Policy brief

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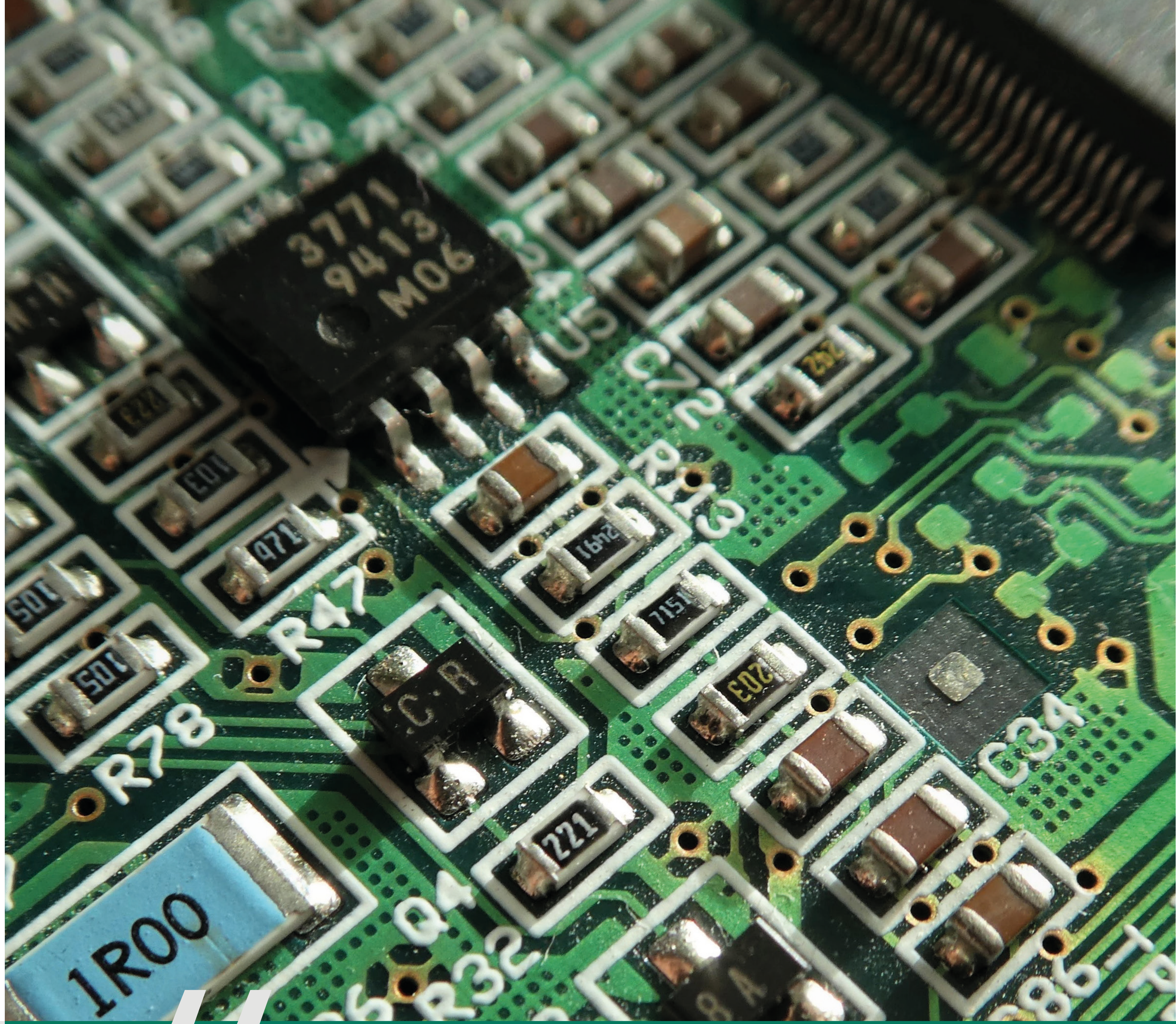

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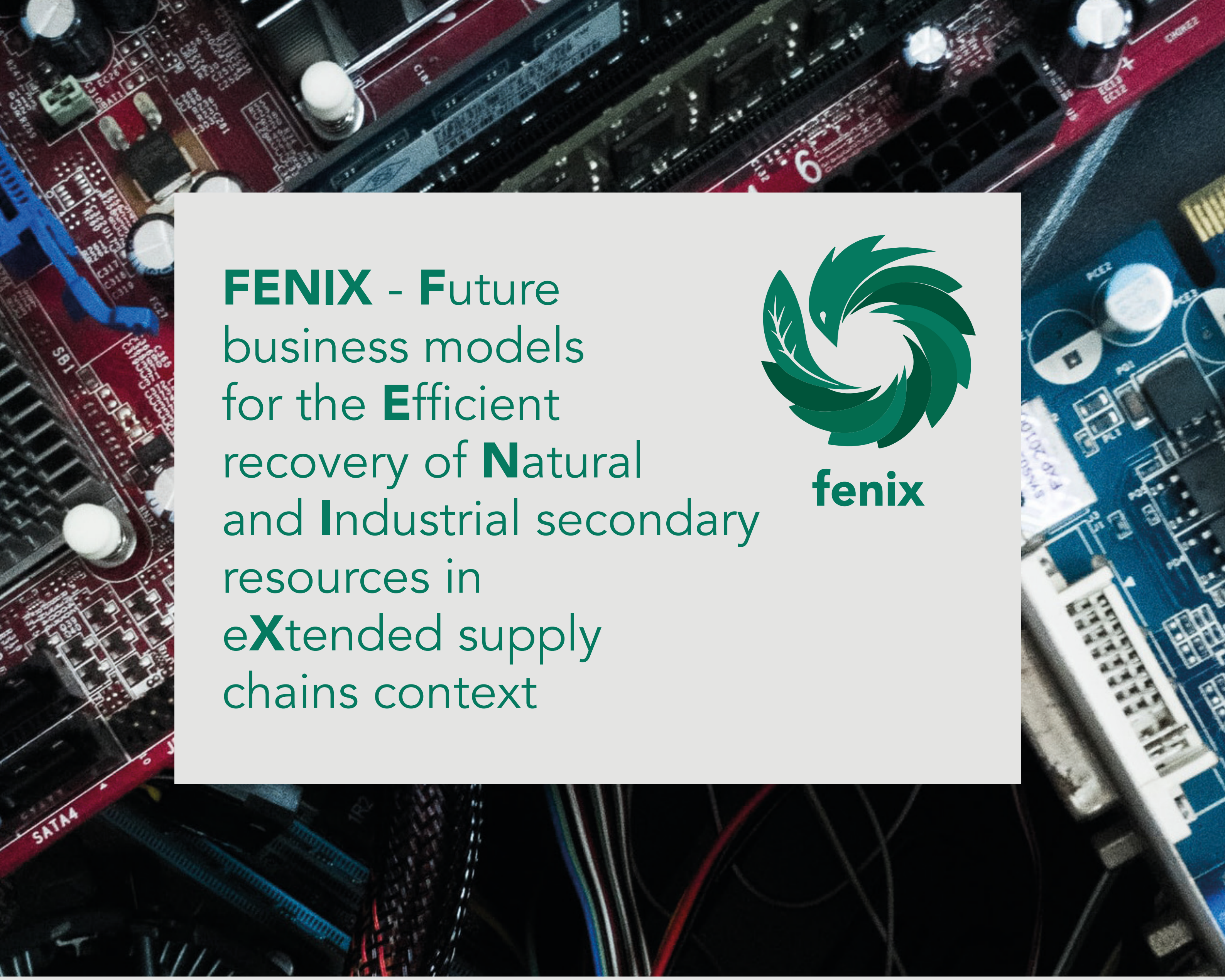
> The transition towards Circular Economy implies not only great changes in the production chain, starting from the design to the consumers' attitude.



FENIX - Future business models for the Efficient recovery of Natural and Industrial secondary resources in eXtended supply chains context

fenix

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TABLE OF CONTENTS

Introduction

The circular economy philosophy focusses on **using materials and products as efficient as possible** by introducing sharing, renting and leasing concepts, by repairing of products and by designing products so that the lifespan is longer. Even all those actions are introduced, **at a certain stage a product reaches its end of life** and becomes waste. In this afterlife stage the idea is to re-use the product as components or parts of products or to recycle the materials in a product into new products, so extraction and production of new materials can be avoided.
Also landfill and incineration of waste is eliminated in this case. **This re-use of components and recycling of materials also reduces GHG emissions**.

