EME

PILOT REPORT

Excess Materials Exchange

A dating site for Excess Materials

Colofon

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Use of information within this report is allowed when referrenced.

PREFACE

"Waste to wealth. This is a subject that needs to be close to all our hearts if we are to achieve the future we want for our families, our businesses, our society and of course our one and only planet.

We are using resources faster than Nature can replenish them and damaging our own life-support system. Every discarded plastic drinking straw, wet wipe, cup, bottle or bag tells a clear and unequivocal story of waste and missed opportunity, both to generate value and to address the over-arching challenge of climate change, recently listed of course by the World Economic Forum as amongst the biggest threats facing the world.

So, it is clear that recycling is part of the answer. We have become very good at making things – now we have to get much better at un-making and re-making them. And to assist that process we have to find ways of giving what we unhelpfully refer to as 'waste' a proper value – we have to monetize it.

Many forward-thinking businesses are, I know, already putting the principles of the circular economy into practice. However, as things stand, the sums do not add up. If we are to have any chance of limiting climate change to well below two degrees, as set out in the Paris Agreement and as highlighted by the I.P.C.C.'s recent report, we are going to have to use much less of the Earth's resources and use them more efficiently too. This is going to require changes at both speed and scale. And in my experience the only way to achieve that is to mobilize the skills and ingenuity of the business community, where necessary backed up by regulation.

As some of the pioneers have shown, there are opportunities too. Finding solutions to the challenges of using resources more effectively can deliver lower cost, higher value ways of working – beneficial to businesses, to the communities they operate in and to the environment. In essence, therefore, one man's – or business's – waste can be another's raw material... But to what extent do we join up the dots effectively?

One of the challenges is how best to put sellers in touch with buyers. How does one company know what another might be able to offer? A centralized location would be one solution, but it doesn't make sense to move materials farther than is necessary. So, I was intrigued to hear about the innovative approach being developed in the Netherlands by a company called **Excess Materials Exchange**. They have developed a digital marketplace where companies can exchange materials and products, and which seeks to identify the highest-value uses. This is still at the pilot stage but does look promising as an example of a new approach that might help unlock the full potential of the circular economy.

If I can just leave you with a final thought. We are the first generation to understand, in full and terrifying scientific detail, that we are testing our world to destruction. And we are the last to be able to do something about it."

- Prince Charles, HRH the Prince of Wales -
At Business in the Community 'Waste-to-Wealth' Summit

EME - Value Proposition

The Excess Materials Exchange (EME) aims to reinstate waste for the valuable resource that it is. The EME is a facilitated, digital marketplace where companies can exchange any type of excess materials (materials, components, products) business to business. This ranges from for example textiles, to plastics and organic materials.

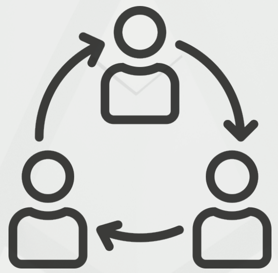
The EME functions like a dating site. We actively match supply and demand, and materials with their highest-value reuse potential. In so doing, we help businesses turn waste into wealth while contribute to the realisation of a truly circular economy. Our value proposition is as follows:

Increased high-value reuse and recycling of materials and products

Turning a cost into a revenue stream (waste into wealth)

Help achieve sustainability goals

Extensive knowledge and network of the circular economy and business models



Facilitation of circular alternatives by active matchmaking, including legal, financial and accounting support

Helping companies position themselves as a frontrunner in the circular economy by providing materials with an identity

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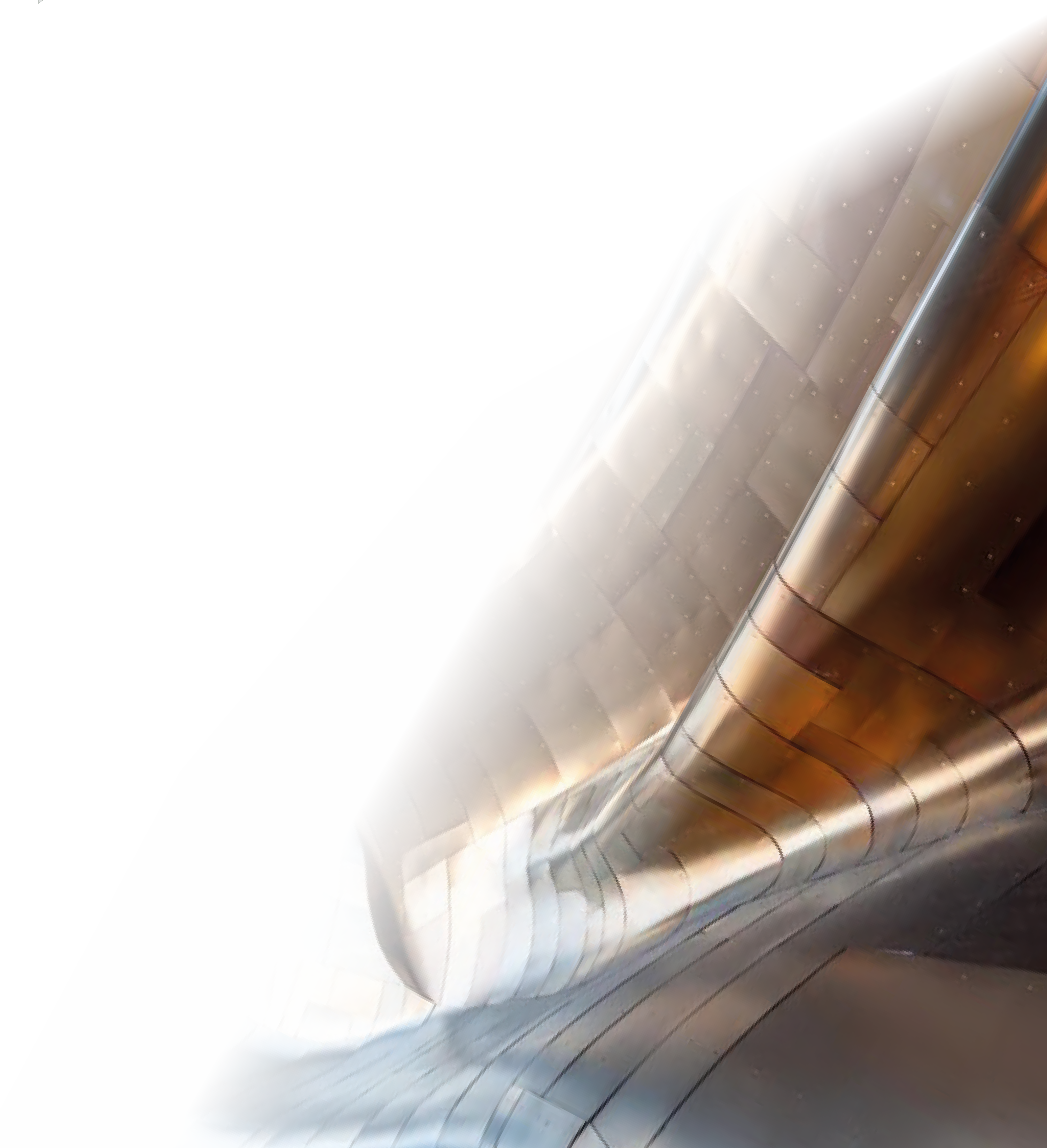


EXECUTIVE SUMMARY

The Excess Material Exchange

The Excess Materials Exchange (EME) facilitates the transition to a circular economy. Instead of relying mainly on primary resources, as is customary in our current 'take-make-waste' model, we envision a move to a wasteless economy in which excess materials endlessly loop through value chains.

The transition to a circular economy requires us to overcome a number of challenges, for example: a lack of transparency on the availability of resources, a lack of organisational awareness, lack of urgency, lack of quality control and, consequently, a failure to adequately scale markets for secondary resources. In order to speed up the adoption of circular models, we need to ensure secondary resources are available when they are needed, in the quantities and quality requested, and that their availability can be predicted (see chapter 1).

EME hopes to overcome these hurdles by providing four tools:

- A Resources Passport to give materials an identity and to store material, component and product information;
- A Tracking & Tracing module to connect Resources Passports with real-life assets and follow them through value chains;
- A Valuation module to quantify the financial value and environmental and societal impact of the resources we map;
- A matchmaking platform to facilitate and ensure high-value uses of materials.

However, these tools alone are not enough for companies to transition towards a circular economy. The tools are only effective when they are part of a holistic approach. Our approach includes help with implementation of the tools in an organisation. Furthermore, we help companies understand how our tools fit within their current legal, accountancy and financial contexts. Moreover, we always use network type solutions, like involvement of stakeholders, to optimise for the contextuel parameters in which companies operate. We further encourage the development of the larger ecosystem by raising awareness of circular business models and building a network of excess-material providers and sellers. Finally, we promote adoption of circular business models by helping our clients undertake the required organisational and cultural changes.

The Pilot

Together with ten companies, among which ProRail, Rijkswaterstaat, Schiphol, Aquaminerals, Heembouw, Sodexo and Tarkett, we took the first steps in exploring the possibilities of the EME. The goal of the pilot was to better understand what is necessary for the optimal functioning of a platform that can exchange excess material flows between industries and sectors. In addition, we helped our clients understand what is necessary to exchange materials on a platform such as ours.

For each partner we looked at multiple excess material flows and investigated how these excess matrials could be reused at their highest value. 18 different materials made their way through our platform for which we calculated the possible financial gains, water, CO_2 emissions and energy savings that could be achieved by finding high-value alternative uses for the - currently wasted - resource streams. Our findings are documented in the corresponding resource passports. Additionally, together with law firm Stibbe, accountancy firm EY and the bank ABN AMRO, we explored the legal, accountancy and financial framework we are operating in and established formal frameworks for measuring the social and environmental impact of the Excess Materials Exchange.

Pilot outcomes

The pilot confirmed the need for a holistic approach to overcome the obstacles laid out above. Such an approach requires an identity for resources, the ability to track and trace materials, methods for quantifying the financial value of excess materials, as well as tools to quantify the environmental and societal impact for reusing them. We further confirmed that our current legal framework provides room for cross-sectoral exchange of excess materials.

Pilot impacts

The 18 materials mapped by the EME weigh 70,000 tonne (equal to the weight of seven Eiffel towers). The identified matches together account for the following potential impact reductions:

- A CO_2 emissions reduction of 123 kilotonnes CO_2, which equals the emission of all citizens of Amsterdam (862,987) driving from Amsterdam to Milan;
- An energy saving of 2,883 TJ, equal to the energy consumption of the public lights in Paris for at least five years;
- A water reduction of 2.1 million m^3 equal to the content of 860 Olympic-size swimming pools;
- €54 million in environmental cost reduction and €64 in financial value creation. The potential savings on waste treatment cost add up to €5.4m annually;
- Through our pilot we sparked organisational change and furthered the conversation around circular economies.

Next steps

Based on our learnings, we have identified the following next steps:

1. Implement the matches we created and update our clients' operations to accommodate these excess materials;
2. Further develop our tools and digitise our tools on the marketplace;
3. Start training our matchmaking algorithm;
4. Onboard more companies to the EME and help them reduce their environmental impact and transition to a circular business model.

If you also want to transition to a circular economy and would like to join our journey please contact us for more information at:
info@excessmaterialsexchange.com

Box 1: potential impact of the 18 material flows in the pilot

A CO_2 emissions reduction of 123 kilotonnes CO_2, which equals the emission of all citizens of Amsterdam (862,987) driving from Amsterdam to Milan.

An energy saving of 2,883 TJ, equal to the energy consumption of the city lights in Paris for at least 5 years.

A potential creation of €64m in financial value and a reduction of €54m in environmental damage (eco-cost), resulting in a Total Value creation of €118m. The potential savings on waste treatment cost add up to €5.4m annually.

Organisational changes. For example, one of the participants put together a special team to oversee the matching of the materials. Another embarked on new collaborations with garbage disposal companies.

Water savings equal to the content of 860 Olympic-size swimming pools.

The summed weight of the streams analysed in the pilot is 70,000 tonnes, which is equal to the weight of seven Eiffel towers.

Chapter 1

INTRODUCTION

> *"More than half of all greenhouse gas (GHG) emissions are related to materials management activities. GHG emissions related to materials management will rise to approximately 50 Gt CO2- equivalents by 2060*
>
> *- Global Material Resources Outlook to 2060, OECD -"*

WHY WE ARE DOING THIS

Currently, we only recycle 9% of plastics produced worldwide[1]. The rest makes its way to our oceans and landfills, where they join metals, rubber, leather, food scraps and paper products that we discard every single day. Every minute, a waste management truck filled with plastic is dumped into our oceans[2], such that by 2050 there will be more plastic in the oceans than there are fish (by weight)[3]. Our economic systems provide little incentives to value the resources that remain at the end of our production and consumption processes. They are not viewed as part of our revenue streams but are instead discarded as quickly as possible. Out of sight, out of mind. Waste is an afterthought, an annoyance.

For a long time, our planet showed enormous resilience, while it graciously absorbed the piles of waste we produced. But as the human population continues to grow and our production capacities continue to expand, we can no longer ignore the impact of our actions. According to the United Nations, extractive industries are together responsible for more than 80% of the loss in biodiversity. At the same time, rates of return on the extraction of primary resources are diminishing. As resources become scarcer and more costly to extract, the environmental impact of resource extraction and processing are becoming more evident. It is time for our production processes to shift away from using primary resources in favour of secondary resources.

To create that shift, we need to change the way we think about our waste. Our dream is to create a paradigm shift in which we turn waste from something worthless into a valuable resource. The Ellen MacArthur Foundation estimates that by discarding our plastic after a single use we effectively waste €80-120 billion in value every year. Our annual electronic waste, meanwhile, is worth an estimated €55 billion. In fact, we capture a meagre 5% of the total potential value of our waste. The remaining 95% is lost in the metaphorical waste bin[4].

The poorest members of our society have long been aware of the value of waste. In the global south, exported e-waste is recycled by informal labourers who pillage through the discarded electronics in search of valuable materials. Excess materials are their bread and butter, but it is a broken system at best. For the most part it is still cheaper to mine new resources than to reuse existing ones. The same way buying a new television set is still more economical than having a broken one fixed. It is therefore no surprise that only a small percentage of materials is being reused.

A number of forces are slated to alter this status quo. A growing world population and rising welfare standards are putting more pressure on our planetary resources. Increasingly scarce resources are often sourced from unstable regions, where political tensions could lead to spikes in resource prices and limit overall availability. This presents a risk to businesses that rely on steady streams of materials to operate, while governments risk becoming beholden to regimes they have little control over. In short, our reliance on resources from all over the world, including volatile regions, is disrupting business-as-usual; threatening complex value chains and resulting in price volatility.

At the same time, social pressures are on the rise. Armed with images of plastic-filled birds, consumers and NGOs are demanding sustainable alternatives. Governments are joining the fight as well. Faced with these realities, the European Union and countries such as the Netherlands have prioritised the transition to a circular economy.The largest stock of resources on this planet can be found in the products and buildings in Europe. The Netherlands introduced the Resources Agreement, which states that by 2030, 50% of the materials in our society need to be non-virgin. By 2050, all materials flowing through the Dutch economy will have to be from secondary sources.

Doing so helps relieve environmental pressures and makes good business sense as well. At the moment, most companies spend valuable resources to discard of their waste. Adopting circular economy practices would allow them to improve their bottom line by turning their waste into wealth. A study by the Ellen MacArthur Foundation & McKinsey (2015) concludes that shifting to a circular economy could result in overall benefits of €1.8 trillion by 2030[4]. This transition would also increase the number of jobs and decrease GHG emissions by up to 48% by 2030 and up to 83% by 2050 (based on three sectors). This makes abundantly clear why we took it upon ourselves to use our platform and the circular economy, as a lever to create a more equitable and sustainable world.

TOWARDS A CIRCULAR ECONOMY

What is a circular economy?

Circular economy means different things to different people. In fact, one study found 114 definitions for the circular economy[5]. We maintain the Ellen MacArthur Foundation's definition, which defines a circular economy as follows:

"A circular economy is restorative and regenerative by design. Relying on system-wide innovation, it aims to redefine products and services to create value, design out waste, while minimising negative social & environmental impacts."

The circular model is a departure from the extractive 'take-make-waste' model and aims to refocus our attention away from economic growth at the expense of our environment and society at large. That means we need to move economic activity away from the consumption of finite resources towards a model in which waste no longer exists: not by accident but by design (figure 1).

The Ellen MacArthur Foundation identifies three key principles (EMF website):

- Design out waste and pollution;
- Keep products and materials in use;
- Regenerate natural systems.

