energy recovered by WtE plants can displace energy from fossil fuel sources, **helping abate GHG emissions, at an estimated 360 kg of CO_{2eq} per tonne of waste treated**, while for **material recovery, the abated emissions are 60 kg CO₂ equivalent** per tonne of waste treated. Overall, WtE plants generate emissions of about 400-450 kg of fossil CO₂ per tonne processed by delivering a public service of general interest and providing a treatment option for residual waste, but above all, **WtE plants help prevent CO₂ emissions with avoided emissions amounting to more than 1000 kg CO₂ per tonne of waste treated.**

³¹ European Commission (2023), Commission opens €4 billion call for proposals for net-zero technologies under the Innovation Fund. At: [€4 billion call for proposals for net-zero technologies](#)

³² Confederation of European Waste-to-Energy Plants (CEWEP) (2022). *Waste-to-Energy Climate Roadmap Technical Annex (TA) main assumptions & methodology.*, Düsseldorf: CEWEP.

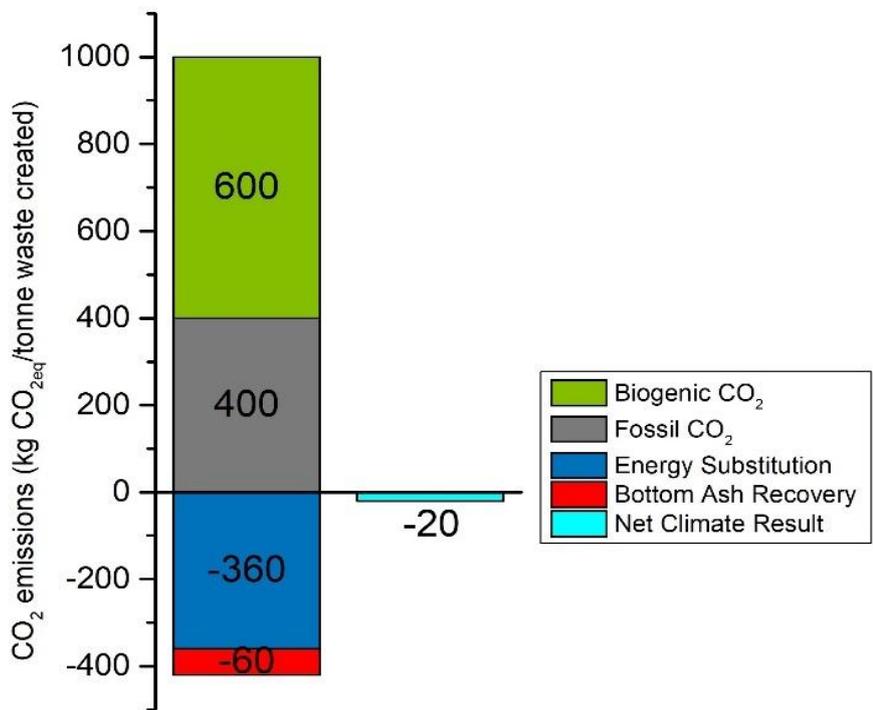


Figure 7. Net climate effect of treating one tonne of residual waste via Waste-to-Energy (WtE). Data source: CEWEP Climate Roadmap, 2022. Graphic source: ESWET.