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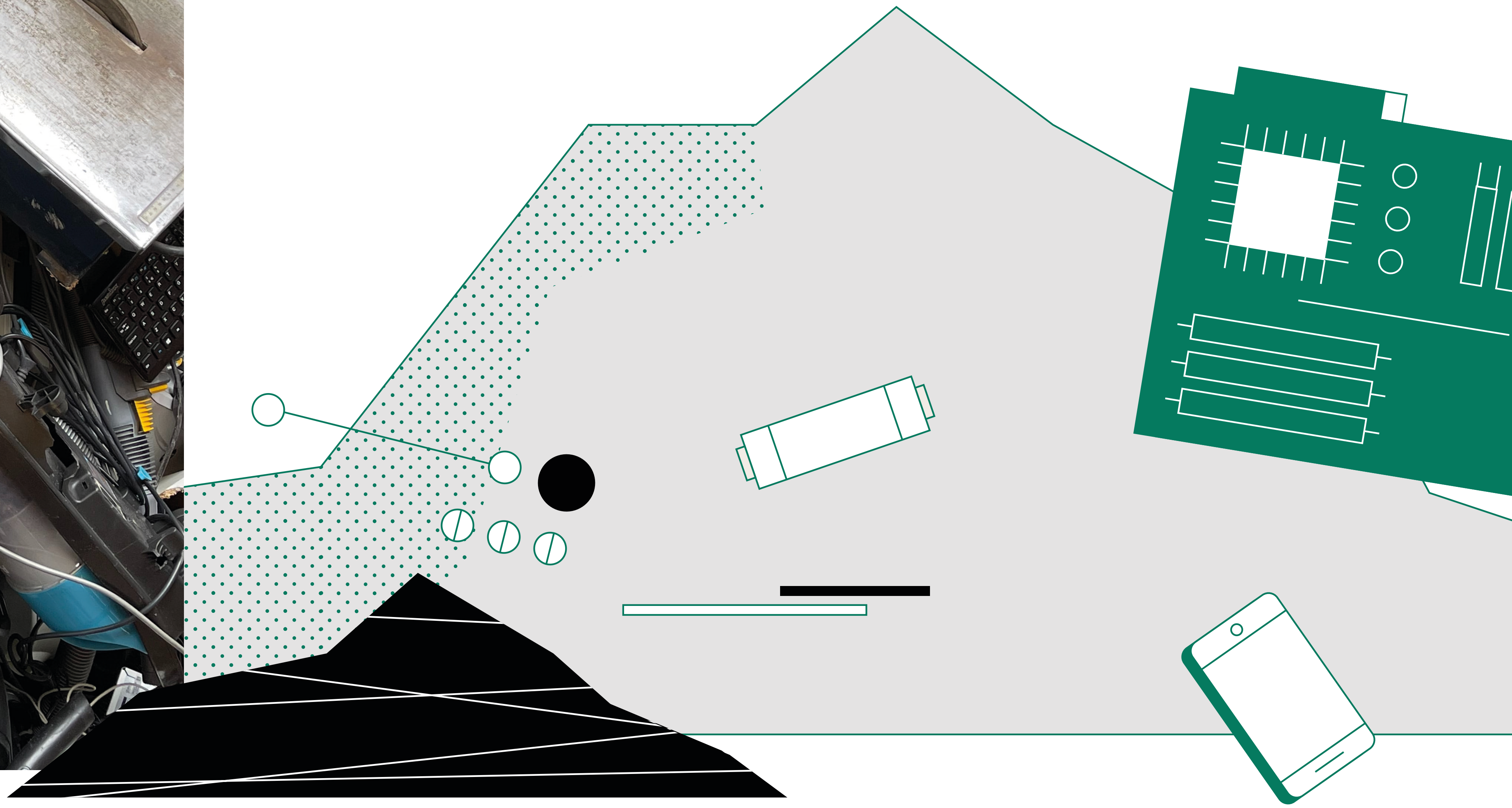
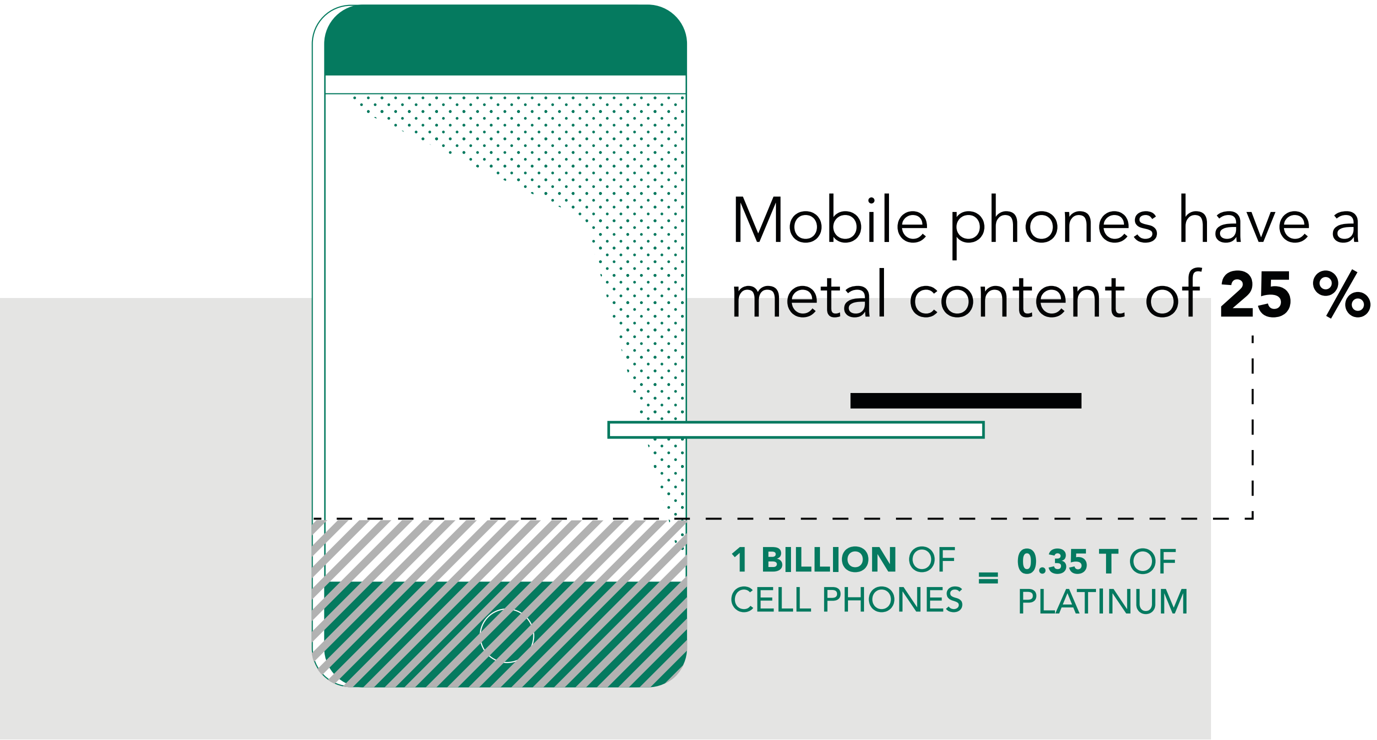
02

State of the art

2.1 GENERAL BARRIERS FOR RECYCLING AND GENERAL SOLUTIONS

The **main barriers** for more circular economy in the afterlife are **high costs** (disassembly, sorting, separation, recycling) and lower costs for alternatives (landfill, MSWI) and primary materials. Recycling rates in industry vary from almost zero for some special plastics and many critical raw materials to almost 100% for conventional metals. **Recycling policies are mainly focusing on packaging**, so packaging recycling scores also higher. Re-using of components is also rare in most industries. A general solution for this is to **make virgin more expensive and recycled materials cheaper**, reduce labour costs for disassembling (the recycle industry). Or introduce **obligations** (law) which asks for a certain percentage **of secondary material in new products**.