The circular model approaches problems of resource depletion and climate change on a systemic level. In contrast to recycling models in which resources obtain a second or third life before being discarded, the circular model looks to eliminate waste altogether by closing the loop. Excess materials are not wasted but reused endlessly.

Transitioning to a circular model

Given the promises of a circular economy to the environment, society and our wallets, what is stopping us from adopting this model across all industries? The short answer to that question is that, for the moment, we lack the infrastructure, transparency, standardisation and cultural shift required to fully transition.

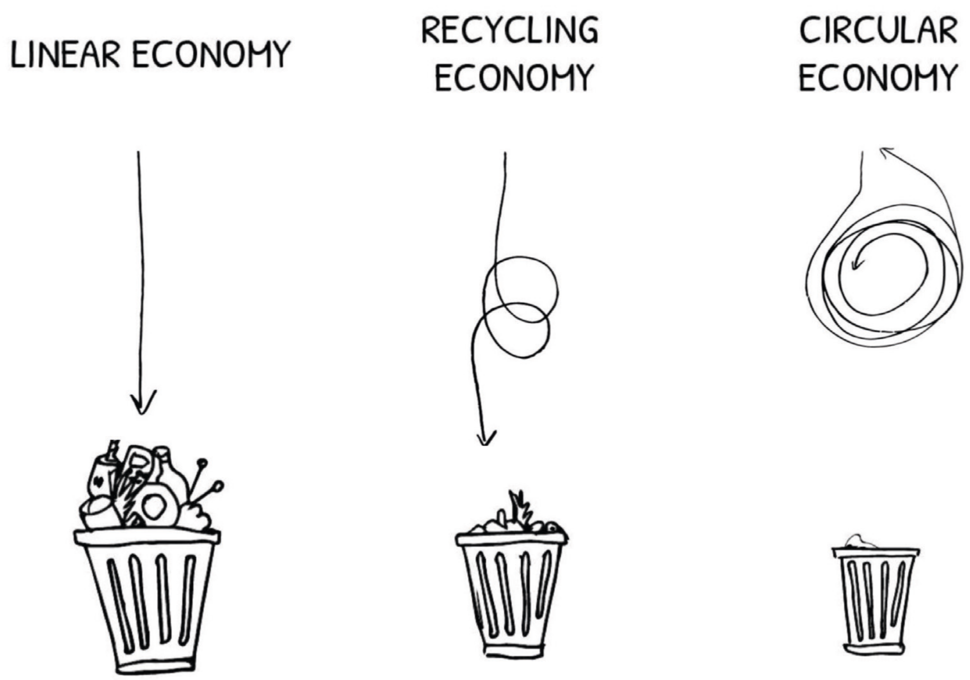


Figure 1: Economical systems by "Plan C".

To bring about a truly circular economy, we need to facilitate cross-sector collaboration. The transition is, for the most part, demand driven. As of now, the supply of waste and excess materials is sufficient. However, the demand for excess materials is still relatively small. Once demand increases, we need buyers from one sector to be able to source their materials from sellers in a completely different industry. This requires a common language. A marketplace with Resources Passports can aggregate several small streams and create economies of supply and demand.

In addition, it is currently difficult to guarantee materials will be available exactly when they are needed, and that they will be available in the right amounts for a large number of buyers. As companies initially focus on closing loops locally, more resource-efficient and environmentally-friendly uses of secondary materials are missed. For example, take a coffee company that - with all the best intentions - dries and burns their leftover coffee grounds to heat their facilities and, hence, close the loop locally. They claim to have no waste. This is true. However, there are higher-value uses for coffee leftovers, such as: the production of ink, water strainers or bioplastics. The circular economy is not only the elimination of waste but more so optimising an economic system around resource effectiveness.

This requires a paradigm shift. Organisations that are excited about these new circular business models often fail to update their culture and processes. Instead, circular models are embedded in existing linear approaches. The result is a myriad of inefficiencies that could have been avoided with a more holistic approach. Our work in the pilot has led to the identification of eight obstacles towards the transition to a circular economy. These are described on the next page.

BARRIERS TO A CIRCULAR ECONOMY

From our experience with helping companies transition to a circular economy we identified eight main barriers.

Lack of transparency

The circular economy requires transparency. Oftentimes, companies in close proximity to one another have no idea they can use each others' materials. This could even be the case between different locations within the same organisation. One organisation's excess material can be a valuable input for another organisation.

Timing

Timing matters. The release of an excess material often does not coincide with the moment when they are needed. Construction is a great example of that. When a building is deconstructed, the materials coming out of that building are not always immediately needed for another purpose. Storage of materials is expensive, and every handling of the materials adds costs that make transactions difficult.

Quality

In buying secondary materials and/or components, quality plays an important role. Unfortunately, secondary materials have less predictable characteristics and are harder to track. For example: carpets are often collected as a separate stream. However, the quality between carpets can differ greatly. Some carpets can be reused readily. While other carpets that were produced outside of the EU, may contain toxins that make it impossible to recycle them. Incineration to generate energy is often the only option.

Quantity

The quantity of materials released by companies can be an obstacle for the reuse of secondary materials. Quantity is very much tied to timing. The quantity of materials released is in most cases not in line with its next user. For example, supermarkets have leftover streams of orange peels. Their weekly quantity is not enough for a single supermarket to set up a scalable production process themselves. Hence the peels very often end up in the regular waste stream and a lot of value is wasted.

Friction with traditional business models

New circular business models often create friction with existing linear models. A good example is the leasing model, where, for instance, washing machines are offered as a product-as-a-service (PaaS) model. In theory, it should be cheaper to rent a product that has a long lifespan and high acquisition costs. However, there are several reasons why execution is difficult. Amongst others, PaaS models have fairly high financial and insurance costs. These costs are incurred because the financial and insurance world has little data on these models. This results in a high-risk premium, which is cost prohibitive for consumers with little money (the ideal customers of PaaS models). This is compounded by the fact that these models compete with a mature secondhand market for washing machines. OEMs of washing machines may be hesitant to offer PaaS models, as it cannibalises on their conventional make-sell business model.

Local sub-optimisations

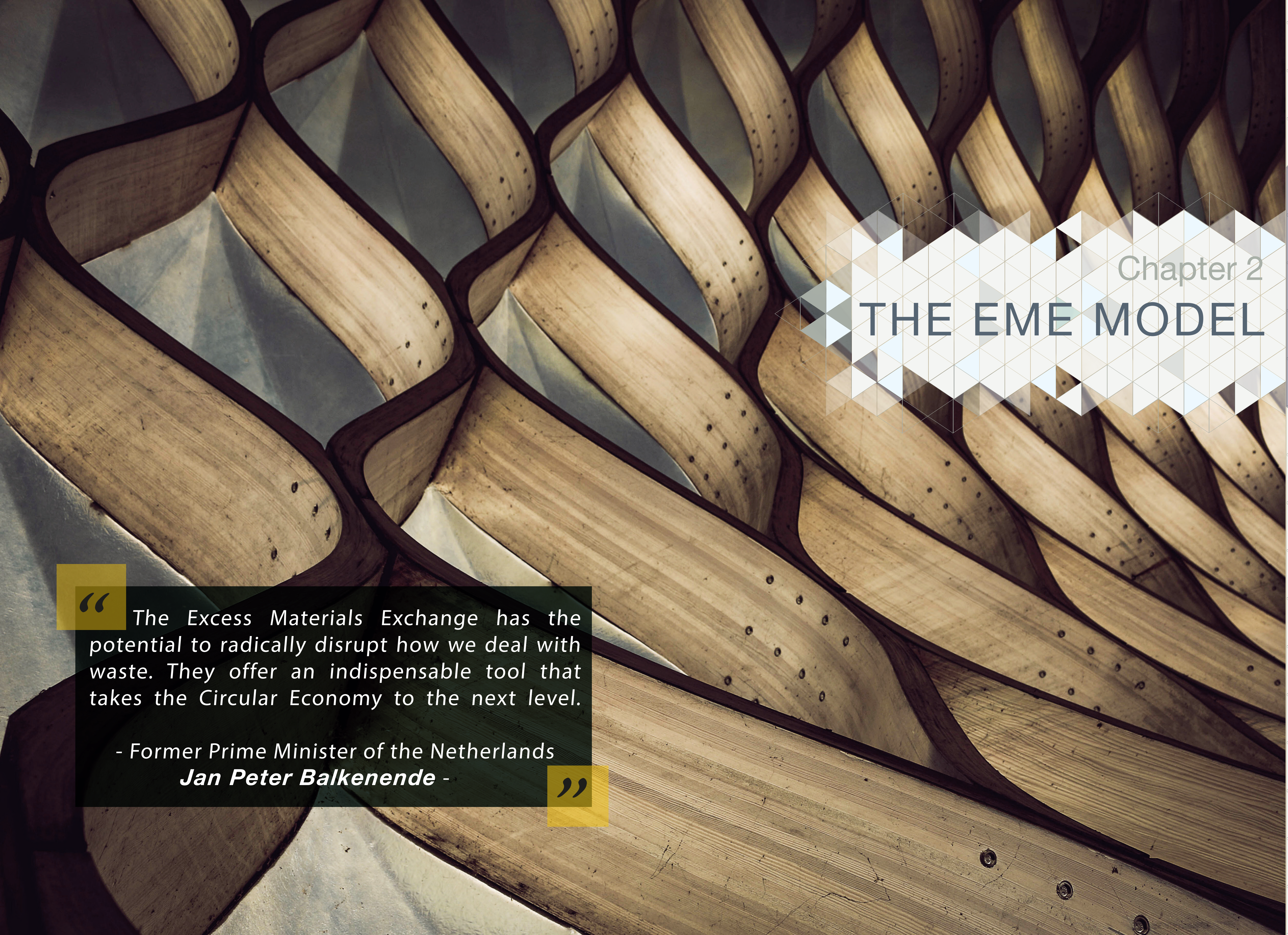
In the circular economy, we see that with a lot of good intentions, organisations often find local or internal destinations for their excess material flows. Like previously described, a good example is a coffee company that produces significant amounts of coffee waste. They have started a project with their waste processing service provider to dry the coffee waste and burn it to generate energy for their production processes. This initiative is commendable. However, far higher uses in terms of financial value and environmental footprint reduction, can be found for coffee waste than burning it. Coffee waste can be used for the production of ink, PLA, production of mushrooms, soap, and cosmetic products.

Lack of urgency

Despite ambitious plans from both the Dutch and EU governments, most organisations do not feel a need to take action (right now). We see that conventional solutions provide enough comfort and do not prompt companies to take action. For example: prices of virgin resources are still quite low. Oftentimes, circular solutions introduce more risk. In these transitional times, the 'reward' is not big enough yet to incentivise businesses to take action.

Solutions do not scale

So far, the circular economy has produced some interesting and creative solutions for end-of-life products. However, a lot of those solutions are difficult to scale. A good example is turning windmill blades into playgrounds for kids. It is great this is happening, but this is unlikely to be a scalable solution. The amount of windmill blades far exceeds the number of playgrounds needed.



Chapter 2

THE EME MODEL

> "The Excess Materials Exchange has the potential to radically disrupt how we deal with waste. They offer an indispensable tool that takes the Circular Economy to the next level.
>
> - Former Prime Minister of the Netherlands
> ***Jan Peter Balkenende*** -"

THE EME MODEL

Our work has taught us that transitioning to the circular economy requires a holistic approach. Developing new tools is not enough to completely realise the envisioned paradigm shift. Therefore, we developed multiple tools and combined them to create a holistic approach, which helps companies in the transition. In a continuously changing world this is an ongoing effort.

The four most important tools we use currently are:

- A Resources Passport to store material, component and product information;
- A Tracking & Tracing module to connect Resources Passports with real-life assets and follow them through value chains;
- A Valuation module to quantify the financial, environmental and societal value of the resources we map;
- A matchmaking platform to facilitate the matchmaking and high-value uses of materials.

The tools we have developed are only effective once they are combined with guidance and change management. The combination of those tools and services are represented in our 'circular house' (Figure 2). The house provides an overview of which elements (building blocks) we include in our approach and how they are linked. Our holistic approach maximises high-value reuse and ensures that new ways of working are embedded in relevant, existing business practices. The building blocks of the circular house will be explained in more detail below. We start with the four tools.

A Resources Passport to enhance transparency

Our Resources Passport creates more transparency in the exchange of excess materials. The passport is a data structure that records information on product, component and material level and their various attributes throughout their life cycles. It offers a clear and uniform format in which organisations can log the characteristics of their streams (origin, composition, toxicity, embedded energy, carbon emissions, etc.), thereby providing anonymous excess materials with an identity relevant for reuse. The structured and standardised format enables scalability in the exchange of materials. By mapping the availability and characteristics of resource flows, we will make high-value matchmaking possible.

The circular economy needs data transparency. This creates a potential conflict with companies that do not want to share all their information. Be it for safety reasons or to secure competitive sensitive information. To mitigate this risk, we created an environment where organisations can securely share information about the resources they need or would like to sell without revealing business sensitive information. We do this using blockchain technology in combination with an authorisation matrix. Our users determine which information they want to share with whom, under which conditions and for how long. Information is always stored on our client's own servers. This way we are able to enhance transparency without compromising privacy.

Securely Track & Trace materials

The ability to track & trace materials is of paramount importance in the circular economy. Our Resources Passports have the ability to communicate with various identifiers. Our system is compatible with Bar and QR codes, NFC-chips or RFID chips. Furthermore, we are technologically agnostic, which means we will continue to facilitate the most optimal technology to achieve this connection between a digital passport and the material/product stream.

The combination of tracking & tracing with our Resources passport allows us to do the following:

- Predict where, when and how many materials will become available;
- Use blockchain technology to converge towards a platform with high-quality information where matches are built around trust.

Valuation

Our valuation module quantifies the financial, environmental and social impact of high-value uses of excess materials. We incorporate economic value of the material after use, as well as environmental values, such as CO_2 emissions, transportation distances, water use, etc. The non-financial values are expressed using the so-called 'Eco-cost' indicator. We quantify these numbers so they can be easily compared with the financial value of a material flow. Combined, they are expressed in the 'Total Value' indicator (explained in more detail in the glossary). The Total Value indicator will allow decision-makers make better data-driven decisions on what to do with their excess material flows.

Matchmaking

Based on the information gathered and generated with the previous three tools shown in the centre of figure 2, we use our matchmaking framework to find high-value circular uses across industry and sector boundaries. We look for optimal matches by using Total Value, a solid business case and the maximum number of life cycles of any excess material, all the while being mindful of our clients' needs and constraints. EME takes a hands-on approach to matchmaking. We facilitate the process every step of the way. The matchmaking is based on our knowledge, experience and assisted by an AI toolset.

Value-added providers

For every process and tool, the question always remains: how do the tools fit in the context specific scope of the client? Especially considering several key factors such as legal, accounting, financial and technical barriers. For instance, how does the new match fit within the current legal framework or how will alternative applications fit within the current contracting and procurement procedures? The matches that we identify are combined with bespoke advice on how to embed new circular solutions in existing business processes. These questions and this context is taken into account together with a key set of value-adding providers: Copper8, Alba Concepts, Ernst & Young (EY), ABN AMRO, Stibbe and material experts. They help in navigating all the pitfalls in the transition towards a circular economy.