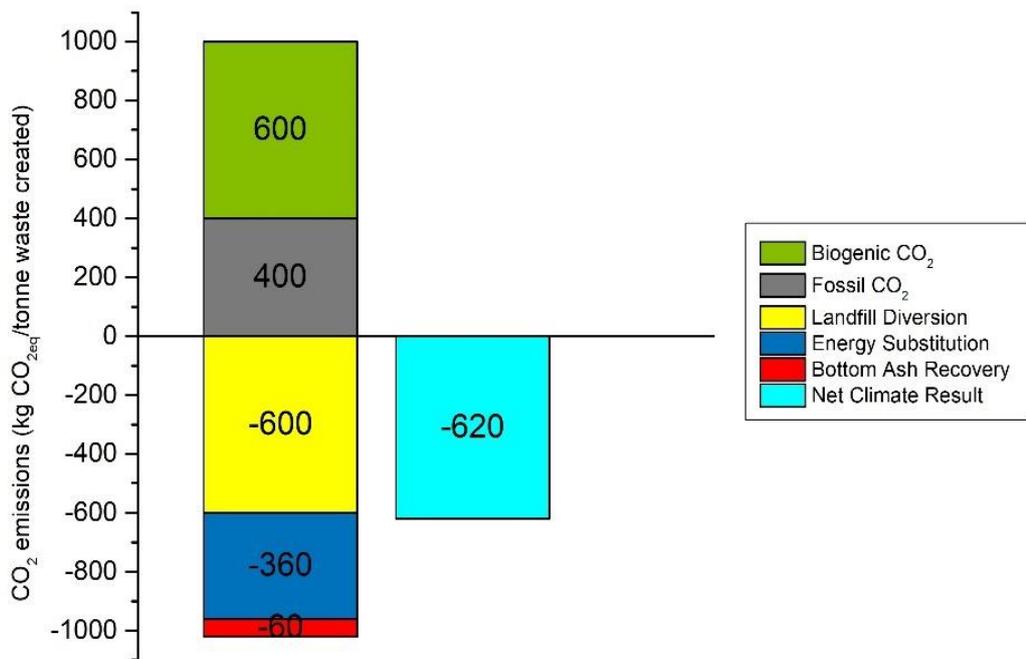
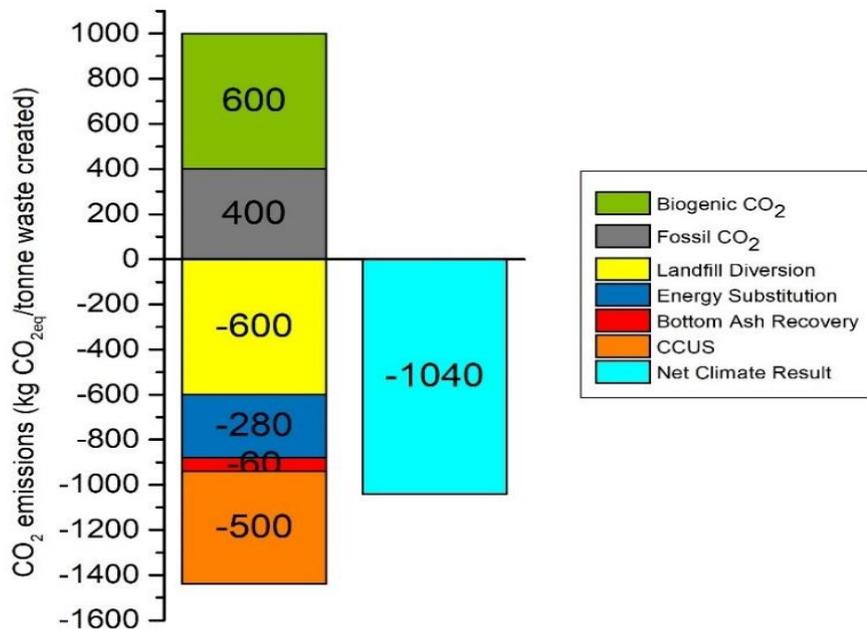


Figure 8. Net climate effect of treating one tonne of residual waste via WtE,



taking into consideration also landfill diversion. Data source: CEWEP Climate Roadmap, 2022. Graphic source: ESWET.

Figure 9. Net climate effect of treating one tonne of residual waste via WtE, taking into consideration also landfill diversion and CCUS. Data source: CEWEP Climate Roadmap, 2022. Graphic source: ESWET.