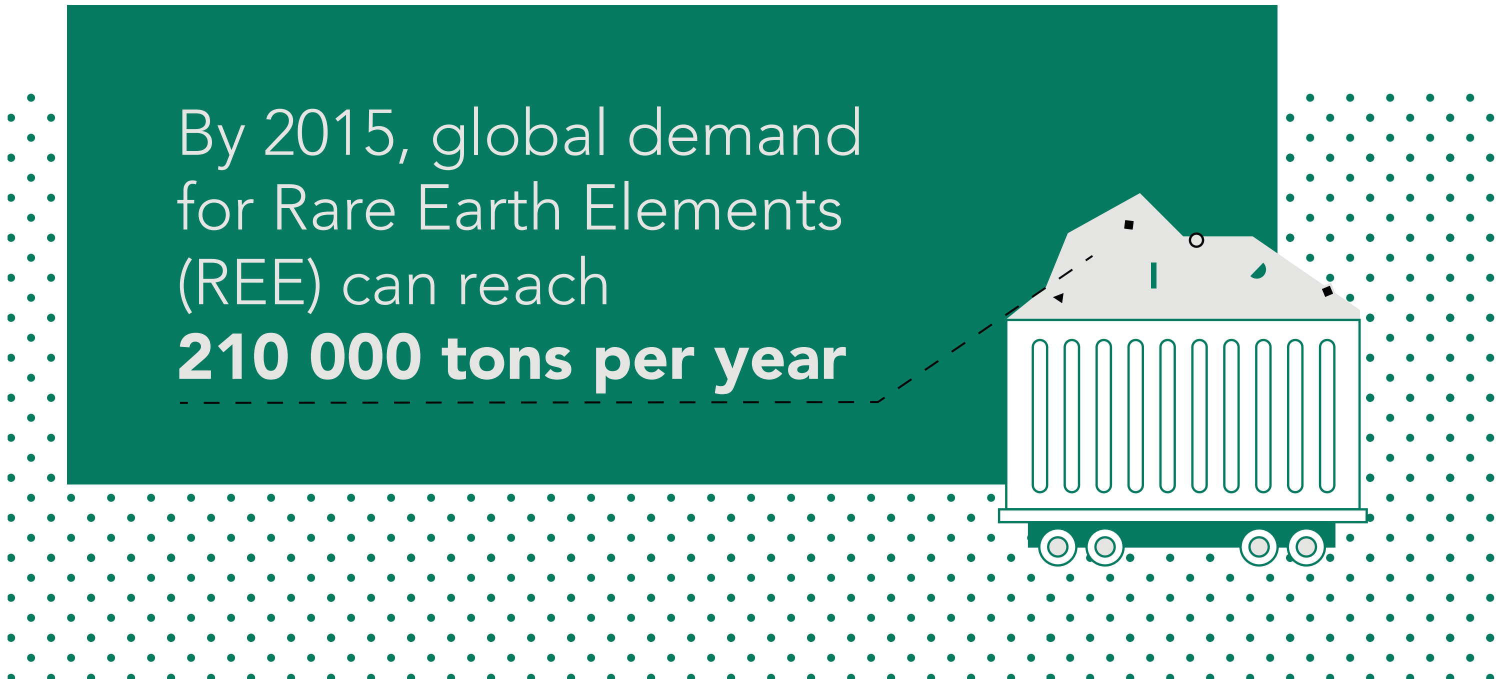


2.2 MATERIAL DIVERSITY AND STRATEGIC METALS

High-tech products (e.g. electronics, automotive, renewable energies, …) consist of a high amount of diverse metals. According to a survey of Sullivan (Sullivan, D. (2007). Recycled cell phones – A treasure trove of valuable materials. USGS) e.g. **mobile phones have a metal content of 25 %** (accumulator and recharger not included), mainly copper (Cu), iron (Fe), nickel (Ni), silver (Ag) and zinc (Zn). Though the absolute amounts of each device regarding the most valuable elements are low (16 g Cu, 0.35 g Ag, 0.0034 g Au, 0.015 g Pd, and 0.00034 g Pt) this adds up to e.g. **0.35 t of platinum based on estimated 1 billion of cell phones in 2010**.
Regardless of their low amount in specific electronic components there are some metals which are highly preferred or are even essential for the present technology. The most famous example is tantalum and niobium, which is processed from the ore coltan.
In 2010 the Raw Materials Initiative of the European Commission defined 14 critical raw materials, most of rare metals (including rare earths oxide) which are used for electr(on)ic devices belong to this category.
Most metals relevant for high-tech products are mined in only 5 – 10 (non-European) countries, some of them in conflict areas without "good governance". CRMs recycling within Europe following today's legislation guarantees minimization of the environmental impact caused by the recovery activities.

The same is not always true for the mining activities outside Europe, e.g. due to poor waste management around the mines.
The **global demand for Rare Earth Elements (REE) was estimated at 136 100 tonnes in 2010** with global production of about 133 600 tons annually. The difference was covered by reserves on the floor or inventories. By **2015, global demand for rare earth can reach 210 000 tons per year**, according to an estimate. The Industrial Minerals Company of Australia (IMCOA) estimated somewhat lower global demand by 160 000 metric tons in 2016 annual demand China is estimated to increase from about 70 000 metric tons (mt) in 2011 to 105 000 tonnes in 2016 according to IMCOA. But the Chinese Association of Rare Earth Industry estimated **demand from China amounted to 130,000 metric tons in 2015**.
The demand for rare earth elements is also expected to increase, according to the USGS. For example, it is expected that the demand for permanent magnet to grow by 10% -16% per year over the coming years. It is expected that demand for rare earths in automotive catalysts and petroleum cracking catalysts to increase between 6% and 8% annually during the same period. It is also expected to increase demand for rare earths in flat panel displays, motors of hybrid vehicles, and defense and medical applications.

The Chinese dominance may have peaked in 2010 when they controlled about **95% of the world's rare earth production** and prices for many rare earth oxides had risen over 500% in just a few years. That was an awakening for rare earth consumers and miners throughout the world. Mining companies in the United States, Australia, Canada and other countries began to re-evaluate old rare earth prospects and explore for new ones. **Mines in Australia began producing rare earth oxides in 2011**. In 2012 and 2013 they were supplying about 2% to 3% of world production. In 2012, the United States produced about 4% of the rare earth worldwide elements in 2013. **India has been producing about 3% of the world's supply** for the past decade. Indonesia, Russia, Nigeria, North Korea, Malaysia, and Vietnam are minor producers.



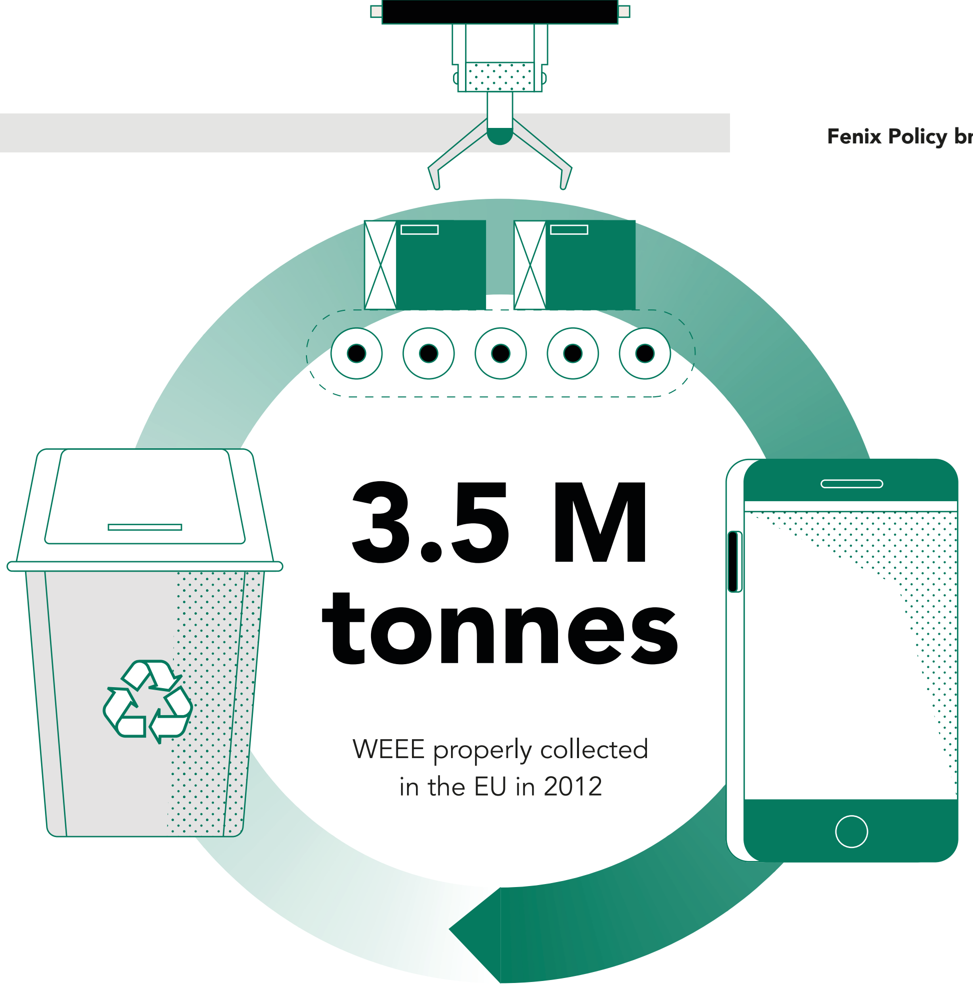
Decision of a number of countries to reduce dependence from a single source of supply led to a renewed interest in rare-earth exploration and development projects underway around the world. As of July 2012, the market analysis firm Technology Metals Research (TMR) has been monitoring over 440 rare-earth exploration projects outside of China and India, located in 37 different countries.
Chinese companies have been purchasing rare earth resources in other countries. **In 2009 China Non-Ferrous Metal Mining Company bought a majority stake in Lynas Corporation** (Australian company) that has one of the highest outputs of rare earth elements outside of China **as well as purchased the Baluba Mine in Zambia**. High prices also caused manufacturers to do three things:

1. seek ways to **reduce the amount of rare earth elements needed** to produce each of their products;
2. seek **alternative materials** to use in place of rare earth elements; and
3. develop **alternative products** that do not require rare earth elements.

This effort has resulted in a decline in the amounts of rare earth materials used in some types of magnets and a **shift from rare earth lighting products to light-emitting diode technology**.
In the United States, the average consumption of rare earths per unit of manufactured product has decreased but the demand for more products manufactured with rare earth elements has increased. The result has been higher consumption. At the same time, world demand was skyrocketing as **rare earth metals were designed into a wide variety of defense, aviation, industrial and consumer electronics products**. China capitalized on its dominant position and began restricting exports and allowing rare earth oxide prices to rise to historically high levels. The United States Geological Survey estimates that although **China** is the world-leader in rare earth production they only **control about 50% of the worldwide reserves**. This provides an opportunity for other countries to become important producers.

2.3. WASTE FROM ELECTRICAL AND ELECTRONIC EQUIPMENT

Waste of electrical and electronic equipment (WEEE) is one the fastest growing waste streams in the EU, growing at 3-5% per year, with a generation above **12 million tonnes estimated for 2020** [1,2]. **WEEE is a complex mixture of valuable materials that can cause major environmental and health problems** if not properly managed due to their hazardous content. The improvement of WEEE prevention, collection and recovery is essential to boost circular economy and enhance resource efficiency, which require new approaches in the design, manufacturing, use and End of Life (EoL) of electrical and electronic equipment (EEE).