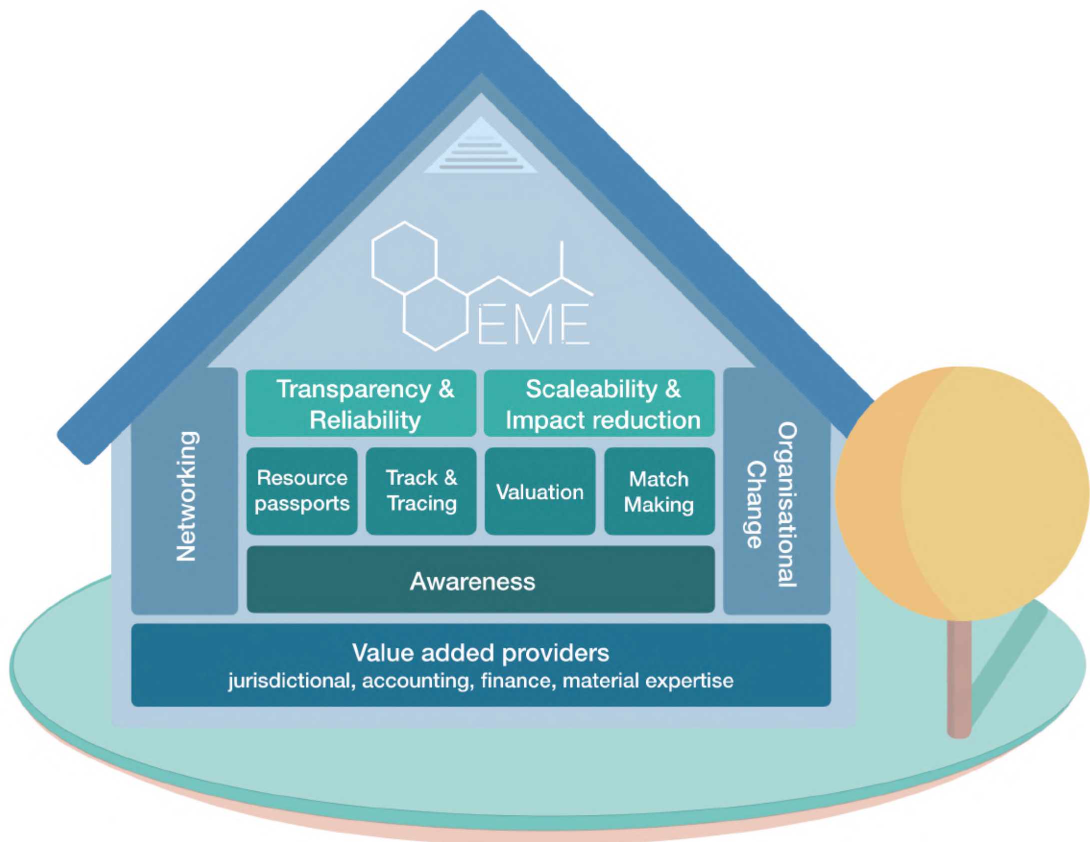


Figure 2: Circular house.

Awareness about the Circular Economy

One of the most important lessons learned from our pilot is: tools are not enough. The tools we developed only work if our clients are aware of their importance in the transition towards a circular economy. This requires awareness building around the topic of the circular economy throughout the organisation. Especially to those who are handling the products and materials. Next to awareness on the topic of the circular economy, it is also important to understand the relevance of the four tools we have developed to ensure their effectiveness.

Network

A successful transition to a circular economy requires cooperation across industries. It is vital, therefore, that our clients are connected to the relevant stakeholders and expertise. The benefit of our network and our role in that network works twofold. Firstly, the EME is connected with frontrunners in the circular economy. Hence, our clients can benefit from the work of the whole network. Secondly, we see that most of the circular solutions require collaboration with key suppliers, strategic customers and third parties (what we call value-adding providers). EME connects these three parties through the platform to make new circular business models happen.

Organisational change

Once we identify the potential for material reuse, we help organisations transition their organisational and production processes to the new circular model. This advice could include suggestions on how organisations should ideally be structured in an economy in which platforms such as ours are commonplace. This change is required to exchange materials on a large scale. Our advice includes (but is not limited to):

- Organisational processes;
- Contracts and procurement processes;
- Software (where possible);
- Strategic suppliers, buyers and contractors.

In addition, we also aid in the creation of new processes, teams and 'resource directors', tenders and management strategies.

EME IN PRACTICE: THE CARPET INDUSTRY

The following example within the carpet industry provides an explanation of how we apply our tools in practice.

Aside from the US, Europe has the largest market for carpet tiles in the world with several of the largest carpet tile factories. Approximately 47% of the demand for carpet tiles in the EU is currently being produced in the Netherlands and Belgium. After being used, however, only 3% of an estimated 1.6 million tonnes of carpet tile waste is being recycled throughout the EU. This means at least 97% is currently being incinerated or landfilled!

To effectively collect and recycle carpet tiles, product identification is of utmost importance. Through product identification, the organisation responsible for the end-of-life treatment of a product would ideally obtain all relevant product information to ensure recyclability. For recyclers, however, it is currently almost impossible to distinguish recyclable carpet tiles from contaminated tiles. A fraction of polluted carpet tile contaminates the entire flow, leaving recyclers with no other option but to incinerate or land fill the entire batch. The Resources Passport ensures the proper collection of material and usage data of a product. In so doing, the passport can help recyclers identify recyclable carpets in order to separate and process them accordingly.

To ensure demand and supply of carpet tiles are matched at the right time, it is important to know when and where this waste stream becomes available. Through our Tracking & Tracing (TT) system, the EME ensures recyclable carpet tiles are traced using a combination of technologies. Even more, the Resources Passport combined with the TT system provides constant access to the quality and location of a material flow. This allows for:

- The proper management of the most optimal and environmentally-friendly logistics;

- Informing recyclers of the timing and type of carpets being received;
- Informing buyers when and which materials can be collected (after processing).

Apart from a lack of transparency and timing, high-quality reuse of materials is problematic due to a lack of urgency and insight into the value of (waste) materials. We determine the value of a material flow with our Valuation Module based on data received from our resources passports and TT modules. The Valuation Module allows for:

- More effective assessment of the financial, ecological and social value of a product;
- Optimalisation of the value of a product over it's entire lifecycle and into the next lifecycle. ;
- Accurate price valuation of a (waste) material flow for (online) markets.

Through our match-making module we enable the connection of waste streams by effectively matching supply and demand. As a result, a marketplace for secondary materials arises: carpet tile manufacturers place their demand for secondary materials on our platform, while other organisations concurrently place their available excess material flows. Since we match supply and demand across sectors and regions, a lack of scale is not an issue, as secondary materials can be sourced from multiple sources. For instance, nylon 66 from the clothing industry or the chalk from the water industry can serve as resources for carpet tiles. We connect providers of secondary materials with buyers on our platform resulting in:

- The choice of the most optimal and highest-value processing option for buyers and recyclers;
- The valuation of flows of (waste) materials;
- The high-value reuse of (waste) materials in consecutive products and services.

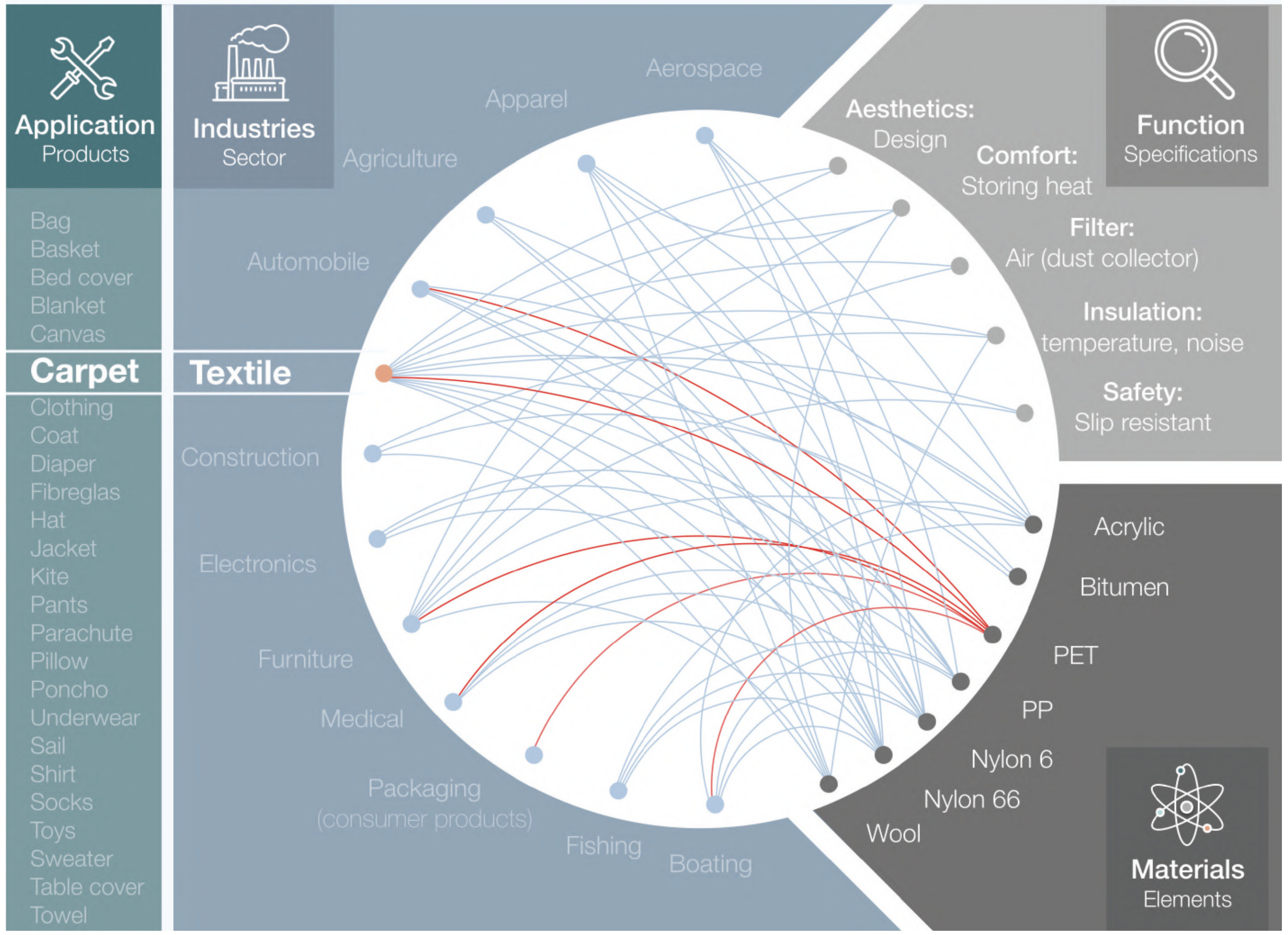


Figure 3:This image illustrates the interconnectedness of industries through using the carpet industry as an example. Since the carpet industry produces, but also collects and recycles its carpets, it is possible to repurpose the containing materials to indirectly connected industries. As shown in the figure, the PET used in the textile industry, can be reused in nummerous other industries.

OUR TEAM

We at EME challenge the status quo of dumping, recycling, landfilling and incineration of materials to only recover the energetic value and shipment to other countries. When we walk across plastic covered beaches, we envision a world in which we reuse and recycle materials to their highest-added value. Just like nature recycles and reuses all the materials of a tree after it dies, we envision an economy in which all materials cycle continuously through open loops while having a positive impact on society and the environment. We are a small team of idealists and entrepreneurs on a mission to help organisations transition to a Circular Economy as fast as possible. We initially started working together because we have a shared goal. We continue on this exciting path together because we have a shared value set, a shared strong inner compass and have a complementary skill set. We are motivated by the creative and innovative power that comes from turning excess materials into new revenue stream for companies. To create an economy in which waste no longer exist is our dream, and to reinstate waste for the valuable resource that it could be is our goal. We are proud to introduce

Christian van Maaren

Founder

Christian, a chronic optimist, always finds possibilities to achieve the seemingly unattainable. With his sense of humor and ability to see the bigger picture he is able to successfully align unconventional stakeholders to face complex challenges, as he did many years for Shell. His vision, curiosity and wit make him a skillful entrepreneur. Driven by making the world inclusive and circular he brought light in remote places with Global Himalayan Expedition and now the Excess Materials Exchange is his new venture. He is convinced that the Circular Economy plays a paramount role in the energy-climate challenge while delivering sound business results.

Maayke Aimée Damen

Founder

With Maayke's passion for sustainability, sharp intellect and strong will it came as no surprise to anyone that she has done some amazing things in her short career. Taking her inspiration from nature to reform economic and industrial systems, she developed the idea of the resource passport that has now been made into Dutch and European policy. Singularity University taught her that exponential technologies hold the key in our transition towards a sustainable society and can deliver the necessary tools. Through various companies and projects she has been working on creating a circular economy for many years. With the Excess Materials Exchange, she can now fully focus on developing a worldwide inclusive circular economy.

Vikas Panday
CTO

Vikas is a technology enthusiast. He is always exploring how new technologies could be applied to solve complex problems and generate a business advantage. In the past, he has worked in various techno-functional roles for start-ups as well as for Fortune 100 companies. Currently, he regularly contributes to open source projects and the development of decentralised solutions (using Hyperledger). At EME, he is responsible for building and leading the technology strategy, as well as innovations that help scale the EME platform. Vikas is convinced that real progress is when society benefits from your contribution and strongly believes that EME is a great example of bringing that positive impact on the ecosystem.

Jasper Roosendaal
Analyst & Resources Passport Lead

Jasper, co-founder and consultant of the Circular Economy Academy, has a background in environmental studies and sustainable business innovation. Having worked as a sustainability consultant for multiple circular initiatives and companies, his strong analytic skills and eye for detail allow him to be a sturdy backbone in his projects. Combining his feeling for sustainable entrepreneurship and experience working with the blockchain, he firmly believes EME is the perfect embodiment of his vision for how circular economy should be done. Therefore, he will put every skill to the test to help EME grow as a cornerstone solution for sustainable growth in our society.

Caspar Aardenburg
Analyst & Resources Passport Lead

Caspar's drive originates from the roots of nature. Starting in the study of holistic environmental systems, ecology and a strong interest for society and economics, he is like a duck takes to water when it comes to circular economy. Through collaboration with several start-ups, governmental agencies in Singapore and a master's in business innovation, he can approach business problems from a wide variety of angles. Except for trivia, Caspar could be in no better place than EME to flourish. Constantly asking the "why" and "how" of things and with a critical mindset, he can crack any problem, providing unconventional solutions in line with the bigger picture.

Jeffrey Wiering
Analyst & Business Developer

Through his experience as circular consultancy intern at Metabolic, Jeffrey developed a fine balance between idealism and pragmatism. He knows how to get things done, properly. The skills and creativity he applies in his music production are reflected in his work and support to make EME grow and prosper. During his academic career, he co-founded Fixy, matching supply and demand through a two-sided marketplace for the refurbishment of bikes, just like EME matches supply and demand for excess materials. With plenty of zen to feed the entire team, a keen eye for detail and a capability for marathon like sprints, he is a perfect match with EME.

Remi Elzinga
Analyst & Business Developer

When it comes to innovation and sustainability, Remi is a true fanatic. His multi-disciplinary background in neuro, behavioral and environmental sciences allow him to solve challenges in original and creative ways. As brilliant as his recipes, Remi brings new flavors to the table when it comes to tackling sustainability challenges. He believes dedication and intellect are necessary traits to create results, but only strong teamwork grants success. This is what makes Remi a great player within the Excess Materials Exchange. His vision of implementing a circular economy through innovative technology and cross-sectoral collaboration is what connected him to EME. Armed with this vision, a curious mindset and a wide variety of skills he is most-ready for the challenge.

Jeremy Croes
Head of Growth

Very early on in his life Jeremy became fascinated with the link between nature and business. Inspired by the book "The Zeronauts" by John Elkington, Jeremy launched and managed the Zer0 Waste 2030 program for the biggest airport in The Netherlands. Today this airport is a global leader in the circular economy. Along the way Jeremy also founded his own companies and developed a passion for validating circular business models, e-commerce, internet marketing and growth hacking. He was a Sustainability Professional by day and a Growth Marketer by night. He founded SPINUP in 2018, which allows him to combine all his passions and help circular businesses, like the EME, grow their impact.

Chapter 3
THE PILOT

“VW Beatle” by studio DRIFT - Materialism, photograph by Ronald Smiths.

THE PILOT

Introduction

During a pilot we, together with ten companies and our collaborators, explored the viability of the EME. The goal of the pilot was to help organisations transition to the circular economy by creating a scalable market, including a market price, for secondary materials. Seven of the ten pilot participants are listed in this report.

During the pilot we investigated the optimal functionalities of the platform to de-risk use and be able to scale internationally. Furthermore, we prepare companies to, on a large scale, buy and sell secondary materials.

We offered our clients the following:

- Our Resources Passport that provides an identity to their materials/product;
- Tracking and Tracing of their materials/products;
- Financial and non-financial (ecological and societal impact) data about their streams.
- Alternative, high-value destinations for their materials/products.

In addition, we guided their exploration into the use of secondary materials to substitute current inputs. The organisations on the next page participated in our pilot. We choose this diverse range of organisations, since they are all frontrunners in the circular economy and have expressed high ambitions. Moreover, we see that the highest-value matches are often not made within the same sector but between sectors. Hence, testing our marketplace and helping frontrunners from different sectors was a great place to start.

We aimed at creating win-win partnerships, in which our platform taps into the strength of other organisations. We partnered with the following organisations to combine efforts to transition to a circular economy: law firm Stibbe, consultancy firm Ernst & Young and the bank ABN AMRO.