The three graphs above show the net climate effect of treating one tonne of residual waste via WtE, highlighting the contributions from emissions and avoided impacts:

1. **Graph 1 (Figure 7) (Baseline – electricity-only WtE):** When only electricity is recovered, WtE delivers a marginal **climate benefit of 20 kg CO₂eq/tonne**, as fossil CO₂ emissions are only partially offset by energy substitution and bottom ash recovery.
2. **Graph 2 (Figure 8) (WtE with landfill diversion):** Diverting waste from landfills to WtE adds a **substantial climate benefit** due to avoided methane emissions, leading to a net result of **620 kg CO₂eq/tonne**.
3. **Graph 3 (Figure 9) (WtE with CCUS):** Combining landfill diversion with Carbon Capture, Utilisation and Storage (CCUS) **further enhances the climate performance**, achieving a total **benefit of 1040 kg CO₂eq/tonne**.

[Data and analysis from CEWEP Climate Roadmap, 2022].

These figures highlight the significant climate mitigation potential of WtE, which is highly relevant in the context of climate targets and broader decarbonisation efforts. The primary mission of the WtE sector is to safely treat society’s residual,

non-recyclable waste; unlike other industrial sectors, WtE cannot “switch fuels” (it should be noted that waste in general, and residual, non-recyclable waste more specifically, is not a fuel) or control the composition of its input, as it is determined by upstream consumption and product design. Despite this, WtE delivers substantial greenhouse gas reductions by diverting waste from landfills, preventing methane emissions, recovering energy that substitutes fossil fuels, and enabling material recovery from incineration bottom and fly ashes. This means that, when considering the full system benefits, the sector is already close to climate neutrality or even net negative in terms of emissions. However, these societal and environmental benefits are often **not fully captured** in standard assessments or in the design of carbon pricing mechanisms like the ETS. As a result, the unique role of WtE in supporting both climate and circular economy objectives risks being **overlooked**, potentially leading to policies that do not reflect the sector’s true contribution to decarbonisation and resource efficiency.

The Intergovernmental Panel on Climate Change (IPCC) explicitly acknowledges WtE's climate mitigation role, stating that **"When WtE technologies are equipped with proper air pollution reduction facilities, they can contribute to clean electricity production and reduction of GHG emissions"**.³³ Furthermore, The United Nations Economic Commission for Europe has defined WtE as **"the most sustainable solution for non-recyclable waste as it recovers energy and materials while providing an alternative to highly polluting landfills"**.³⁴

When evaluating the climate impact of WtE, it is important to consider the broader context: approximately 100 million tonnes of residual waste are treated annually through WtE in Europe - waste that might otherwise end up in landfills or be exported outside the EU.

With emissions savings of up to 2,000 kg CO_{2eq} per tonne of recycled metal, the recovery of metals from WtE alone could save up to 3.8 million tonnes of CO_{2eq} each year, highlighting the sector's key role in reducing emissions and bolstering Europe's material security in a time of growing geopolitical uncertainty.

Additionally, as briefly mentioned in the previous chapters, bottom ash and fly ash offers promising potential for CO₂ sequestration through natural carbonation. As the mineral fraction of the ash matures through exposure to air and rain, the lime it contains reacts with atmospheric CO₂

³³ Intergovernmental Panel on Climate Change (IPCC) (2022). *Climate Change 2022 Mitigation of Climate Change. Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 2022*. At: https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf

³⁴ United Nations Economic Commission for Europe (UNECE) (2022). Guidelines on Public-Private Partnerships for the Sustainable Development Goals in Waste-to-Energy Projects for Non-Recyclable Waste: Pathways towards a Circular Economy. At: https://unece.org/sites/default/files/2022-10/ECE_CECI_WP_PPP_2022_03-en.pdf

- permanently capturing it - to form stable calcium carbonate (CaCO₃). This process can capture around 30 to 65 kg of CO₂ per tonne of ash, contributing further to the sector's carbon mitigation potential.³⁵

The carbon sequestration potential of IBA was also recognised by the European Commission in the proposed Act³⁶ on permanent CCU, which aimed to define the conditions under which greenhouse gas emissions can be considered permanently embedded in a product.