The first WEEE Directive (2002/96/EC) provided for the creation of WEEE collection schemes with the aim to increase its recovery. **A recast WEEE Directive (2012/19/EU) entered into force in 2012**, setting out ambitious targets for collection, recovery, preparation for re-use and recycling. However, **only one-third of WEEE in the EU is being reported by compliance schemes as separately collected** and managed. The remaining two-thirds are either collected by unregistered companies and treated or even illegally exported, or disposed of as part of residual waste [3].
The total amount of WEEE properly collected in the EU was 3.5 million tonnes in 2012; **75% of this amount was recovered**, whilst the amount recycled/re-used was 70%, with re-use only representing 2%[4]. These rates were sufficient to comply with the minimum targets set by the WEEE Directive until 2015, but the targets are more ambitious today and will be even stricter as of 2018.
At present, the main driving forces for WEEE treatment are the removal of hazardous substances and the recycling of metals, since they have a high market price and have so far contributed mostly to meet the WEEE recovery/recycling targets [5]. However, other alternative and complementary solutions are still needed to **move the EEE sector towards a true circular economy**, allowing to reach the regulatory targets and helping to reduce the illegal export of WEEE and the derived impacts.

1. Huisman et al. (2008). Review of Directive 2002/96 on Waste Electrical and Electronic Equipment.
2. Fischer & Davidsen (2010). Europe as a Recycling Society: The European Recycling Map.
3. Huisman et al. (2015). Countering WEEE Illegal Trade (CWIT) Summary Report.
4. Eurostat (2015). Waste statistics - electrical and electronic equipment.
5. European Commission (2011). Plastic waste in the environment.

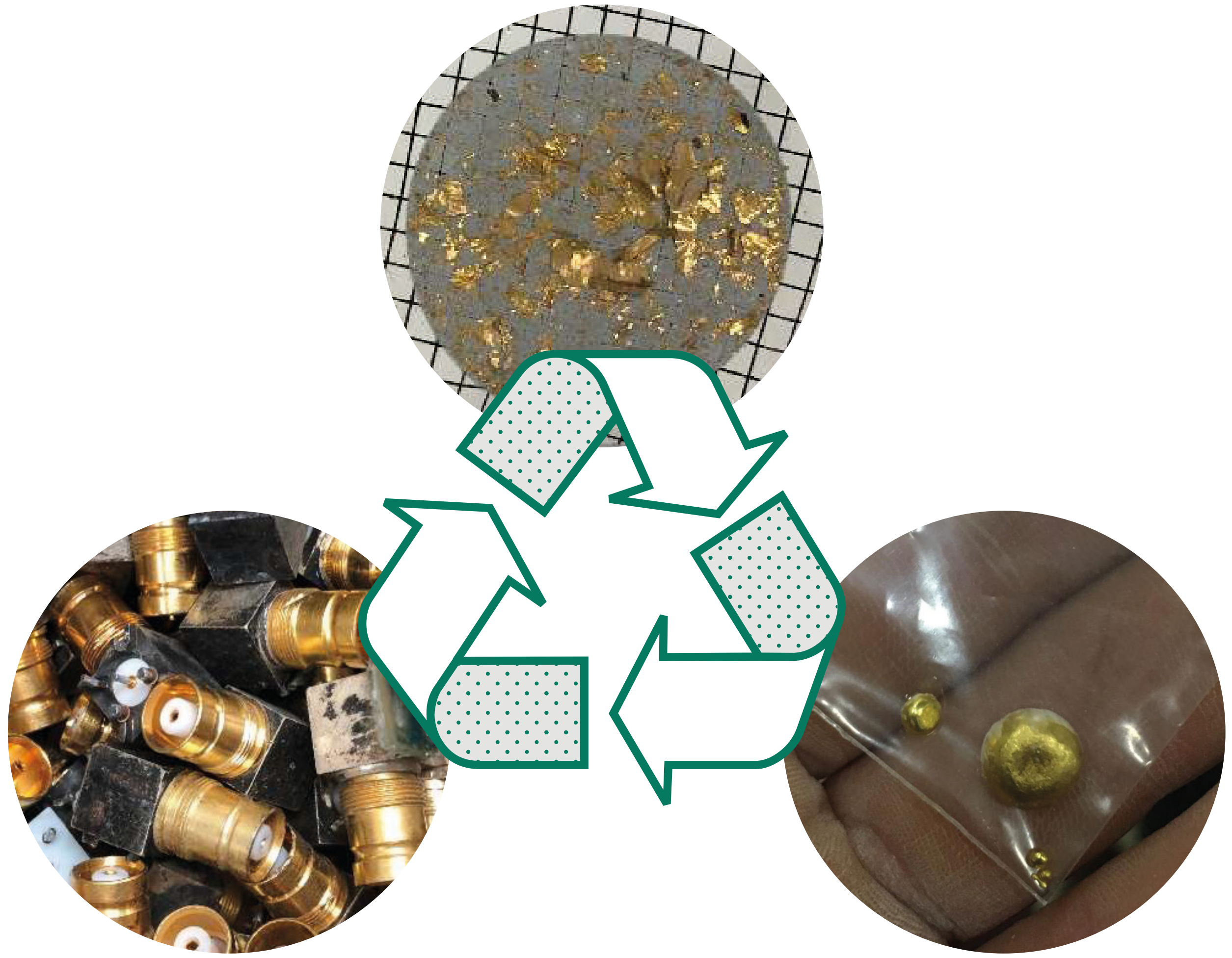
03

Challenges and knowledge gaps

Since the industrial revolution the growth model "buy-use-dispose" has been the leading one as the belief of everlasting resources, easy to dispose and that would always lead to an End-of-Life for each product, also called linear model.
However, the EU definitely heads to a more sustainable direction in the last years, through an objective of waste reduction and recycling.

Circular Economy is the answer to an increasing waste generation, following the EUROPE 2020 strategy, aiming to a wise and sustainable growth, through a **longer lasting life of goods**, hence reducing the waste volumes. This new policy has various reasons to be developed: **greater global consumption of non-renewables, a progressive decrease of commodities, the lack of specific waste disposable areas, hence a need to reduce the amount of waste**. Also the compulsory need to monitor the environmental health endangered by the waste reduction procedures and generally a much greater social attention concerning "waste" in general, but especially waste treatment (landfilling, incineration, ...).
The transition towards Circular Economy implies not only great changes in the production chain, starting from the design to the consumers' attitude.

This does imply a systemic change in technological innovation, logistic, in society, in finance, touching all the bullet points of governance.
Circular economy can indeed develop new markets with a different outlook through a redistribution of goods and an optimized utilization.
The change from linear to circular economy has been **rather easy and favored by the value** of some commodities such as **basic and precious metals** – steel, aluminum, copper, gold, silver, platinum and so on- also thanks to new European regulations.



3.1 CHALLENGES AND KNOWLEDGE GAPS IN CIRCULAR ECONOMY IN ELECTRICAL AND ELECTRONIC SECTOR

Much of the recent thinking on circular economy has been on short and medium-lived consumer products[6]. Some individual EEE manufacturing companies have begun to take steps toward a circular flow of products and materials, but the **EEE sector as a whole has not undertaken the changes required at the business model level** for a true transition to circular economy. There are limited wide-scale practical applications of circular economy in the EEE sector at a product level. Indeed, the market for 'products-as-a-service' is still very immature and the potential of the application of these business models not yet fully understood by most market participants.[7] **Creating circular economy requires important changes throughout the EEE value chain as well as throughout the products' life cycle**.

Despite the increasing recognition that circular economy can offer significant business opportunities and economic benefits, **its application in the EEE sector is in its infancy** and large companies are currently dealing with waste rather than concentrating efforts on the return of materials and products as value to the economy.[8] Additionally, **circularity principles are still applied inconsistently** across the value and supply chains.

Developing a common understanding of circular economy and its key principles can help to lay the groundwork for a wider take-up of the concept and its effective implementation. A wide number of standards that support waste prevention, resource efficiency and eco-design have been in place for years, but there was no one standard focussed entirely on the concept of the circular economy until recently **BS 8001[9], a ground-breaking British standard for the circular economy**, has been developed.