Our collaborators provide us with the legal, accounting and financial skills and knowledge we need to build the foundations of EME, plus help exchange secondary materials on a large scale. Over the course of several in-depth workshops with them and together with our pilot participants we explored the legal environment to reuse and exchange secondary materials, fleshed out the financial implications of the exchange and found ways to estimate the environmental and social impact of making materials available for secondary use. On the subsequent pages, our collaborators describe their reasons to partner with the EME. They address the results of the joint research we conducted and discus the next steps.

On the subsequent pages you will first discover more about our collaborators and the results of our combined efforts. Thereafter we will tell you more about our pilot participants and the results of the research that we conducted with them.

In the pilot, EME identified a potential CO_2 emission reduction of 123 kilotonnes CO_2, which equals the emission of all citizens of Amsterdam (862,987) driving from Amsterdam to Milan.

Collaborators

ABN·AMRO

EY Building a better working world

Stibbe

A Selection of Pilot Participants

Schiphol Group

ProRail

Ministerie van Infrastructuur en Waterstaat

sodexo

Heembouw

Tarkett

aqua minerals

ABN·AMRO

- Written by ABN AMRO -

ABN AMRO is a modern full-service bank with a transparent and client-driven business model with traditional and digital banking products, a moderate risk profile, a clean and strong balance sheet, a solid capital position and strong funding profile. They serve Retail, Private and Corporate banking clients, with a primary focus on the Netherlands and with selective operations internationally. ABN AMRO is in the top 10% of the DJSI and wishes to accelerate the sustainability shift together with its clients.

Circular economy goals

ABN AMRO has the ambition to show action leadership in the transition from a linear to a circular economy. By 2020, it is their goal to finance circular business assets of one billion euros through at least 100 circular financing deals in all sectors. The total emissions reduction is to be at least one million tonnes of CO2.

They provide support to their clients and work on financing new circular business models. For example, they offer the Business Innovation Workshop to their clients and employees, during which they help clients develop a more circular business model. When it comes to financing, ABN AMRO reserved a special envelope to finance circular business models. All transactions in this envelope are studied to gain experience in financing circular businesses. Also, they initiated developing a shared definition of circular finance which can be found in the Circular FinancenGuidelines together with their peers ING and Rabobank. And last but not least, this autumn was the one-year anniversary of their circular pavilion Circl in the centre of the Amsterdam Business District.

Partnership with EME

ABN AMRO strongly believes in the EME, because it is cross-sectoral, holistic and matches are facilitated. Because the platform is cross-sector, more creative and valuable matches can be realised. The platform is holistic because it regards not only financial value, but also social and environmental value. First a lot of data and users need to be on the platform, ABN AMRO is a partner to help the EME grow and to learn from this process.

ABN AMRO has committed to a pilot where the bank actively introduces EME to its commercial clients. They actively promote the EME to their sales force and ask them to show this as a solution to their clients.

Outcomes and next steps

EME has inspired and engaged many ABN AMRO employees on the subject of circularity. We encourage more companies to partner with the EME and identify their excess materials on the exchange. The more parties participate, the less materials turn to waste. Also, the prices and destinations determined by their AI system will become more accurate whereby the reliability of the platform increases. In the future, they would be happy to use to increase the accuracy of their assets' valuation.

Maayke Aimée Damen and Christian van Maaren, the EME founders, build a great network of circular professionals around the pilot by organising regular meetings. It is a nice way to meet other professionals active in the area of circularity. Also, ABN AMRO enjoys their progressive thinking about the circular economy and can-do mentality. This is a source of inspiration for ABN AMRO.

> "The EME, partner of ABN AMRO, builds knowledge that functions as a catalyser for modular design, residual stream separation and improvement of data management.
>
> -ABN AMRO -"

Collaborating towards a circular economy

- Written by Julia van Boven and Sander van Wijk, ABN AMRO -

At ABN AMRO we have a strong belief that circular business models are going to be the business models of the future. That the circular economy will be the economy. That this system will increase social welfare and limit further global warming. Therefore, we strive to accelerate this systemic change, a transition away from the current take-make-waste economy that requires creativity, experimenting, and most of all, collaborations. Here you read about our story of collaboration with our banking peers, our clients, and the Excess Materials Exchange for the shared purpose of creating a circular economy.

Developing shared language

Our first important step was to set three goals for ABN AMRO. By 2020 we want to achieve €1 billion for financing in circular assets, 100 circular financing facilities and a related 1-million-ton reduction in carbon emissions. When we communicated these goals, there was no common definition of a circular financing facility. Therefore, we combined forces with ING and Rabobank, our Dutch banking peers. Together we established the Circular Economy Finance Guidelines. By introducing these guidelines together, the banks lay the groundwork for accelerating investments in circular business models that has been used as input for the UN High Level Political Forum; the conference where ambitions to achieve the SDG's are shared.

Understanding new business models

Despite our belief in circular business models, financing them poses a challenge for the financial sector. Many circular companies are start-ups, lacking a track record and making it more difficult to apply traditional risk assessments. To overcome this challenge, we seek close collaboration with our clients. Firstly, we have established an ambassador network of forty client-responsible employees, that dedicate twenty percent of their time to sustainability and the circular economy. They are the antennae with clients through which we source and distribute information on changing circular business models. In addition, we have allocated money for more high-risk circular investments. As a result, we are able to serve clients who are frontrunners in the field of circularity. Together with them, we learn about the risks in circular business models and gather new data on which new risk models can be developed. These new risk models are essential in understanding and estimating the risk of new business models.

Innovation beyond 2020 with the Excess Materials Exchange

Our partnership with the Excess Materials Exchange (EME) serves a purpose that goes beyond our 2020 ambition. We collaborate with the EME, because we wish to develop a completely different way of banking: the materials bank. We believe we can use our capacity and experience in managing streams of money to steward streams of materials. For example, by lending materials to commercial clients with a product-as-a-service business model. This drastic reorganisation of ownership will stimulate extensive and high value (re-)use of resources and can help this client group by lowering their need for upfront investments.

To start the materials bank, we need to gain knowledge about the usages and value of secondary materials. We also need to learn about the environmental and social impact of different reuse possibilities. The EME, partner of ABN AMRO, builds this knowledge. Knowledge that functions as a catalyser for modular design, residual stream separation and improvement of data management. These are steps towards a circular business model that we encourage our clients to make. Also, for this reason we started a pilot with the EME in 2018, "Opportunities with waste". We actively start the conversation about residual streams with our corporate banking clients in the sectors construction, retail or industries. Often, this conversation gives the advice to compose a resources passport and identify reuse opportunities with the help of the EME. Through this new way of collaboration, we build towards a circular bank and make a positive impact along our journey. The circular economy can only be realised through collaboration. This is true for our commercial clients, active in all different parts of the value cycle, just as it is true for ABN AMRO with our ambition to accelerate the transition to a circular economy. We are proud of the pilot the EME has realised and look forward to our further cooperation.

Stibbe

- Written by Stibbe -

Stibbe is an internationally-orientated full-service Benelux law firm with over 375 lawyers. From their main offices in Amsterdam, Brussels and Luxembourg, together with their branch offices in Dubai, London and New York, their lawyers work in multidisciplinary teams to deliver pragmatic advice. They build close business relationships with their clients that range from multinational corporations to state organisations and public authorities. By understanding the commercial objectives, market position and sector or industry of their clients, Stibbe can provide specialist and effective advice.

Circular economy goals

Stibbe is committed to reducing its carbon footprint by implementing sustainable practices and by heavily investing in their facilities. In addition, they are proud that their legal expertise is often used in the context of sustainability.

In September 2017, their new office in Amsterdam received a BREEAM Excellent (four stars) quality mark from the Dutch Green Building Council. Eco-friendly aspects of the building include the heat and cold storage installation (ATES/WKO), sustainable use of materials and incentives to use public transport to travel to and from work.

When dealing with third parties and suppliers, they ensure that they agree to comply with their terms in meeting environmental and social requirements. As a forward-thinking law firm, they enjoy advising and working with companies like the EME given their role in supporting the circular economy.

Partnership with EME

They collaborate with the EME via their new programme called Stibbe StartsUP, which was launched in 2017 with the aim of providing legal advice to start-ups at the forefront of innovation. Being able to provide this kind of legal service as an experienced commercial law firm is valuable for start-ups because they often find themselves operating in uncharted territory. For them, this partnership is particularly interesting because the EME is also involved in new markets that have not been fully explored before. They wanted to help the EME handle legal aspects connected to developing their platform and at the same time improve their understanding of the challenges companies deal with in the rapidly expanding digital marketplace. The fact the EME also supports the circular economy also appealed to them given their focus on sustainability.

Outcomes and next steps

Together with the EME Stibbe has developed various legal models to help and create a sustainable business. For example, Stibbe has researched different excess materials (e.g. cardboard boxes) and assessed the legal implications to ensure reuse options can be easily facilitated. The possibilities to find a reuse option for the materials in the easiest legal way.

According to Stibbe, the EME is a professional and knowledgeable organisation. They are very enthusiastic and genuinely want to do all they can to speed up the transition towards a circular economy. They have thoroughly enjoyed working with the EME and look forward to working with them in the future.

> “Some challenges in Dutch waste law remain, but we are certain that we will be able to make waste understandable and predictable for EME and its users.
>
> - Stibbe-”

How to make waste legislation more circular economy proof

- Written by mr. Bram Schmidt, mr. Anna Collignon & dr. mr. Valérie van 't Lam -

Stibbe has been EME's legal advisor for over a year, covering a wide range of legal subjects. Although Stibbe has helped EME with drafting employment and intellectual property contracts, they have mainly focused on administrative law issues (e.g. waste law). For EME and its users, waste law continues to pose many challenges, but EME and Stibbe are confident that these challenges are manageable. Before we tell you how and why these challenges can be overcome, we will first describe Dutch waste law and outline some of the difficulties.

The challenges of Dutch and European waste law

Under Dutch waste law, secondary materials may qualify as 'waste' even if they have economic value. This is because waste is defined as "any substance or object which the holder discards", which is particularly broad. This definition comes from European law, so it applies to the whole European Union. According to the definition, even the most valuable goods can be waste, as long as the holder of these goods wants to get rid of them. Essentially, it is all about the intention of the person who discards the goods. Therefore, it is very subjective whether materials qualify as waste or not and depends on the specific circumstances of the case. As a result, waste law has been quite unpredictable. This unpredictability impacts EME, as its business model operates on the borderline between waste and normal resources. For example, if an EME user wants to sell his leftover materials, does he want to 'discard' them? Or is the transaction a normal sale of materials? Whether goods are regarded as waste or not is important because once the goods qualify as waste the following legal obligations may apply: companies may need to (i) apply for a permit for the processing of waste, (ii) notify the competent authorities when they receive or transfer certain materials, or (iii) register the kind of waste they process and how much.

EME wants to help transfer useful materials from a party that does not need them anymore, to another company that does. To gain a better understanding of the needs of EME's clients, EME and Stibbe organised an expert meeting on waste law and the implications for its transactions. One of the outcomes of this meeting was that EME's clients consider it difficult to predict whether secondary materials are waste or not. Instead of risking non-compliance and enforcement, companies prefer to treat their secondary materials as waste, which means that they often take on unnecessary administrative burdens. EME and its users do not consider the secondary materials as waste, but instead see them as valuable resources. The qualification of secondary materials as waste is unhelpful because it imposes unnecessary burdens on EME and its users given that they are not actually dealing in waste, but in resources. The qualification as waste also does not properly reflect what EME actually does and intends. Therefore, EME and Stibbe have examined how to interpret waste law in a helpful way, so that it only applies when necessary.

How to overcome the challenges of waste law

EME and Stibbe have searched for an interpretation of waste law which benefits EME and helps it to realise its objectives. This search is also in line with developments in Dutch waste law in general. Over the last few years, there have been many positive developments, suggesting a more lenient approach in waste law, which promotes the circular economy. Dutch case law from the Council of State and the Supreme Court, and case law from the European Union is no longer as strict as it used to be. The most important source of European waste law, the Waste Framework Directive, was amended in 2018 in order to facilitate the circular economy, although the changes have only produced a slight improvement in practice. The Dutch government has been influential in making changes to Dutch waste law, so it is ready for the circular economy. The government has consulted many companies about their difficulties in transitioning to a circular economy. The Ministry of Infrastructure and Water Management issued a guidance document on the difference between waste and non-waste in the summer of 2018. The guidance document is helpful in practice, especially by providing examples of cases where the difference is not always clear.

EME and Stibbe are also contributing to these developments. They met with the Ministry of Infrastructure and Water Management, the Ministry of the Interior and Kingdom Relations and with the European Commission. EME, Stibbe and the ministries are now working together on solutions, such as: (1) an exemption from various rules of Dutch waste law in order to experiment with EME and comparable initiatives, or (2) to first obtain a legal opinion from the Ministry of Infrastructure and Water Management on whether certain substances are waste or not. These solutions may finally clarify certain aspects for those dealing with waste law. Stibbe will further advise EME on the exemption and the possibility of obtaining a legal opinion from the Ministry of Infrastructure and Water Management. The meeting with the European Commission was also very useful by clarifying that 'waste 'as defined in European waste law, will remain the same for at least the next few years. The parties also discussed the possibility of further contributing to accessibility and predictability of waste law by adjusting the guidance documents. These meetings and experiments could be valuable in further developing waste law.

Like the Dutch government, EME and Stibbe want to develop the circular economy. They want to ensure that EME's users can navigate through waste law without difficulty. Some challenges in Dutch waste law remain, but we are certain that we will be able to make waste understandable and predictable for EME and its users.

> "EME wants to help transfer useful materials from a party that does not need them anymore, to another company that does
>
> - Stibbe -"

EY Building a better working world

- Written by EY -

At EY, they are committed to building a better working world – with increased trust and confidence in business, sustainable growth, development of talent in all its forms, and greater collaboration. They want to build a better working world through their own actions and by engaging with like-minded organizations and individuals. EY's Climate Change and Sustainability (CCaSS) multidisciplinary team combines its core experience in assurance, tax, transactions and advisory with climate change and sustainability skills and deep industry knowledge.

Circular economy goals

EY is committed to building a better working world. A better working world must foster sustainable growth based on strong fundamentals – societal value, increased productivity, innovation and a broader talent pool. A circular economy can contribute to these fundamentals. EY CCaSS believes that if organizations are to benefit from the circular approach, high-impact decisions are to be made. EY has the knowledge and the network to be a partner in this transition. EY's circular business approach answers three main questions for their clients:

- What are the main drivers of circular business?
- What is the appropriate circular business model?
- How can your organization design circular solutions

EY's True Cost Accounting (TCA) approach offers transparency on the process of value creation and value consumption of an organization by measuring and monetizing shared value and externalities. This means that environmental, social and economic effects (both positive and negative) are considered, resulting in an integrated profit & loss statement. TCA is a method aimed to inform decision makers in a manner that allows them better decision making for the company and its stakeholders.

Partnership with EME

EY believes in the vision of EME that we should not see products that cannot be used anymore in one function as waste products, but as potential inputs for another product. EY CCaSS has many years of experience with TCA and circular economy. EY supports EME with quantifying environmental (and in the future potentially social) impacts of excess materials with the purpose to help EME and participants to understand the non-financial value creation of their products and supply chain.

EY envisions that this cooperation will spread the knowledge on TCA and will enable companies and external stakeholders to improve decision-making and become more transparent and fulfil their societal purpose.

Outcomes and next steps

By creating a digital marketplace for excess materials, EME's role is to facilitate the transition and to create awareness across industries over the worth of their waste. So far, EY has cooperated in the pilot phase by working with EME on what data should be collected for the waste streams and how this data is used in order to calculate the environmental impacts of the materials. Together they engaged with pilot participants over how circular economy can be realized and what information is important for them to be able to make better decisions for their waste materials.

In the future, EY could also take on an assurance provider role, providing confidence to the tool users on the quality of the information. In a future project EY would also like to investigate further together with EME and the participants, the opportunity to incorporate social impact measurement data in the tool. EME is working hard on bringing different industries together in order to promote circular economy. EME has given the opportunity to participants to engage in conversations about their needs and expectations, but also their difficulties with moving towards a circular economy. EME is passionate with creating the tools that will enable companies to take the next step and they are eager to also develop their knowledge and the participants knowledge on the true value of materials.

Chapter 4
RESULTS

RESULTS

In this section we will go into depth in the work that we did with our collaborators. We are proud to have ten organisations participate in our pilot. On the following pages, the reusults of a selection of participants is shown: ProRail, Rijkswaterstaat, Schiphol, Aquaminerals, Heembouw, Sodexo and Tarkett.