In the UK, an "end-of-waste" status was granted for the carbon negative aggregate - made of fly ash and captured CO₂ - by the Environment Agency in 2011³⁷, meaning that it can be considered as a product at the legislative and commercial level.

Moreover, on the environmental benefits of material recovery, fly ash can also be used as an adsorbent in flue gas and wastewater treatment, either within the facility itself or externally, further enhancing the sector's circular economy profile. Fly ash also contains recoverable heavy metals such as zinc, which can substitute virgin materials in industrial processes. One promising example is a pilot-scale zinc recovery process applied to acid-washed fly ash³⁸. While various treatment methods for fly ash already exist and can be further deployed, targeted funding and policy support are essential to scale up these technologies and unlock their full potential.

Supporting the recovery of valuable materials from (treated) IBA and fly ash offers wide-ranging environmental and strategic advantages. In addition, it directly contributes to the objectives of the Landfill Directive by reducing the volume of residual waste sent to landfill and at the same time reduces reliance on primary resource extraction, thus lowering environmental degradation and aligning with EU sustainability goals.

4. Policy recommendations

WtE should be recognised as a relevant contributor to the EU's advanced materials agenda. Through the treatment of non-recyclable waste, WtE enables the recovery of both minerals and metals with demonstrated environmental, circularity and

³⁵ Costa, G., Baciocchi, R., Poletti, A., et al. (2007). Current status and perspectives of accelerated carbonation processes on municipal waste combustion residues. *Environmental Monitoring and Assessment*, 135, 55-75. At: <https://link.springer.com/article/10.1007/s10661-007-9704-4>.

³⁶ European Commission. (2023). *Emissions trading system (ETS) - permanent emissions storage through carbon capture and utilisation*. At: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14135-Emissions-trading-system-ETS-permanent-emissions-storage-through-carbon-capture-and-utilisation_en

³⁷ Gunning P., Hills C.D. and Carey P.J. (2013), Commercial application of accelerated carbonation: Looking back at the first year, ACEME.

³⁸ Karlfeldt Fedge, K. & Andersson, S. (2020). Zinc recovery from Waste-to-Energy fly ash – A pilot test study. *Waste Management*, 118, 90-98.

performance benefits. The mineral fraction of IBA can be utilised in applications like construction, offering improved environmental performance, while metals recovered from incineration residues - including CRMs, such as aluminium and copper - can feed advanced manufacturing processes, including high-performance alloys and clean technology value chains. Together, these recovery pathways support the EU's objectives on circularity, climate mitigation, industrial resilience and strategic autonomy.

To fully harness this potential, a coherent and enabling policy framework is required. In this context, ESWET calls for the following:

Policy recommendations

- 1. Explicitly recognise metals and minerals recovered from incineration residues as potential contributors to the production of advanced materials, reflecting their proven performance, circularity benefits and contribution to EU industrial and climate objectives.**
2. Harmonise and standardise the use of secondary materials from incineration residues, addressing End-of-Waste and certification schemes, lack of harmonised testing, limited industrial deployment, and slow permitting for IBA mineral treatment and reuse, in order to facilitate market uptake and cross-border use.
3. Ensure coherence across EU policy frameworks, including the Advanced Materials agenda, the Circular Economy Act, the Critical Raw Materials Act, the Clean Industrial Deal and sustainable finance tools, so that recovery pathways for minerals and metals from WtE residues are consistently recognised and supported.
4. Support research and innovation efforts focused on the use of materials recovered from incineration residues in the production of advanced materials. Encouraging collaboration between industry and research institutions will accelerate the development of innovative applications and ensure that these materials meet the high-performance standards required for cutting-edge industries.

Integrating metals and minerals recovered from IBA into the EU's advanced materials agenda would strengthen Europe's ability to deliver circular, high-performance materials while reducing reliance on primary resources. Recognising these recovery pathways would support climate and environmental objectives, enhance resource efficiency, and ensure greater coherence between advanced materials, circular economy and raw-materials policies.

ESWET – European Suppliers of Waste-to-Energy Technology

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