3.2 CHALLENGES AND KNOWLEDGE GAPS IN WEEE RECYCLING

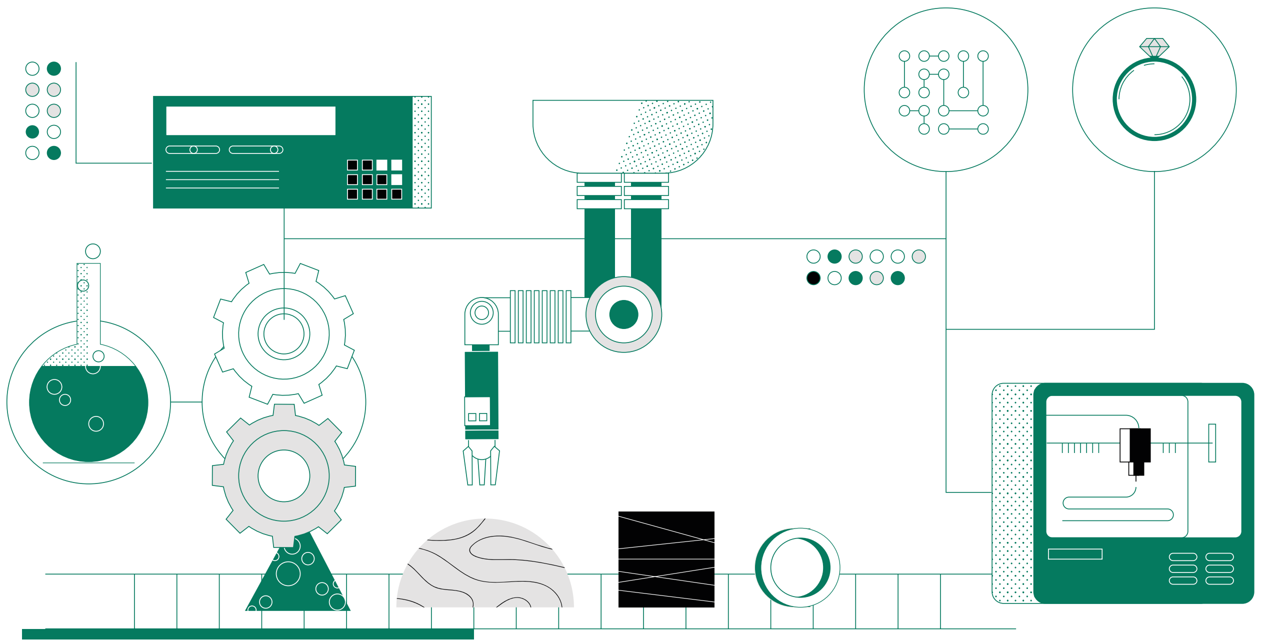
The primary driving forces for WEEE treatment are the **mandatory removal of hazardous substances and the recycling of metals**, since metals have a high price in the secondary materials market and have so far contributed mostly to fulfil the recovery/recycling targets of the WEEE Directive.[5] Conversely, other materials (e.g. plastics and critical raw materials like rare earth elements) have played a very limited role in fulfilling the WEEE targets; e.g., the current situation regarding **WEEE plastics is much less positive with a recycling rate of 14% reported by 2012**.[10]

The amount of WEEE that is estimated to come on the market annually in Europe by EERA, the European Electronic Recyclers Association, is estimated at 11,5 million ton, of which some 2,5 million ton is processed by its 38 members per the European regulations. The remaining part is processed by non-EERA members, and **most of the WEEE scrap is disappearing to either landfill or exported to countries outside the EU**.

Based on the pilot demonstrations and flow sheet modelling, and consequent extrapolation to the EU, it was concluded that the **EU can potentially fulfil more than its current annual demand for neodymium (107%), 74% of its praseodymium and 56% of its dysprosium, in case all WEEE scrap would be processed and its contents in REE would be extracted.** The latter unfortunately is rather hypothetical, in the light of the large re-exports of WEEE scrap. In summary, most sector experts mention on first place costs as the main barrier for more circular activities.

> Creating circular economy requires important changes throughout the EEE value chain as well as throughout the products' life cycle

6. Pollard et al. (2016). The circular economy – a reappraisal of the 'stuff' we love.
7. Accenture Strategy (2017). Circular economy business models for WEEE.
8. Benton et al. (2015). A Circular Economy for Smart Devices.
9. BSI (2017). BS 8001: Framework for implementing the principles of the circular economy in organisations
10. Hestin et al. (2015). Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment.



Policy recommendations

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4.1. INTRODUCE FINANCIAL POLICIES FOR CIRCULAR ECONOMY

The current economic rules in the EU and member states are developed for the linear economy. **Virgin materials** which are in many cases mined outside the EU are **imported without or with very low import taxes** and also the **CO2 emissions** of mining and refining these virgin materials are **not priced** in the EU ETS system. In some countries virgin materials are still subsidized by governments directly or indirectly.
Also **landfilling or incineration of waste instead of recycling is cheap in many EU countries**. For many circular or repair options in the EU the economic rules mean a substantial tax on labor for sorting, repair and recycling and a substantial tax on energy use for recycling by SMEs. Without being aware the economic and policy rules which have been developed for a linear economy favor this economy above a circular economy which we prefer now.

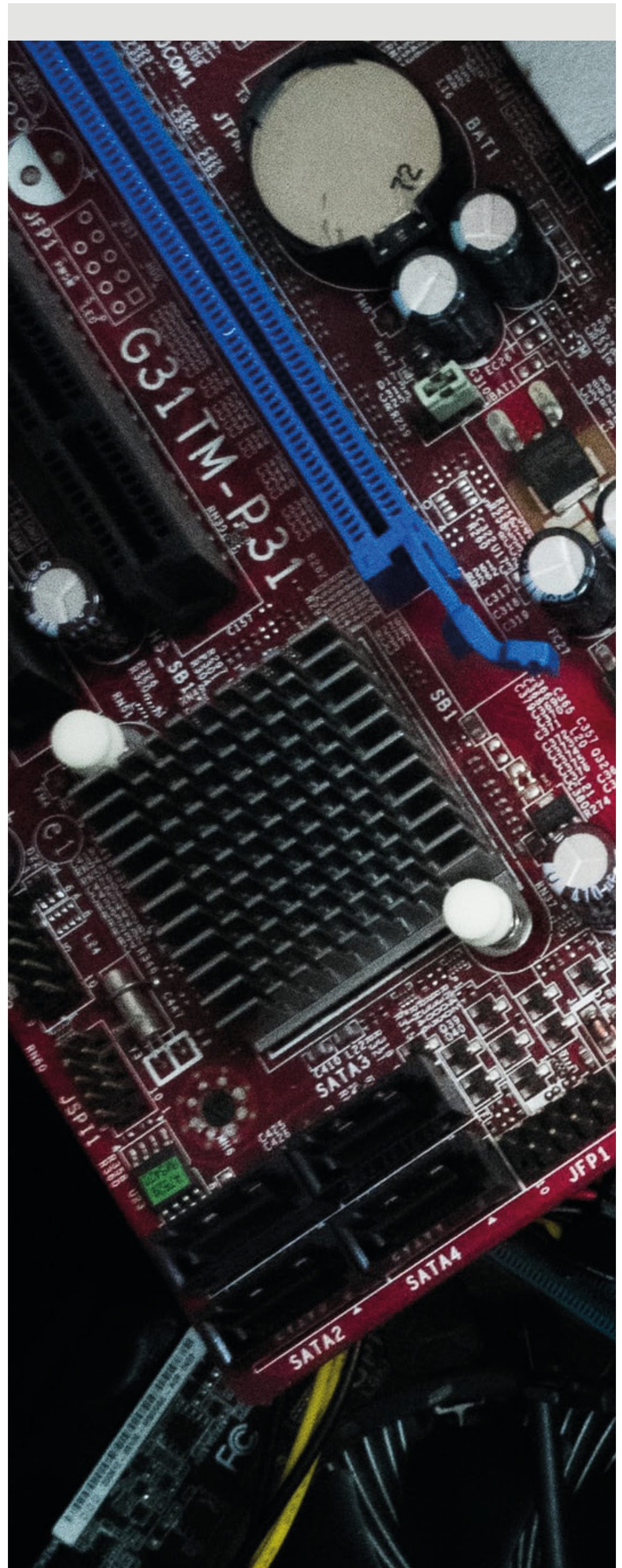
For issues connected to the circular economy like energy and climate policies these economic unbalances are investigated and solutions like a general carbon tax are proposed and discussed and partly implemented. For the circular economy this will also help but it is not clear what other adjustments of our economic systems have to be made to steer more efficiently towards this circular economy. **Therefor we advise to have more research in the economic and cost benefit area** about the best way to steer towards a circular economy.

4.2 PUT HIGHER TAXES ON LANDFILLING AND WASTE INCINERATION

In many countries it is still cheaper to landfill or burn waste than to treat it for recycling. **Some countries have (low) taxes on landfill and/or incineration** (e.g. Austria, Belgium, Denmark, Finland, Ireland, Italy, the Netherlands and the UK). Other countries have no tariff at all and some countries are varying the tariffs over the years. This different tax policies for landfilling and burning of waste in different member states of the EU is **no stable support for the circular economy and also stimulates imports and exports of waste just to avoid taxes**.

The ideal situation will be a stable and balanced tax regime in Europe for landfilling and burning of waste. **The EU could introduce a minimum tariff and a maximum tariff for both landfilling and incineration**. Because landfill is the least favorite option this tariff should be higher. Furthermore, a predictable system with known and increasing tariffs for the coming 5 to 10 years could help investors in alternatives for landfilling by decreasing the uncertainty of policies.

The **EU should negotiate** with member states a system of **minimum and maximum taxes on landfill and burning of waste**. This system could be similar as the current minimum and maximum ranges in other tax policies **like the VAT system**.