All these organisations are frontrunners in the transition to a circular economy and have expressed ambitious goals to achieve this. These organisations have expressed that EME is one of the avenues to quickly transition. We offered our clients the following:

- A Resources Passport that provides an identity to their materials/product;
- Tracking and Tracing of their materials/ products;
- Financial and non-financial (ecological and societal impact) data about their streams;
- Alternative, high value destinations for their materials/products;
- In addition, we guided the exploration into the use of secondary materials to substitute current inputs.

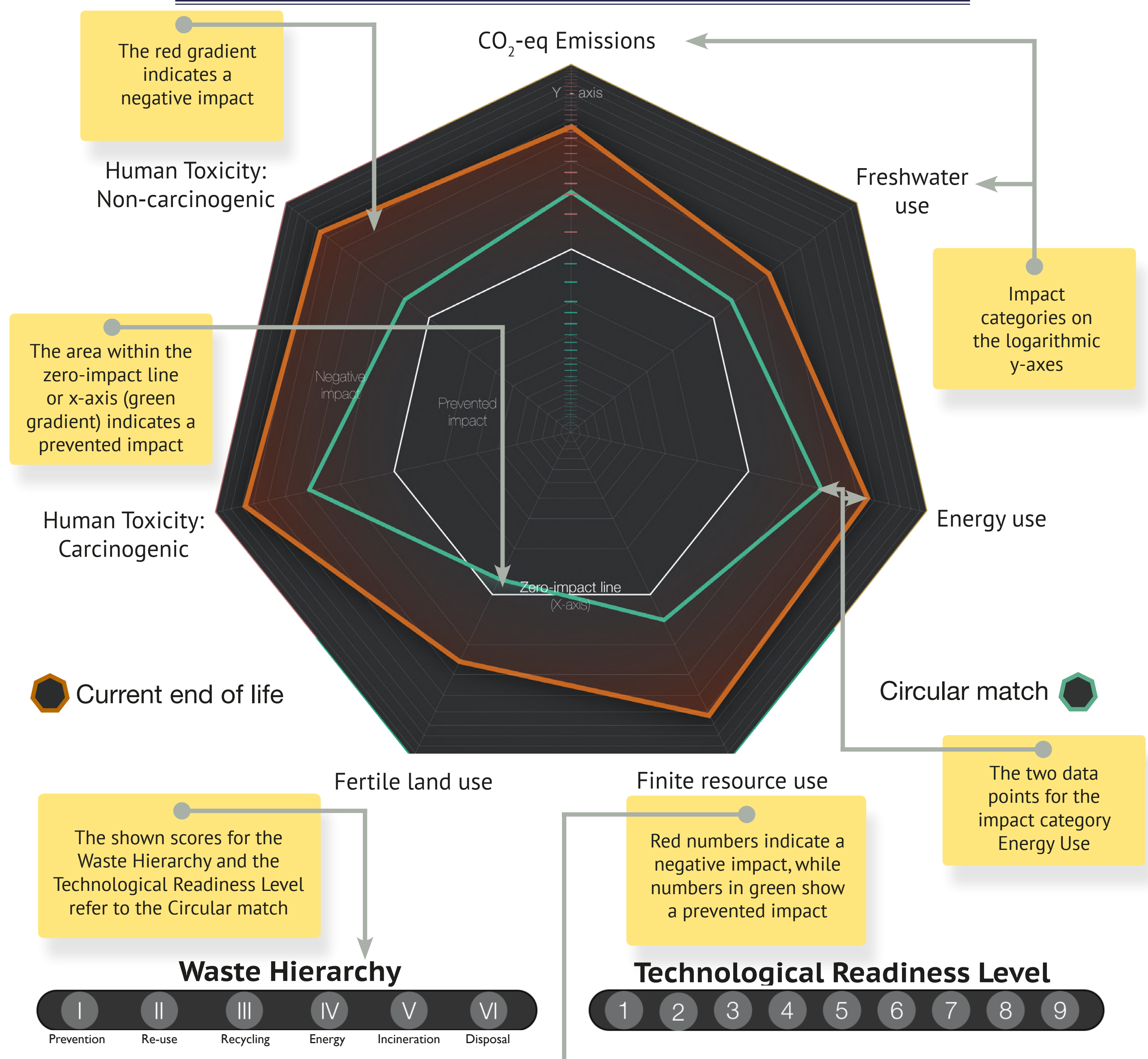
On the coming pages we will go into depth regarding the work we did together with a selection of our pilot participants. You can find a short introduction about the organisation, their ambitions and their motivations to participate in the EME pilot. Thereafter, you can find an overview of the material/product streams that we analysed for these companies and the results of this analysis. The results include a circular match, an alternative high-value destination and the financial and non- financial (environmental and societal) impact thereof.

We used two different measures, Eco-Costs and Total Value, to describe the potential of the circular match. Eco-Costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution, material depletion related to the production, transportation and end-of-life treatment of a product. As of yet, eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). Furthermore, in order to assess the Total Value creation of a process or product, we need an approach able to incorporate all dimensions of sustainability and externalities. Herewith, Total Value represents the sum of the financial business case combined with the environmental and social values expressed as eco-costs. This measurement offers transparency and enables better decision making.

On the right side of this page we show the radar chart visualising the impact of all 18 streams. We have added textboxes providing information on how to effectively read the radar chart. The **glossary** on page 85 provides explanation for the figures, visualisations, Technological Readiness Level and Waste Hierarchy included on the match pages.

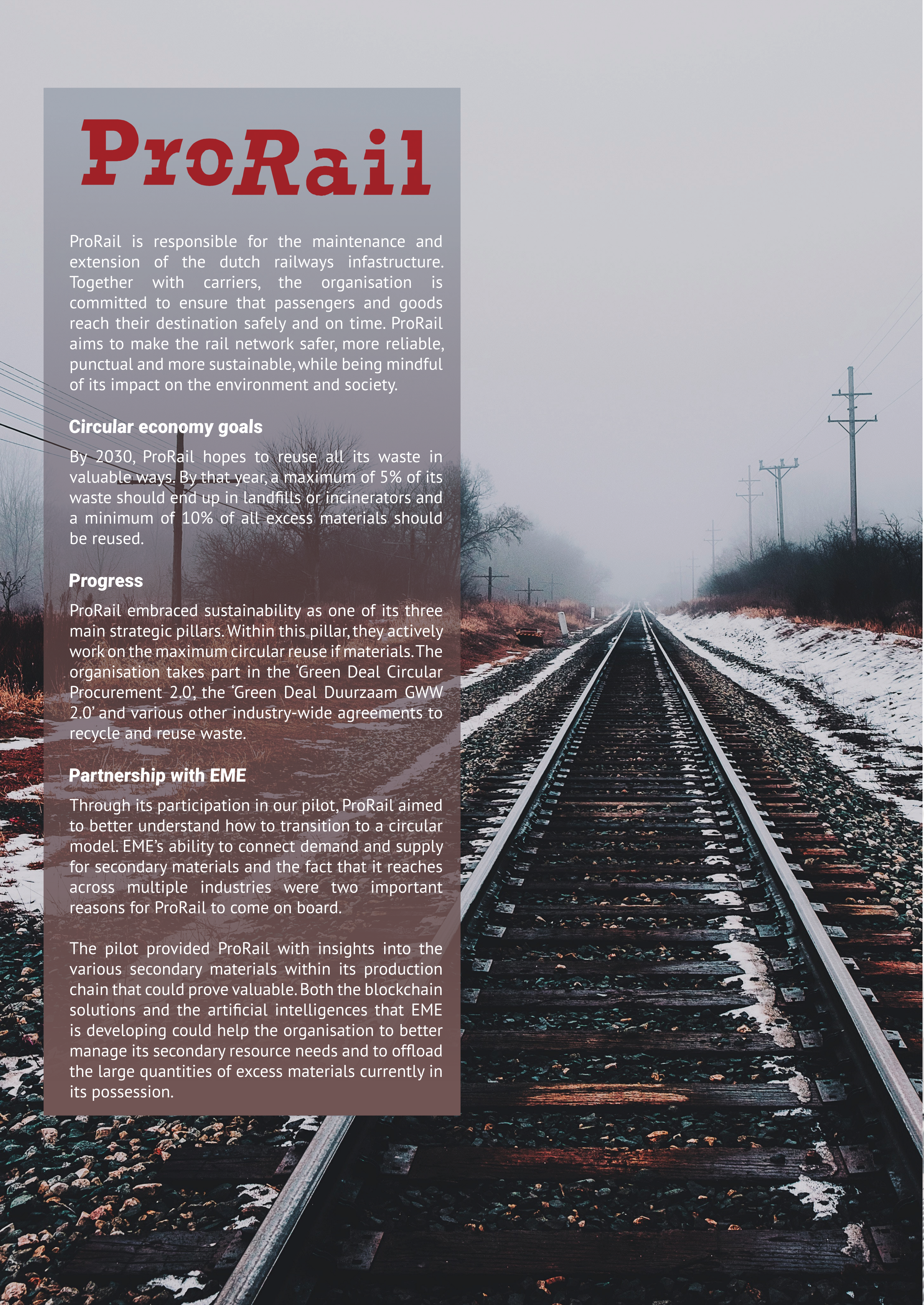
Total Potential Impact of the Pilot

Current end of life vs. Circular Matches



Total Impact of the Pilot		Current end of life	Circular match	Unit	Percentage Change
Impact Categories	CO_2-eq emissions	217,106,704	94,101,824	kg CO_2-eq	57%
	Freshwater use	2,862,614	711,980	m^3 water-eq	75%
	Energy use	4,379,301,594	1,496,638,522	MJ	66%
	Finite resource use	6,246	1,289	kg Antimony-eq	79%
	Fertile land use	366,715,247	-53,936,247	kg C Deficit	115%
	Carcinogenic	161.38	89.49	CTUh	45%
	Non-carcinogenic	166.56	37.49	CTUh	77%

EME



ProRail

ProRail is responsible for the maintenance and extension of the dutch railways infastructure. Together with carriers, the organisation is committed to ensure that passengers and goods reach their destination safely and on time. ProRail aims to make the rail network safer, more reliable, punctual and more sustainable, while being mindful of its impact on the environment and society.

Circular economy goals

By 2030, ProRail hopes to reuse all its waste in valuable ways. By that year, a maximum of 5% of its waste should end up in landfills or incinerators and a minimum of 10% of all excess materials should be reused.

Progress

ProRail embraced sustainability as one of its three main strategic pillars. Within this pillar, they actively work on the maximum circular reuse if materials. The organisation takes part in the 'Green Deal Circular Procurement 2.0', the 'Green Deal Duurzaam GWW 2.0' and various other industry-wide agreements to recycle and reuse waste.

Partnership with EME

Through its participation in our pilot, ProRail aimed to better understand how to transition to a circular model. EME's ability to connect demand and supply for secondary materials and the fact that it reaches across multiple industries were two important reasons for ProRail to come on board.

The pilot provided ProRail with insights into the various secondary materials within its production chain that could prove valuable. Both the blockchain solutions and the artificial intelligences that EME is developing could help the organisation to better manage its secondary resource needs and to offload the large quantities of excess materials currently in its possession.

RAILWAY TRACKS

54E1-type (R260Mn) railway tracks are the most commonly used railway track in the Netherlands. The majority of these railway tracks are produced by Voestalpine Stahl in Austria and transported by train to the Netherlands in pieces of 120 m. The steel consists of 18 different elements and is extra strong because of higher concentrations of manganese. Manganese is known to increase the hardness and tensile strength of steel. With proper maintenance operations, the tracks have an average lifetime of around 40 years. This means for ProRail that between 200 and 300 km of railway tracks are being replaced on a yearly basis.

> *"EME's ability to connect demand and supply for secondary materials and the fact that it reaches across multiple industries were two important reasons for ProRail to come on board.*
>
> *- ProRail -"*

Current End-of-life scenario

In the current end-of-life scenario, around 90% of all tracks are exported to Asia or Turkey for a scrap price of €7,500-8,000 per kilometre (based on a scrap price of €0.14-0.15/kg of steel). After arriving on location, they are either reused or recycled through a melting process. In rare cases, recovered railway tracks are reused in the Netherlands at industrial sites where lower functional requirements for the tracks are in place.

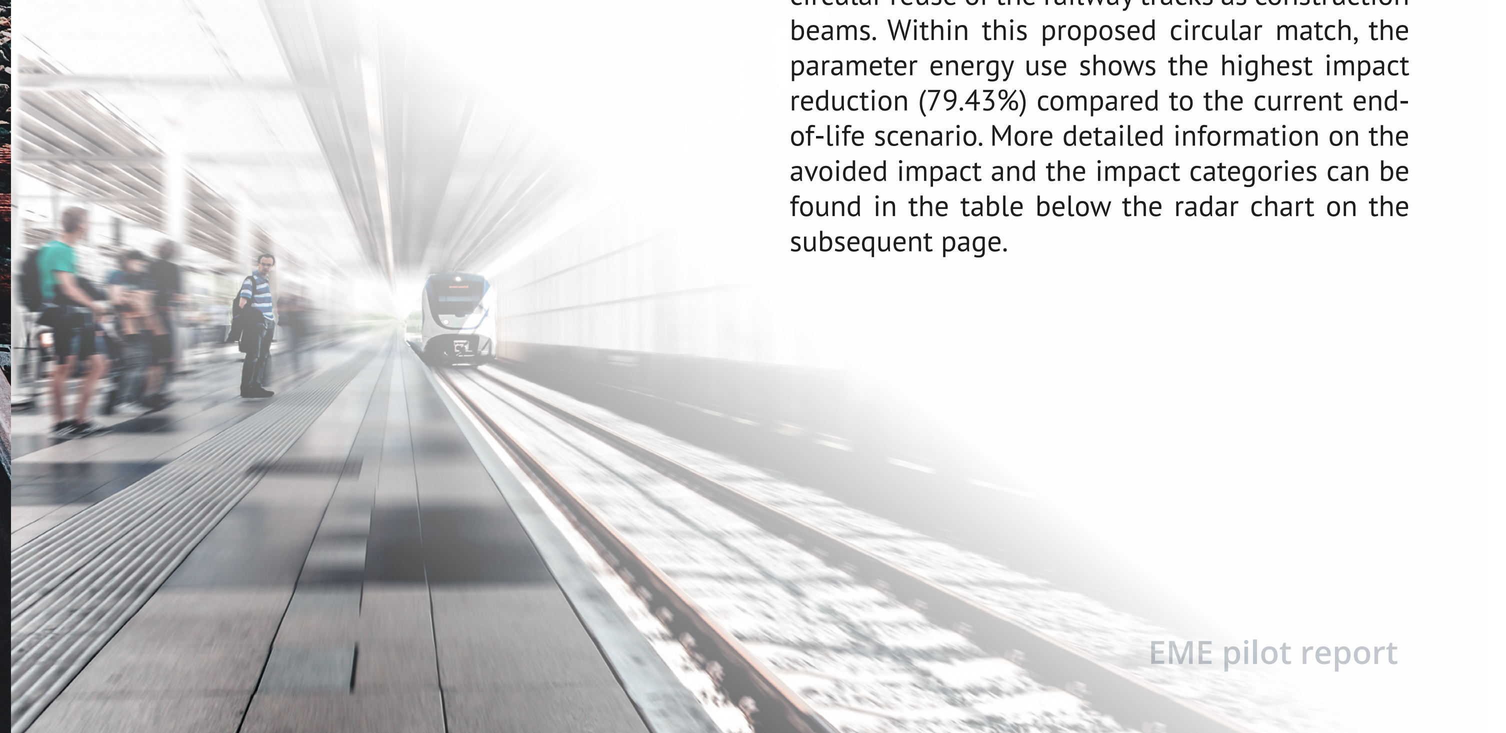
Match Possibilities

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

- Reusing railway tracks as construction beams in buildings with innovation partner Arup;
- Reusing railway tracks as a functional support structure in the shifting water sides of the Amsterdam canals with innovation partner Arup;
- Reusing railway tracks in touristic structures such as bike racks, information panels or wildlife grids.

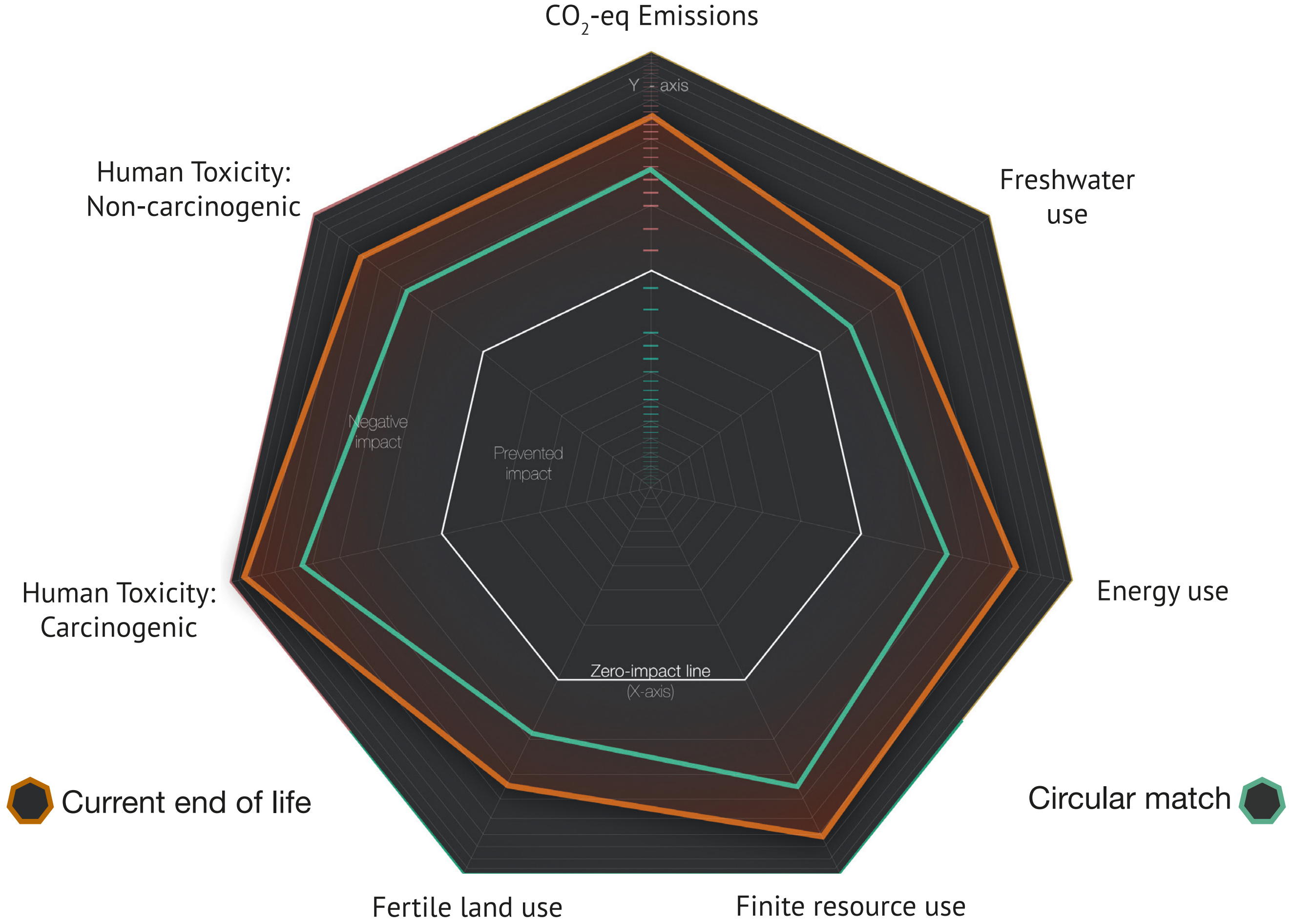
Environmental Impact

We calculated, based on impact data for high-quality steel from the Ecoinvent database (Simapro), the total impact per kilometer track. Taking into account production, transportation and end-of-life treatment for both the current end of life and the proposed circular match, we calculated a complete impact comparison. We visualised the impact of our optimal circular match based on a selected set of parameters; circular reuse of the railway tracks as construction beams. Within this proposed circular match, the parameter energy use shows the highest impact reduction (79.43%) compared to the current end-of-life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart on the subsequent page.

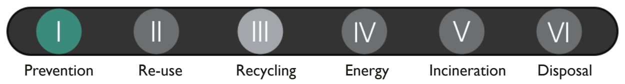


Impact Difference

Current end of life vs. Circular Match

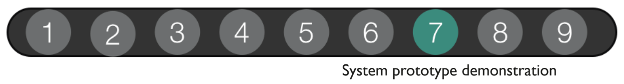


Waste Hierarchy



Railway tracks are currently being recycled. When the proposed circular match is applied, this product prevents virgin materials from being used. This is considered to be two steps higher in the waste hierarchy (in Dutch known as "Ladder van Lansink").

Technological Readiness Level



Prototype models are being placed and tested in an operational environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	89,608	18,756	kg CO_2-eq	**79,1%**
Freshwater use	198.18	41.17	m^3 water-eq	**79,2%**
Energy use	1,045,172	214,978	MJ	**79,4%**
Finite resource use	1.08	2.67E-01	kg Antimony-eq	**75,3%**
Fertile land use	136,805	29,055	kg C Deficit	**78,8%**
Carcinogenic	1.99E-02	4.61E-03	CTUh	**76,8%**
Non-carcinogenic	3.29E-03	9.15E-04	CTUh	**72,2%**

Financial Impact

Railway tracks are sold for a scrap price of €0.14 per kilogram. One metre of railway track weighs 56.4 kilograms, resulting in a value of €7,900 per kilometer. Based on an average replacement of 250 km/year, the total second-hand value of railway track we estimate at €1,975,000. When railway tracks are reused for consecutive functional purposes such as construction beams the financial value would increase significantly. To illustrate, an average steel construction beam is worth €20-€50 per meter.

Eco-Costs

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. As of yet, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in Figure 4. For railway tracks, the eco-costs of the current end-of-life scenario are €14,772 per kilometre. When subtracted from the financial value of €7,900 per kilometer, the Total Value per kilometre railway track amounts to -€6,872. In comparison, the eco-costs of the proposed circular match are €5,903 per kilometer. When substracted from the financial value of the proposed circular match, on average €35,000 per kilometer, the resulting Total Value amounts to €29,097 per kilometre of railroad track (Figure 4). This is an increase in Total Value of €35,969 per kilometer.

Recommendations by EME

ProRail has expressed its intention to make better use of material flows that are currently not being reused at high value. ProRail could collaborate with EME and Arup in the process of realising an implementation trajectory for railway tracks as construction beams. This circular match has been recommended by EME, due to being the option with the highest financial value and potential impact reduction. In line with their ambition to realise the full potential of materials circulating within ProRail, we have started the collaborative development of an internal marketplace. This platform will create an overview of its internal material flows, making it possible for ProRail to effectively trade within the organisation. For example, by mapping the location and quality of the used railway tracks, ProRail can effectively start using these materials internally in the construction of its buildings and railway stations.

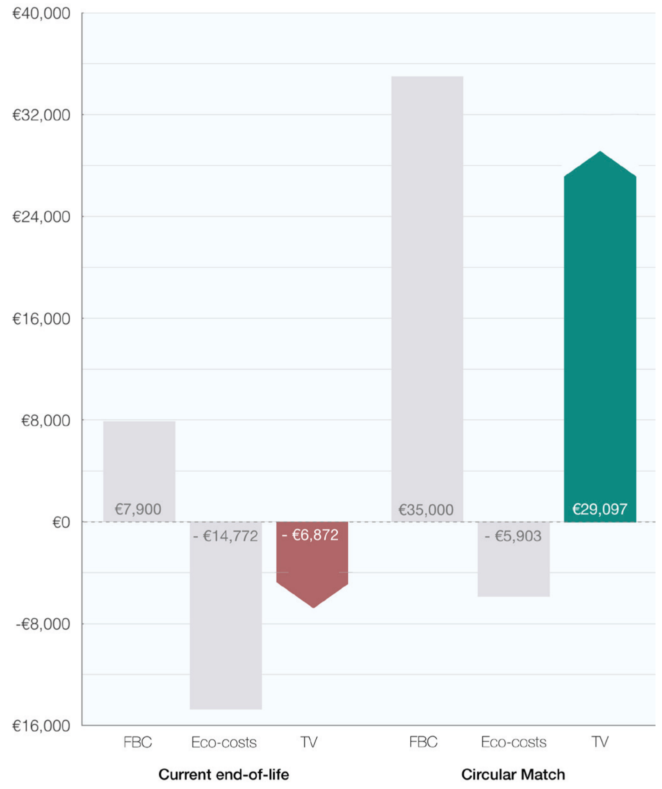


Figure 4: This graph visualises the financial business case (FBC) of railroad tracks per km and shows the difference in "Total Value (TV)" with eco-costs included.

RAILWAY SLEEPERS

This analysis focusses on NS90-type railway sleepers. NS90-type railway sleepers are rectangular blocks made out of reinforced concrete and are placed perpendicular to the railway tracks every 60 cm. Railway sleepers have the important function of keeping railway tracks in place and sustaining the ability to hold railbound vehicles and machines. Railway sleepers have a potential lifetime of 20-30 years. Each railway sleeper contains 288 kg of concrete and 6 kg of reinforcement steel.

Current End-of-life scenario

Railway sleepers have a lifetime of approximately 20-30 years. After this period, they are replaced due to a loss in quality and functionality. End-of-life railway sleepers are checked for quality. Based on this assessment, the sleepers are either reused or are processed by the contractor hired to carry out the replacement. Due to the high value of concrete and steel, railway sleepers are currently being recycled by crushing the concrete. Subsequently, the concrete is being used as a secondary material for filling roads (a common scenario according to Rijkswaterstaat), while the steel is molten for reuse. Contractors transfer the railway sleepers to waste handlers and they follow similar procedures. There is not much information available on this process. We made assumptions on what happens to these products based on various interviews. Yet, there is valuable potential to establish higher-value end-of-life uses for railway sleepers by implementing circular options instead of recycling.

Match Opportunities

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

1. Repurposing railroad sleepers as counter-terror blockades (CT-blocks) with innovation partner New Horizon;
2. Repurposing the railroad sleepers as construction elements replacing concrete slabs with innovation partner Arup;
3. Recycling railroad sleepers by retrieving inactivated cement particles within the sleeper using a Smartcrusher with partner New Horizon.

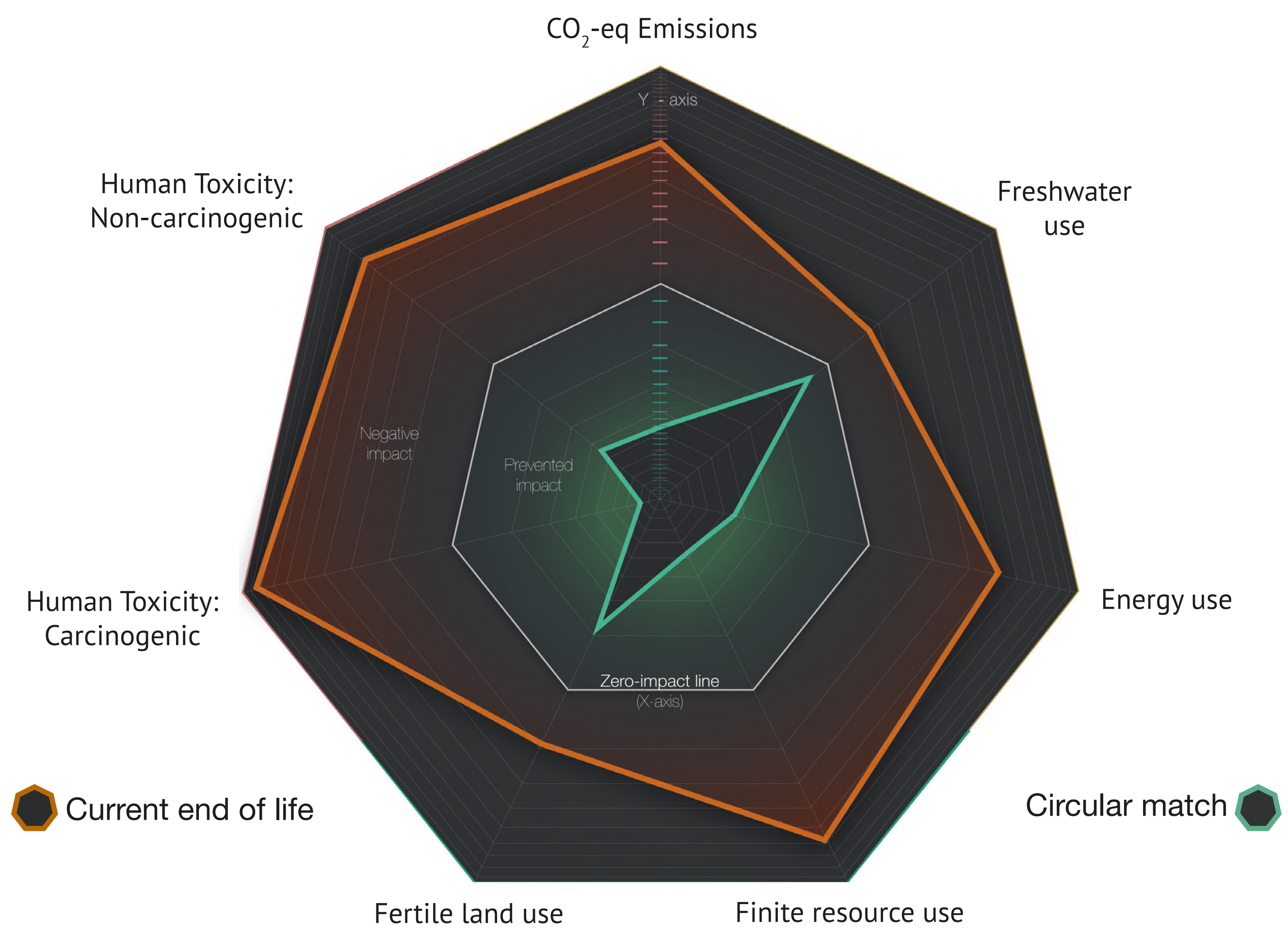
Environmental Impact

Railway sleeper contains 288 kg of concrete and 6 kg of reinforcement steel. Based on this profile, the environmental impact has been calculated per product. Taking into account the impact for production, transportation and end-of-life treatment for both the current end-of-life and the proposed alternative, we calculated a complete impact comparison. On the right side of this page, we have visualised, based on a selected set of parameters, the impact of our optimal circular match: the CT-block. Within this proposed circular match, the parameter "Carcinogenic human toxicity" shows the highest impact reduction (267.61%) compared to the current end of life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.

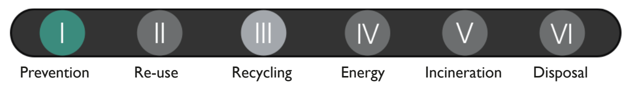
> *"The pilot provided ProRail with insights into the various secondary materials within its production chain that could prove valuable.*
>
> *- ProRail -"*

Impact Difference

Current end of life vs. Circular Match



Waste Hierarchy



Railway sleepers are currently being recycled. When the proposed circular match is applied, this product prevents virgin materials from being used. This is considered to be two steps higher in the waste hierarchy (in Dutch known as "Ladder van Lansink").

Technological Readiness Level

The system has proven to be operational, based on laboratory-conditions, but needs higher levels of validation.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	45.84	-56.36	kg CO_2-eq	223%
Freshwater use	0.04	-0.05	m^3 water-eq	227%
Energy use	496	-376	MJ	176%
Finite resource use	8.83E-04	-1.07E-03	kg Antimony-eq	222%
Fertile land use	100.46	-67.86	kg C Deficit	168%
Carcinogenic	7.37E-06	-1.23E-05	CTUh	268%
Non-carcinogenic	1.67E-6	-7.30E-06	CTUh	536%

Introduction
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Conclusion

Financial Impact

New railroad sleepers have an average value of €75 per sleeper. Per year, 5,000-10,000 sleepers with a purchase price of €375,000-€750,000 end up as waste. When recycled, the average second-hand value is €5 per tonne (€1.66 per sleeper), totaling to a maximum financial value of €8,000-16,000. This is a significant value loss compared to the original purchase price.

CT-blocks have an average price of €85 per piece based on the market value of concrete. Given that one CT-block requires nine railroad sleepers, reusing railroad sleepers as CT-blocks has the potential to generate a financial value of €47,200 to €94,500 per year based on the release of 5,000-10,000 sleepers that end up as waste. Herewith, the end-of-life value increases with 600% compared to the average financial value of recycling.

Eco-Costs

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. As of yet, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total value' (TV) of a product. We visualised this in figure 5.