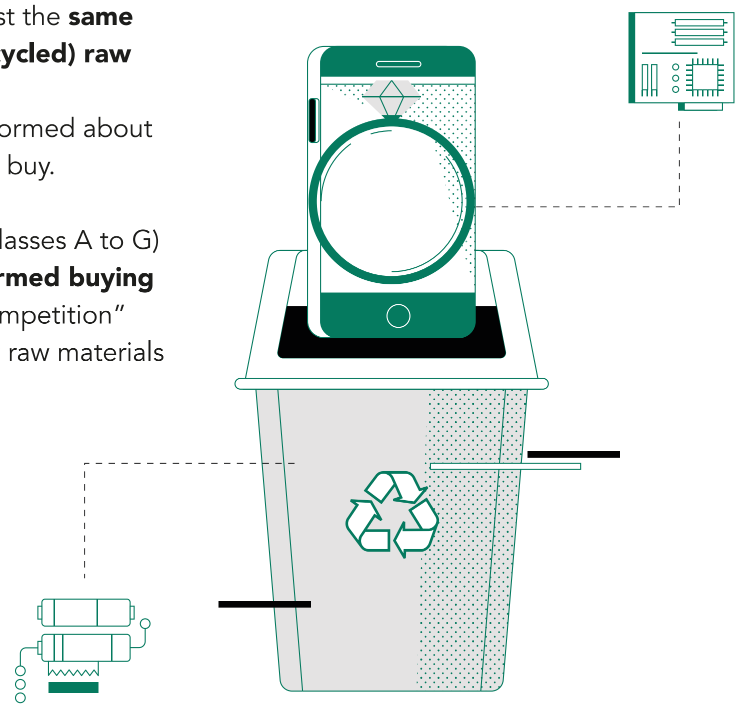


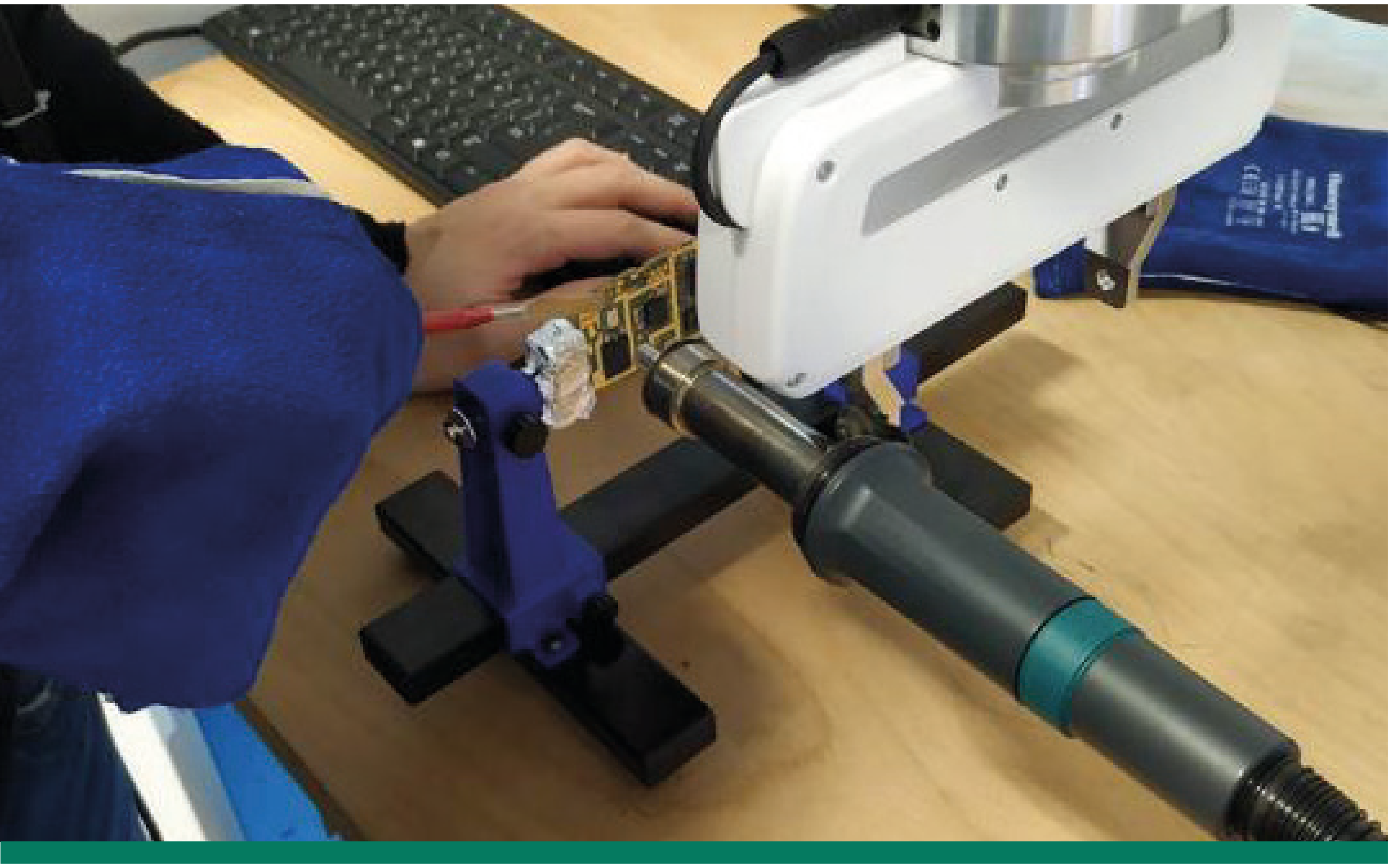
4.3 PROVIDE INCENTIVES FOR RECYCLING

As mentioned before, some governments still subsidize virgin materials directly or indirectly. At least the **same incentives must apply for secondary (recycled) raw materials**.
In addition, consumers are not properly informed about the recycling content of new products they buy.

A similar **ecolabel like the energy label** (classes A to G) **would enable the consumer to take informed buying decisions** at the retail store and start a "competition" between producers to use more secondary raw materials and boost recycling (besides metals).

Finally all these measures have to be **summarized in a new standard** (based on the existing "WEEE Labex" voluntary agreement).





POSSIBLE SOLUTIONS INCLUDE:

Tax reduction (e.g. VAT, labor taxes for employees in recycling companies) or even exemption for recycled materials

Introduction of a **new ecolabel** for products containing recycled material (similar to energy label), maybe incorporating also information of repairability and re-usability

Promotion of European (at least, better international) **standards** to establish trust of consumers and all other market players

Introducing targets in legislation (e.g. WEEE Directive) including a **monitoring system**

4.4 CHANGE THE WEEE DIRECTIVE WITH A CLEAR FOCUS TO RECOVER CRITICAL RAW MATERIALS

Like in most recycling supporting policies or schemes **the amount of recycling and recovery is calculated by dividing kg recycled material by kg of waste collected**. This mass focused stimulation is not addressing the fact that **critical raw materials are often used in small quantities** (e.g. rare earth metals). These materials have a much higher value per kg than non-critical materials like steel, aluminum or glass. But their market price is not as high as for example precious metals and therefore recovered automatically because of its profitability.
The main reason for being considered as a critical raw material in Europe (e.g. rare earth elements) is its lacking primary mining in Europe in parallel to its importance for the European industry. As those metals are **mostly mined in very few countries, political influences on the market price is rather easy** and highly likely as we have seen with rare earths from China.
The purely mass focused recycling targets of today´s WEEE directive can easily be reached with non-critical materials such as base metals, plastics, glass, … .

Therefore, recycling critical raw materials is currently not at all required.
The European Union and its member states should not only **assess the criticality of various materials** for its industry and update regularly the list of critical raw materials, but **take the next step to ensure that the critical raw materials already embedded in our current**

POSSIBLE SOLUTIONS ARE:

Include **specific recycling targets** for critical raw materials in the legislation (e.g. at least a to be defined percentage of Neodymium must be recycled in order to allow Europe to become self-sufficient on the supply side) to make the **recovery mandatory for producers** and the EPR schemes acting on their behalf

Establish specific collection targets for products that are **rich in critical materials** (e.g. in the information technology and telecommunication sector)

Provide **incentives** for scaling up of already **existing recycling processes on lab** or pilot scale in order to bring them to the market