For railway sleepers, the eco-costs of the current end-of-life scenario are €36.87 per sleeper. When added to the financial value of €1.66 per sleeper, the Total Value per railroad sleeper is -€35.21. When repurposing the sleepers as CT-blocks, an eco-profit is generated equal to €9.54 per sleeper. When added to the financial value of the proposed circular match of €9.44 per sleeper, this results in a Total Value of €18.98 per railway sleeper (Figure 5). This is an increase in Total Value of €54.19 per sleeper compared to the current end-of-life.

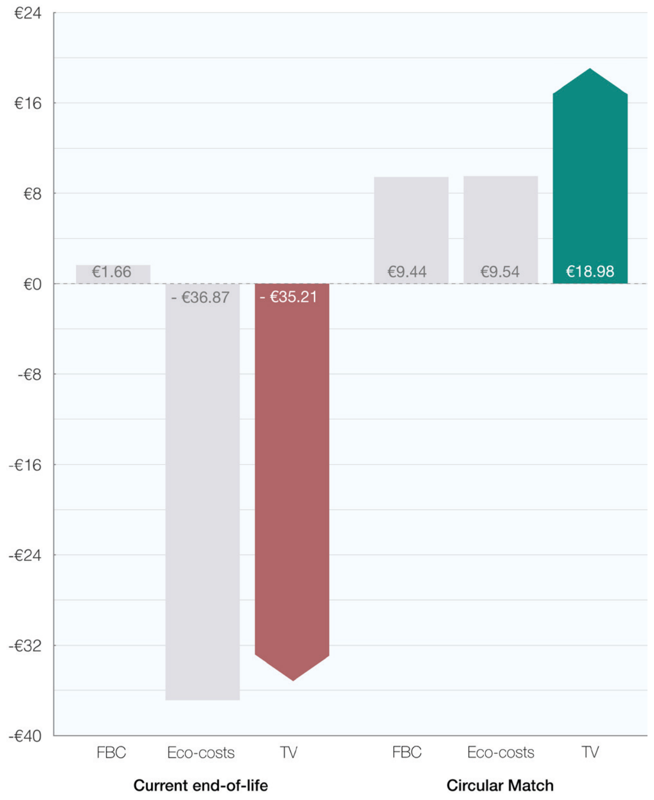
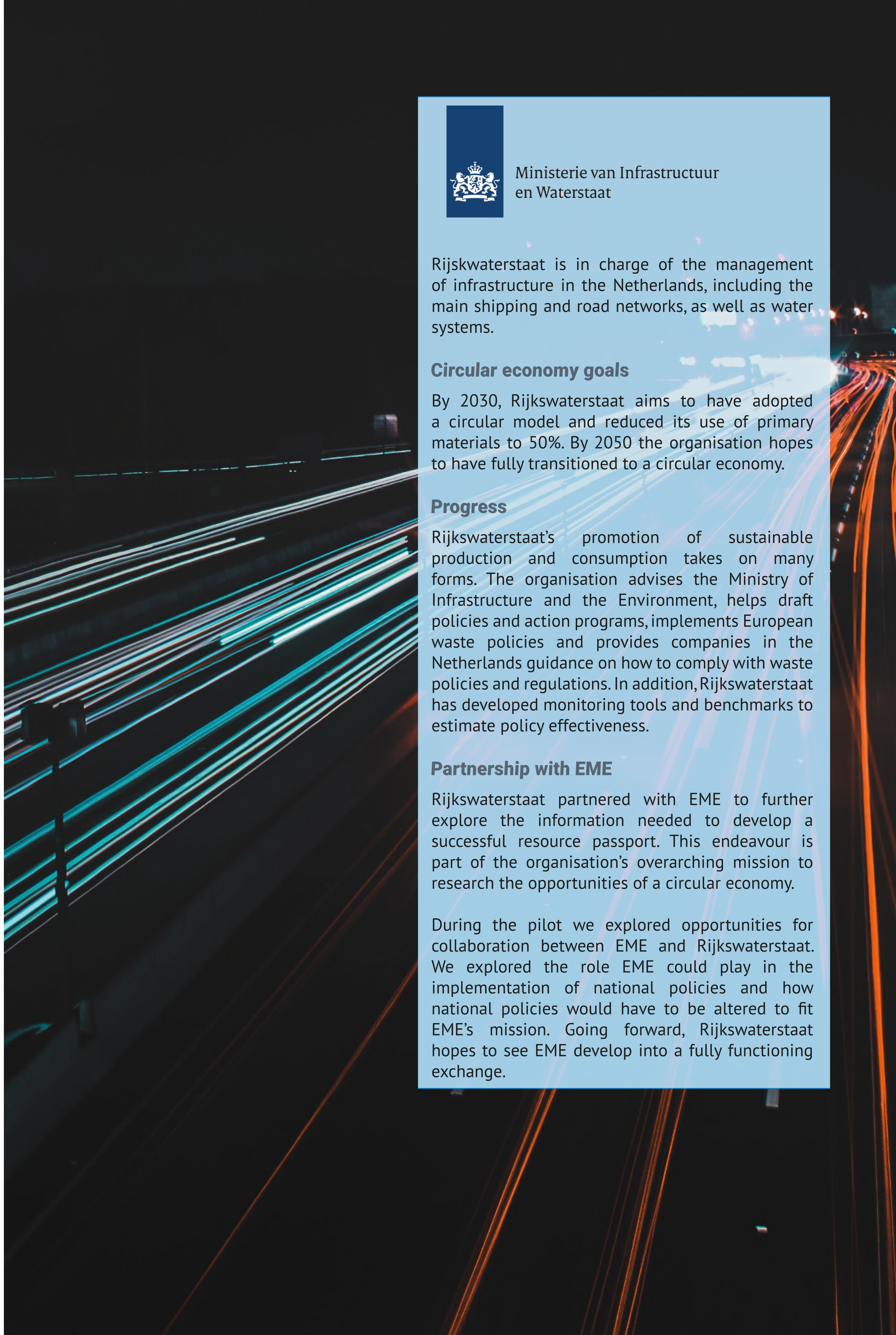


Figure 5: This graph visualises the financial business case (FBC) per railway sleeper and shows the difference in "Total Value (TV)" of a product with eco-costs included.

Recommendations by EME

Over de past few years, we have seen an increasing demand for CT-blocks. This growth enables the opportunity to convert sleepers in CT-blocks with a promising financial and environmental business case for today's and future markets. We advise ProRail, based on developments in the market and our circular matchmaking analysis, to investigate options to repurpose railway sleepers for the collaborative production of CT-blocks with New Horizon. By implementing the proposed circular match, ProRail would multiply the end-of-life financial value of railway sleepers five times, while mitigating €46.40 of eco-costs. Before initiating future endeavours, New Horizon will provide more in depth financial and logistical information regarding the proposed match. We advise ProRail to store railroad sleepers in a circular construction hub whenever it is not possible to match them to a higher value waste management process. Herewith, the potential of sleepers as a construction element will be more easily accomplished.



Ministerie van Infrastructuur en Waterstaat

Rijkswaterstaat is in charge of the management of infrastructure in the Netherlands, including the main shipping and road networks, as well as water systems.

Circular economy goals

By 2030, Rijkswaterstaat aims to have adopted a circular model and reduced its use of primary materials to 50%. By 2050 the organisation hopes to have fully transitioned to a circular economy.

Progress

Rijkswaterstaat's promotion of sustainable production and consumption takes on many forms. The organisation advises the Ministry of Infrastructure and the Environment, helps draft policies and action programs, implements European waste policies and provides companies in the Netherlands guidance on how to comply with waste policies and regulations. In addition, Rijkswaterstaat has developed monitoring tools and benchmarks to estimate policy effectiveness.

Partnership with EME

Rijkswaterstaat partnered with EME to further explore the information needed to develop a successful resource passport. This endeavour is part of the organisation's overarching mission to research the opportunities of a circular economy.

During the pilot we explored opportunities for collaboration between EME and Rijkswaterstaat. We explored the role EME could play in the implementation of national policies and how national policies would have to be altered to fit EME's mission. Going forward, Rijkswaterstaat hopes to see EME develop into a fully functioning exchange.

DRIPS

Dynamic Route Information Panels (DRIPs) also known as matrix signal indicators, are electronic panels placed on a portal above highways, using halogen or LED lights. At the moment, about 1,000 to 1,500 Halogen panels are being replaced yearly with LED panels to increase the overall energy efficiency. The panels typically consist of 11 aluminium parts made of aluminium alloy 5,457 and about 40 stainless steel connection components, such as bolts and screws. On the inside of the structure, fibre glass cables and wiring boards are mounted. 7,500 DRIPs are currently still equipped with halogen technology and need to be replaced. Taking into account the yearly rate of substitution, this will approximately take 5-7.5 years.

Current End-of-life Scenario

When DRIPs are removed from the highway, they usually become the possession of the contractor that removes them. Since the end of life of DRIPs are poorly documented, we made assumptions on what happens to these products based on interviews with scrap dealers and contractors. Contractors sell DRIPs for a scrap price to a waste handler, who dismantles the different components and recycles them. The aluminium is sold as scrap metal. The fibre glass cables are subsequently shredded and incinerated or landfilled. Screws, bolts, nuts and hinges are also sold as scrap metal.

Match Possibilities

We assume the fibre glass is currently being incinerated at end-of-life and the connection components are being sold as scrap metal. Based on the results of the Resources Passport analysis, EME identified multiple possible matches for the aluminium casing of DRIPs. We ranked the proposed circular matches below:

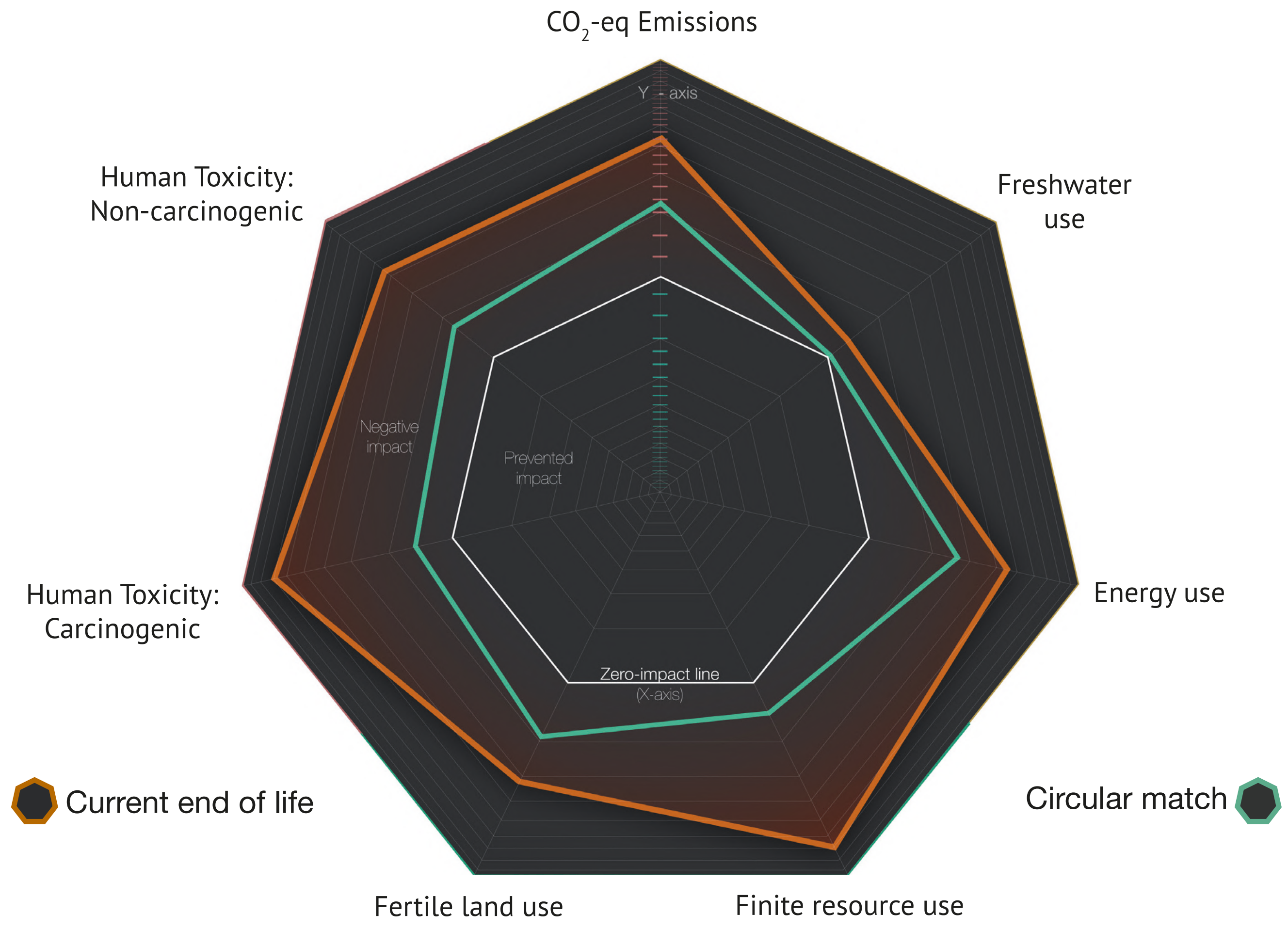
- The aluminium casing can be reused in its current state as aluminium facades with innovation partner Van Campen & Bayards solutions;
- The stainless steel components and the casing can be stored in a circular hub for reuse or re-fitting with LED.

Environmental Impact

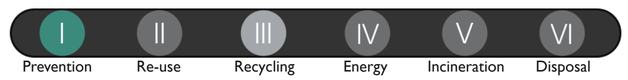
Around 7,500 of 17,000 DRIPs in the Netherlands still need to be replaced by DRIPs with LED lighting. Based on a weight of 80 kg and a profile of 97% aluminium alloy, 2% stainless steel and a remaining 1 percent of glassfibre, the following impact has been calculated per DRIP. On the right side of this page, we have visualised, based on a selected set of parameters, the impact of our optimal circular match; reusing as an aluminium facade for buildings. Within this proposed circular match, the parameter "finite resource use" shows the highest impact reduction (99.82%) compared to the current end-of-life scenario. More detailed information on the avoided impacts and the impact categories can be found in the table below the radar chart.

Impact Difference

Current end of life vs. Circular Match



Waste Hierarchy



Currently, DRIPS are being recycled. When the proposed circular match is applied, this product prevents the production of a new product. This is considered to be two steps higher in the waste hierarchy (in Dutch known as "Ladder van Lansink").

Technological Readiness Level

The theory supporting the technology is being developed and future research agendas are established.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	29	9	kg CO_2-eq	68%
Freshwater use	0.0107	0.0018	m^3 water-eq	83%
Energy use	536	161	MJ	70%
Finite resource use	2.10E-01	3.88E-04	kg Antimony-eq	99,8%
Fertile land use	107	45	kg C Deficit	57%
Carcinogenic	6.12E-05	2.26E-06	CTUh	66%
Non-carcinogenic	2.17E-06	2.56E-07	CTUh	96%

Financial Impact

The average end-of-life value of DRIPs lies between €130 and €160. Based on the yearly replacement rate and the case study trajectory of 7,500 DRIPs still in need of replacement, We estimate financial value of €975,000, since the average end-of-life value of DRIPs lies between €130 and €160. We estimated this value for just one replacement project, while numerous other projects are already planned by Rijkswaterstaat. After dismantling, the DRIPs will become possession of the contractor. Since the remaining financial value of the DRIPs cannot be regained by RWS, the current end-of-life value for RWS is set at €0. However, our proposed circular match will yield up to 2-3 m^2 of aluminium that can be used as aluminium facades. The estimated average market price for recycled aluminium facades is set at €25 per m^2, resulting in an alternative end-of-life financial value of €50 per DRIP.

Eco-Costs

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. Right now, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in Figure 6. For DRIP's, the eco-costs of the current end-of-life scenario are €22.51. When subtracted from the current end-of-life financial value of €0, the Total Value per DRIPs is -€22.51. In comparison, when repurposing the DRIPs as aluminium facades, an eco-cost is generated equal to €2.68 per DRIP. When added to the financial value of the proposed circular match of €50, this amounts to a Total Value of €47.32 per DRIP (Figure 6). This is an increase in Total Value of €24.81.