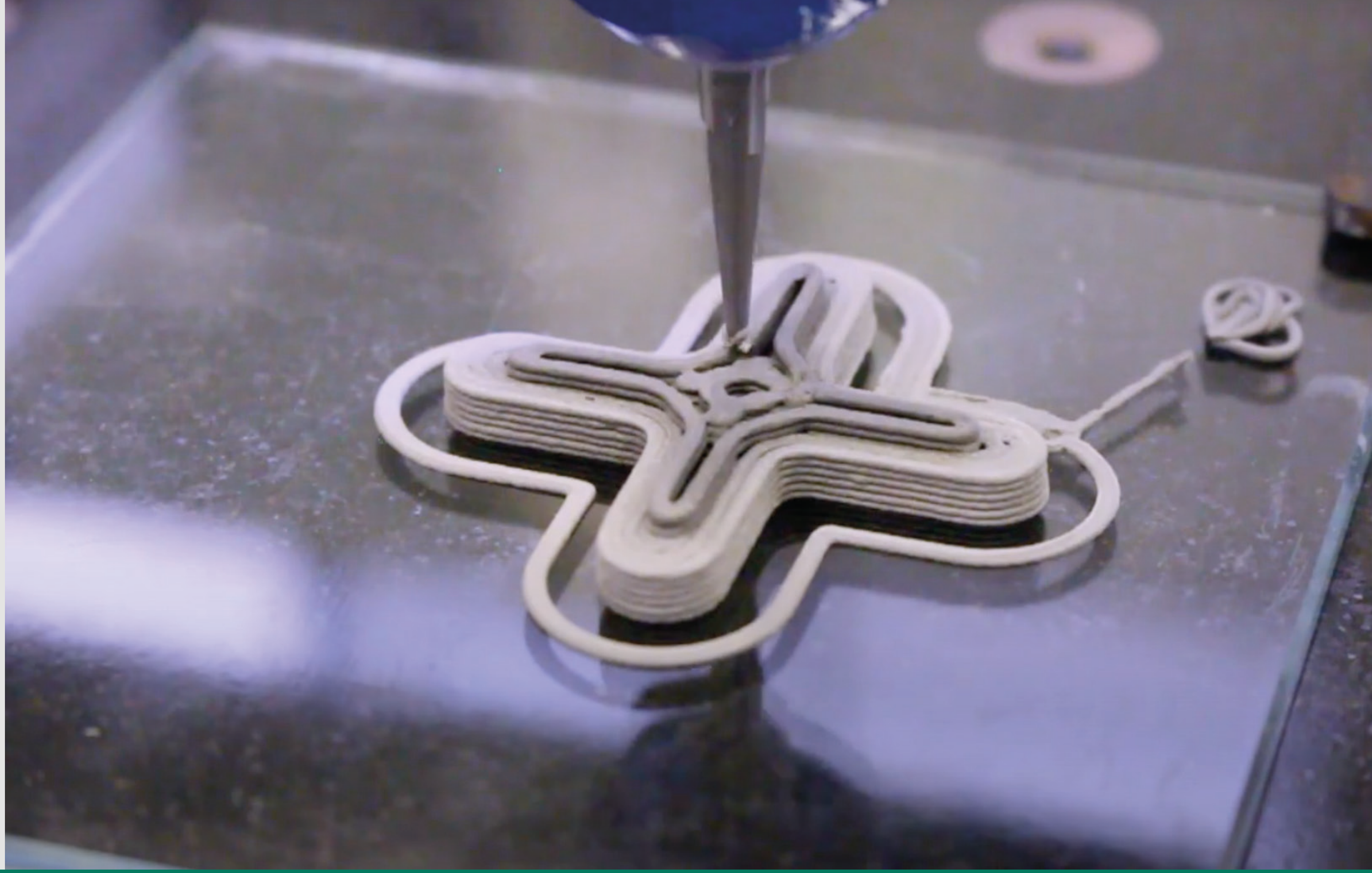
Provide other **incentives for actual recycling** of critical raw materials if the politically influenced low market price does not allow profitable recycling

products are recovered and not lost during the recycling process.

4.5 MORE FUNDING NECESSARY FOR BRIDGING "VALLEY OF DEATH" (FROM LAB/PILOT TO MARKET)

A lot of **promising recycling technologies** (e.g. for critical raw materials) are at the moment already available on lab or maximum on pilot scale. Because of the politically influenced market for certain raw materials (e.g. rare earth elements by China) **the prices for these materials are for the moment being too low** to ensure a profitable recycling. In addition, it is also very risky for the private sector (and most recycling companies are still comparatively small, approx. 80% SMEs according to EUROSTAT) to do large investments in recycling plants for such materials as **the political influence makes a long-term planning close to impossible**.

These are the main reasons why most funded EU projects for the extraction of secondary critical raw materials got stuck before or in



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Include specific **recycling targets for critical raw materials** in the legislation (e.g. at least a to be defined percentage of Neodymium must be recycled in order to allow Europe to become self-sufficient on the supply side) to make the recovery mandatory for the EPR schemes the demonstration phase.

4.6 ENHANCING GREEN PUBLIC PROCUREMENT (GPP) WITH A SPECIFIC FOCUS ON RECYCLING, RE-USE AND CIRCULAR ECONOMY

Most governments in the EU (national, regional and local) have policies to procure their products and services with GPP. Many governments are still struggling with this concept, but steps are made to improve the practice in GPP.

In some countries (e.g. Germany, France, Scotland, Italy, Switzerland, Denmark and the Netherlands,) **governments are also adding circular procurement to the GPP program**. Although there are good examples of circular procurement this is still not common in most European cities and villages. **A stronger policy on circular procurement with target all over Europe** could help to spread this.

The European Union should **suggest guidelines, criteria documents and evaluation systems** for circular procurement that other governments could implement. Ideally green and circular procurement are also integrated because many governments see them as connected or similar.

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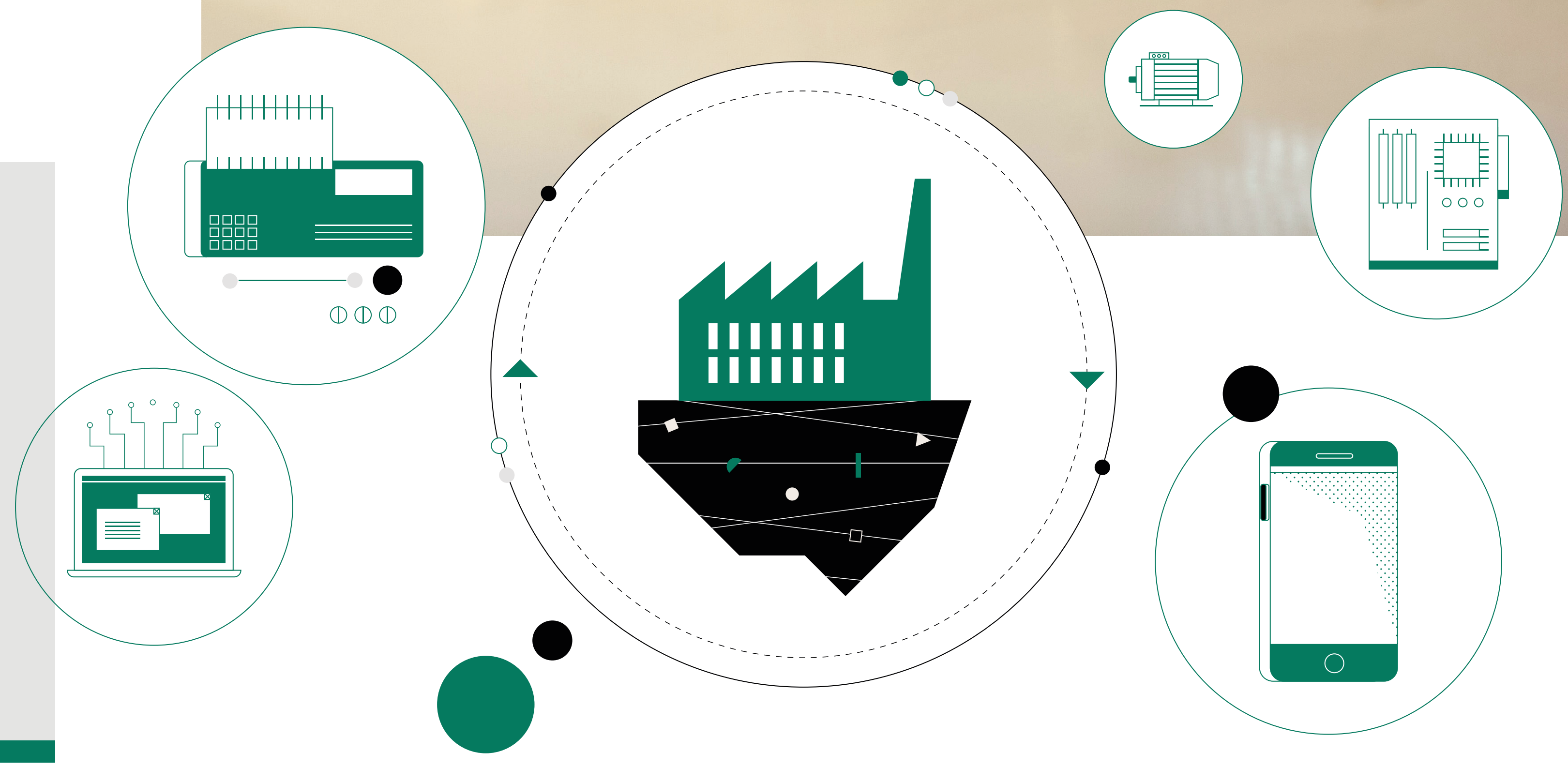

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About Fenix

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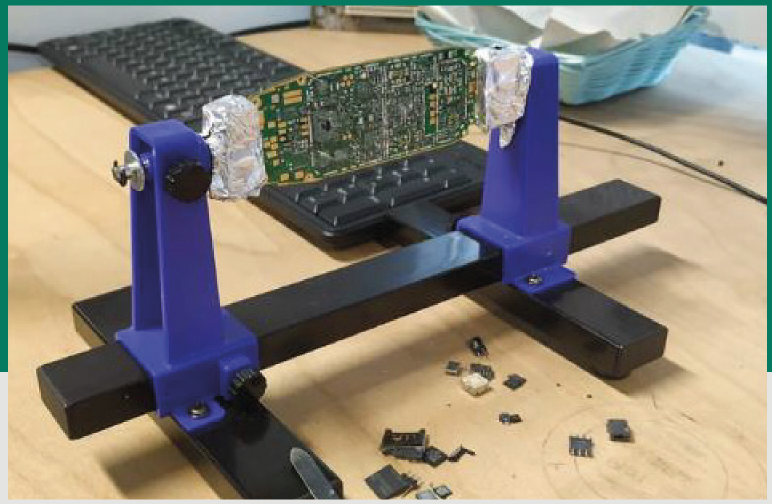
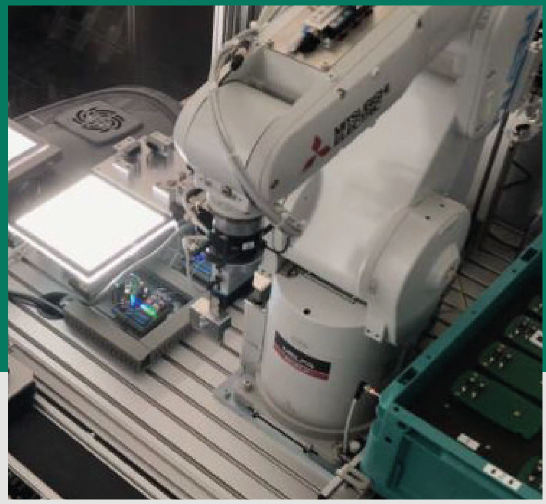
5.1 SUMMARY OF THE CONTEXT AND OVERALL OBJECTIVES

The European Union faces several challenges caused by globalization. Both the delocalization of production plants (leading to more imported products) and the instability characterizing several industrial sectors force economies to **re-think their business models** and re-adapt them in a new context, where the sustainability of products and processes is more relevant. Within this overall framework, the need to think about **innovative business models** and industrial strategies, able to answer to these new requirements is mandatory. One chance is the **exploitation of digital technologies**.

Another is the exploitation of secondary (and critical) resources that, currently, are wasted without any recovery. The project **"FENIX - Future business models for the Efficient recovery of Natural and Industrial secondary resources in eXtended supply chains context"** considered both these issues and their potential at the same time, proposing something that allows Europe to re-appropriate its pertaining position in the global market. The idea has been to **study innovative business models and industrial strategies** (based on the circular economy paradigm) enabling the development of new product-services through the definition of novel supply chains, resulting from an unconventional mix of current ones. This allows **easy re-use, reconfiguration and modularization of production systems**, the exploitation of overcapacity and the renaissance of industrial poles all over the Europe. Furthermore, the circular economy driven business models and industrial strategies proposed by project FENIX have been **demonstrated in existing pilot plants**, adequately reconfigured and integrated based circular economy needs.

FENIX - **F**uture business models for the **E**fficient recovery of **N**atural and **I**ndustrial secondary resources in e**X**tended supply chains context



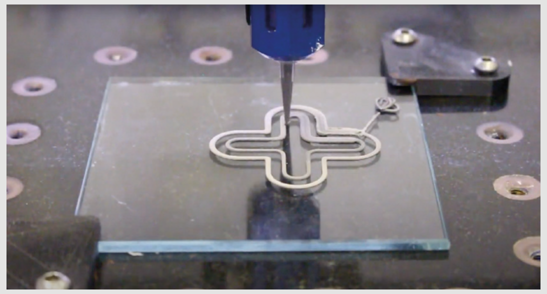


5.2 PROGRESS BEYOND THE STATE OF THE ART, RESULTS AND POTENTIAL IMPACTS

The main results of FENIX have been the development of new business models and industrial strategies for three novel supply chains in order to enable value-added product-services

1. A MODULAR, MULTI-MATERIAL AND RECONFIGURABLE PILOT PLANT PRODUCING 3D PRINTING METAL POWDERS.

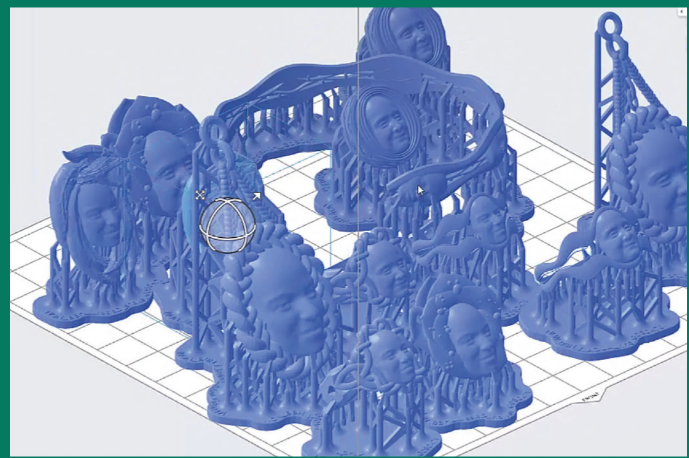
This pilot plant allows the **production of high-quality metal and CerMet powders** to be used in the production of mechanical components through manufacturing processes like **additive manufacturing** (SLM, LMD) **thermal spraying and sintering**. The peculiarity of this use case is that the metals entering the manufacturing process has been recovered **from different kinds of wastes coming from the mass electronics sector**. These wastes, once disassembled to recover hazardous components, have been reduced in powders. Subsequently, powders have been separated in metal and non-metal ones. In this case, **only some specific metals (e.g. Sn, Ni, Cu, Co and Al) present in powders have been refined completely** through bio-hydrometallurgical processes, processed by High Energy Ball Milling and optimized by classification and jet-mills to be used in industrial 3D printing, thermal spraying or sintering processes.



2. A MODULAR, MULTI-MATERIAL AND RECONFIGURABLE PILOT PLANT PRODUCING CUSTOMIZED JEWELS.

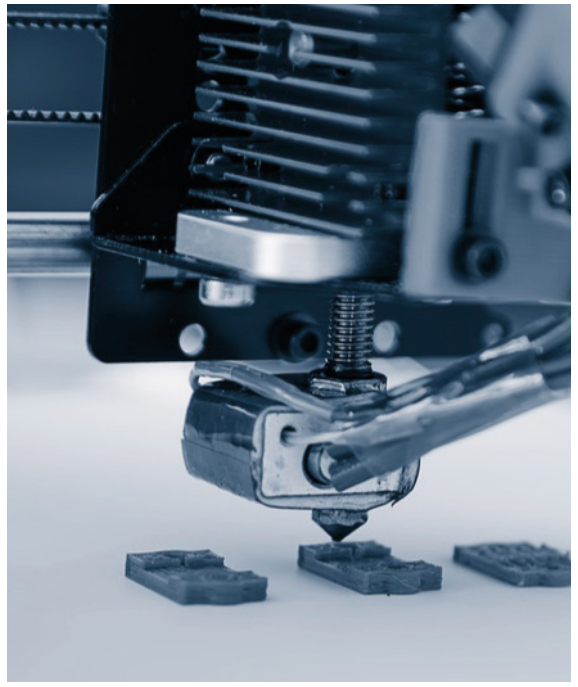
This pilot plant allows the production of **customized jewels** through additive manufacturing processes. The peculiarity of this use case is that the **precious metals** entering the additive manufacturing process have been again **recovered from different kinds of waste** coming from the mass electronics sectors. These wastes, once disassembled to recover hazardous components, have been reduced to powders.

Subsequently, the powders have been separated into metal and non-metal ones. In this case, only **precious metals (e.g. Au, Ag, Pt and Pd)** present in powders have **been refined** completely through **bio-hydrometallurgical processes** and directly used as basic material in dedicated 3D printing processes.



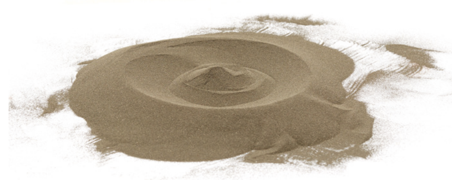
3. A MODULAR, MULTI-MATERIAL AND RECONFIGURABLE PILOT PLANT PRODUCING ADVANCED FILAMENTS FOR 3D PRINTING.

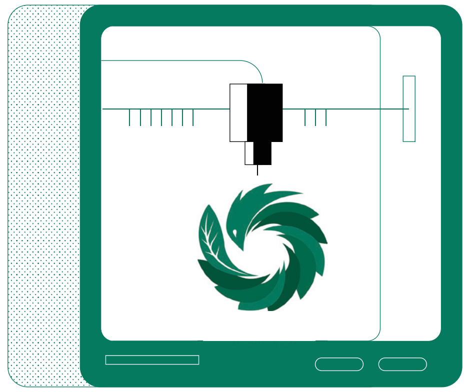
This pilot plant allows the **production of advanced filaments** through **additive manufacturing processes**. Again both **metals (e.g. Cu and Al) and non-metal resins** entering the additive manufacturing process have been **recovered from different kinds of waste** coming from the mass electronics sectors. These wastes, once disassembled to recover hazardous components, have been reduced into powders. Subsequently, powders have been separated in metal and non-metal ones. In this case, only **Cu, Al and a specific set of non-metal materials** (e.g. ABS and epoxy resins) present in powders **have been refined completely through bio-hydrometallurgical** processes and directly used as basic material in dedicated 3D printing processes.



All the three pilot plants **share the same infrastructure**. A modular plant for the joint manufacturing/de-manufacturing of products/components, the **sustainable recovery of materials** and the reuse of material powders in several additive manufacturing applications is a completely new market niche, matching together several Key Enabling Technologies (KETs).

FENIX will allow the expansion of this market niche, by reaching other markets interested in exploiting its results.





For more information, please visit **www.fenix-project.eu**

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