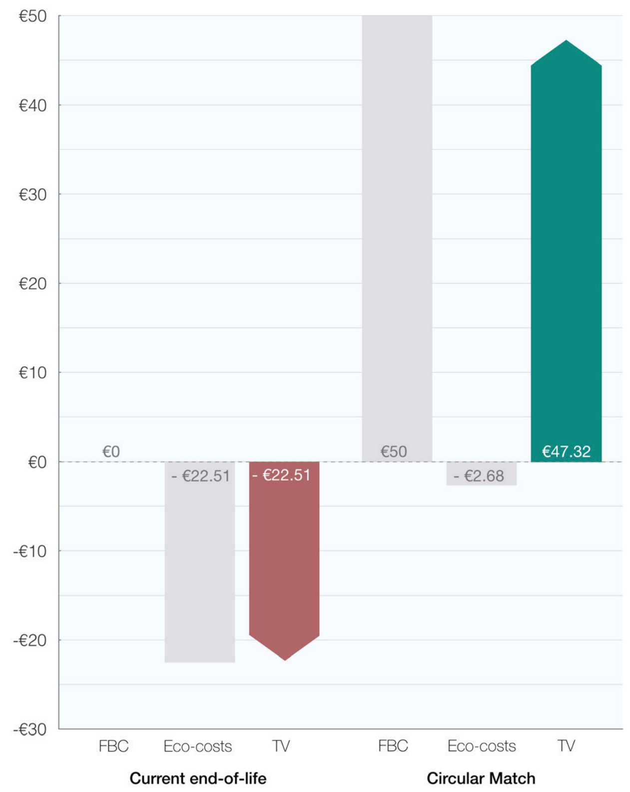


Figure 6: This graph visualises the financial business case (FBC) per DRIP, and shows the difference in "Total Value (TV)" of a product with eco-costs included.

Recommendations by EME

We identified circular matches with a high potential value based on Resources Passport analysis in close contact with the responsible stakeholders for the storage and end-of-life treatment of DRIPs. Refitting old DRIPs with LED technology (match option two) is complex due to the strict terms and conditions regarding the safety and quality of these products. Therefore, we recommend to repurpose these products as aluminium facades (match option one). The DRIPs will be modified to protect buildings from the elements while enhancing the appearance of the building, together with innovation partner van Campen & Bayards solutions. We recommend Rijkswaterstaat to have a meeting with the team responsible for the end-of-life handling and the innovation partner van Campen & Bayards solutions to discuss the circular end-of-life possibilities of the DRIPs. Site Managers have indicated that the DRIPs currently in storage are readily accessible and available for a pilot project.

RWS SPECIALS

For this passport, we have analysed plastic blocks originating form the water system of Rijkswaterstaat, also refered to as specials. For this specific project, we analysed 1,100 special blocks, which have been placed underwater. These blocks are made from High Molecular Weight Polyethylene (HMWPE). The blocks originating form the water system of Rijkswaterstaat enable the valves of the lock to slide and, thereby, open and close. Since the blocks do not meet the prescribed quality requirements anymore, they need to be replaced. RWS requested EME to analyse which circular end-of-life scenario would be most suitable for these blocks.

Current End-of-life Scenario

Rijkswaterstaat is assessing which blocks can and cannot directly be reused. When blocks are deemed not fit for reuse, the aim is to realise an end-of-life destination that is of higher value than storing, burning or landfilling. For that reason, EME performed a match analysis based on the functional properties of the material to find an alternative end-of-life scenario.

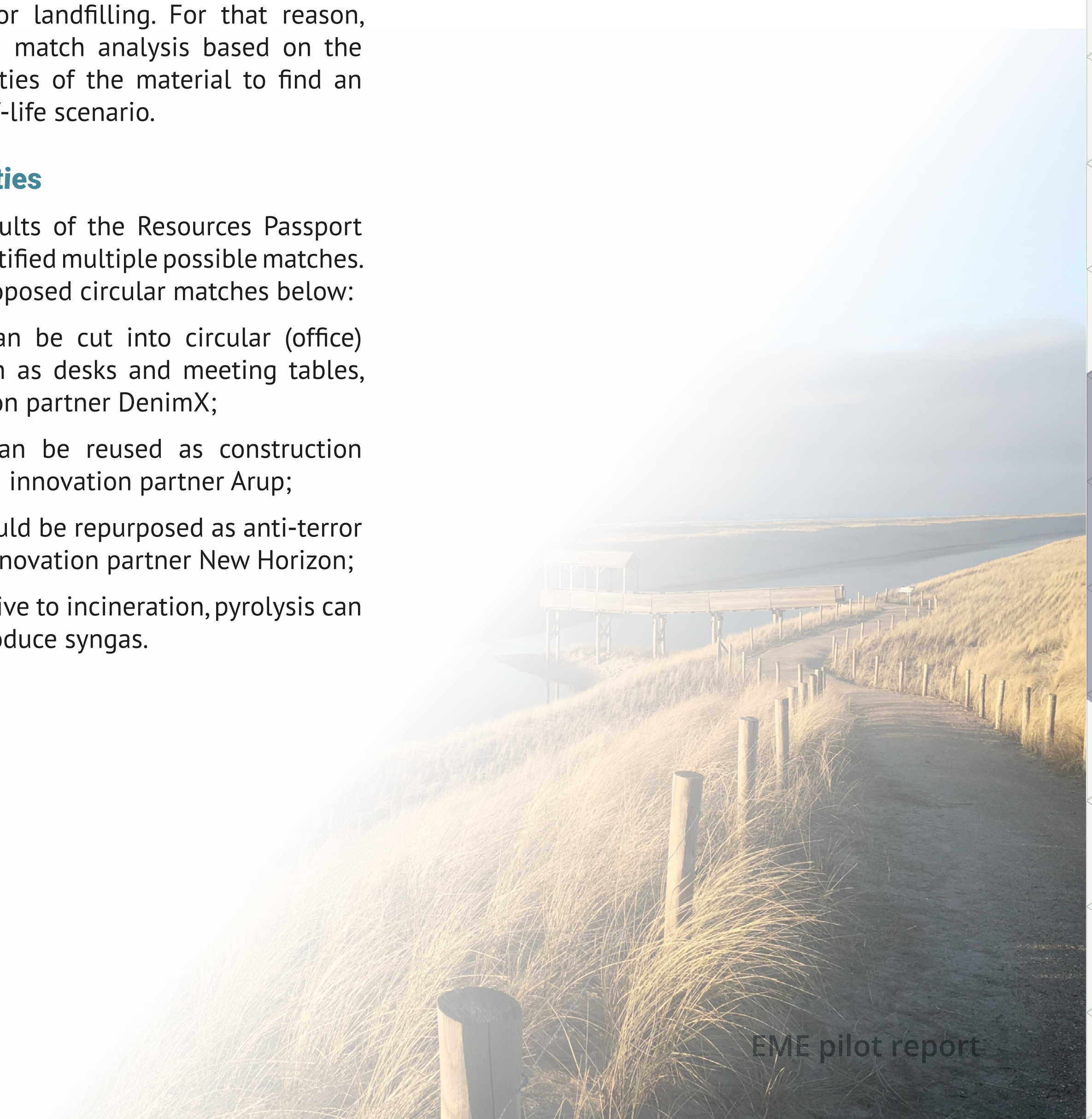
Match Possibilities

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

- The blocks can be cut into circular (office) furniture, such as desks and meeting tables, with innovation partner DenimX;
- The blocks can be reused as construction elements with innovation partner Arup;
- The blocks could be repurposed as anti-terror blocks with innovation partner New Horizon;
- As an alternative to incineration, pyrolysis can be used to produce syngas.

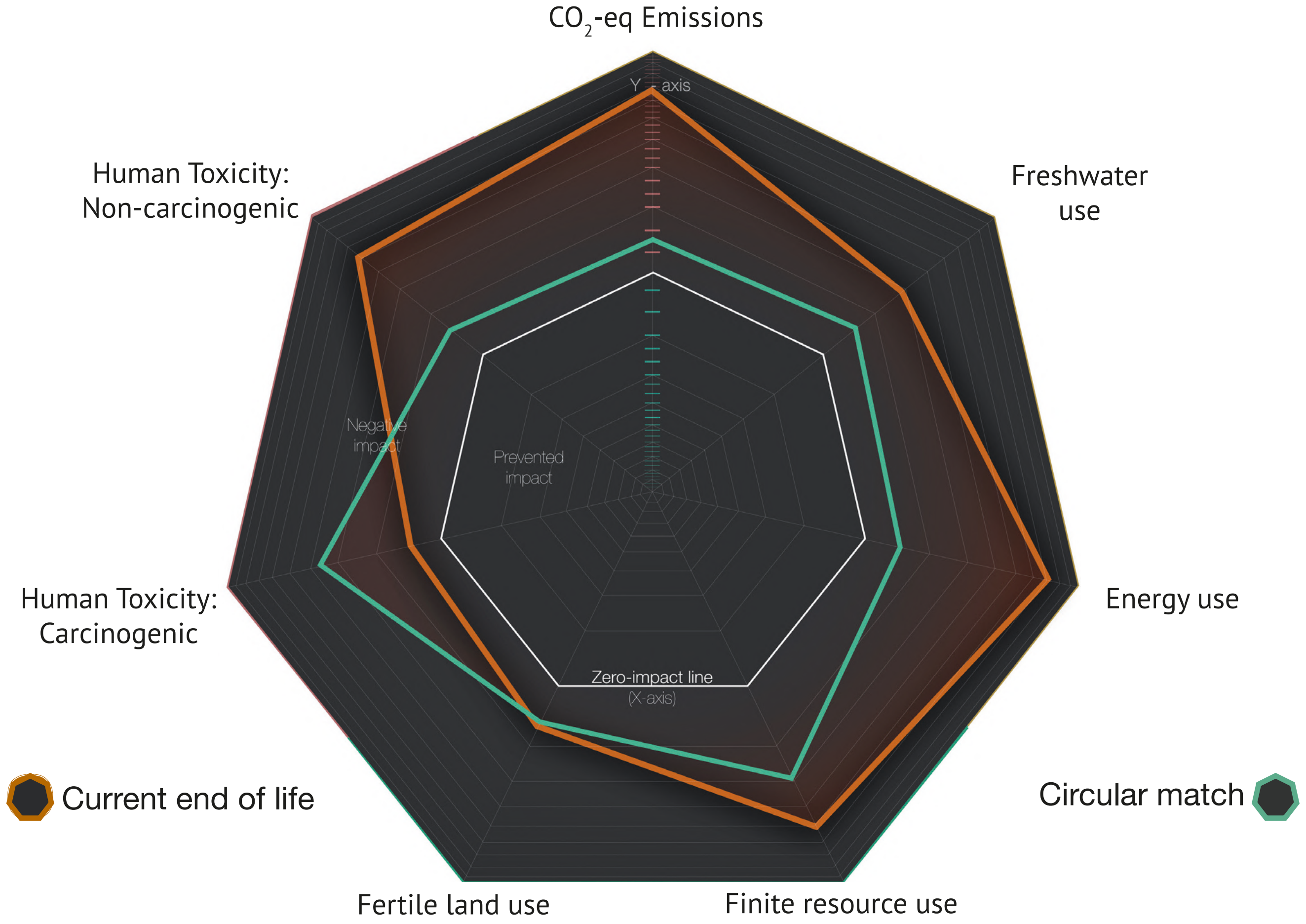
Environmental Impact

We calculated the environmental impact of the specials based on a block of 100% (U)HMW-PE with a density of 949 kg/m^3, weighing 60 kg. On the next page, we visualise the impact of our optimal circular match based on a selected set of parameters; repurposing of the blocks as circular furniture. Within this proposed circular match, the parameter "CO_2 emissions" shows the highest impact reduction (99%) compared to the current end of life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.

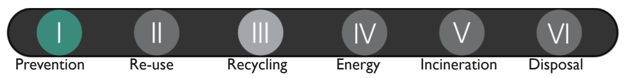


Impact Difference

Current end of life vs. Circular Match



Waste Hierarchy



Currently, the blocks are being recycled. When the proposed circular match is applied, this product prevents the production of a new product. This is considered to be two steps higher in the waste hierarchy (in Dutch known as "Ladder van Lansink")

Technological Readiness Level

Prototype models are being placed and tested in an operational environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	410	5	kg CO_2-eq	99%
Freshwater use	5.72	0.02	m^3 water-eq	99%
Energy use	13,870	77	MJ	99%
Finite resource use	2.88E-04	1.66E-04	kg Antimony-eq	42%
Fertile land use	9.30	9.19	kg C Deficit	1%
Carcinogenic	-3.48E-06	1.74E-06	CTUh	150%
Non-carcinogenic	4.13E-06	8.74E-07	CTUh	79%

EME

Financial Impact

For our calculations, we estimated 1,100 blocks weighing 60 kg a piece will be removed from the watersystem of RWS. We estimated the market price of virgin HMWPE is estimated at €90 per kg. Based on this data, each block has a financial value of €5,400. However, exact processing and disposal cost for the blocks are unknown and are therefore estimated at €17.05 per block based on waste processing standards. When the proposed circular match is implemented, up to three tables can be produced from a single block. The value of handmade tables made of recycled plastic range from €1,000 to €1,500 per table. Corrected for processing and assembly cost, we estimated the price for the circular tables at €1,000 a piece. Therefore, the alternative end-of-life financial value of a single block is €3,000.

Preventing these blocks from being incinerated or landfilled prevents a high loss in financial value for Rijkswaterstaat.

Eco-Costs

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. Right now, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in Figure 7. For the blocks, the eco-costs of the current end-of-life scenario are €130. When subtracted from the set financial value of -€17.05, the Total Value per block becomes -€147.05. In comparison, the eco-costs of the circular match are €2.21. When subtracted from the financial value of the proposed circular match of €3,000 per block, this results in a Total Value of €2,997.79 per block (Figure 7). Our chosen circular match results in an increase in Total Value of €3,144.84 per block.

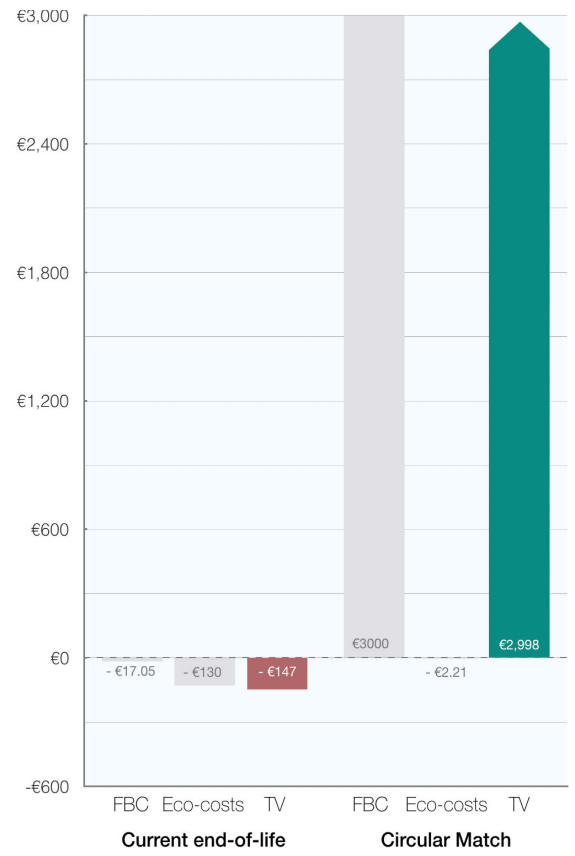


Figure 7: This graph visualises the financial business case (FBC) per block, and shows the difference in "Total Value (TV)" of a product with eco-costs included.

Recommendations by EME

Considering the identified matches, the financial perspective, and the potential impact reductions, repurposing the blocks is a better option than landfilling or incineration. Different types of products can be created from the blocks, but cutting HMWPE generates a significant environmental impact. Therefore, we advise to keep the blocks intact as much as possible when being formed into new products. Since the release of these blocks only happens sporadically as it is such a unique product, we recommend Rijkswaterstaat to showcase the repurposed tables within its own facilities. We identified three possible innovation partners for repurposing the blocks: DenimX, Arup and New Horizon. We recommend to start up pilots to test the feasability of these matches.

STEEL STREET LIGHTS

A recent estimation of "VDL Groep" stated that there are roughly four million street lights stationed along Dutch roads, highways and biking paths. Of those four million street lights, 60-70% are made out of zinc-layered steel (97% steel, 3% zinc) and 30-40% are made out of 100% aluminium. Rijkswaterstaat is transitioning from the use of halogen to LED lights resulting in a yearly replacement of 150,000 street lights, or 100,000 steel and 50,000 aluminium street lights. The following pages shows our analysis for the street lights made out of steel.

Current End-of-life scenario

After an average lifetime of 30 years, nearly all street lights are recycled, which means they are either melted for the production of new street lights or sold to international markets (mostly Asia) for a scrap price. During the production of virgin steel, 20% second hand (scrap steel) is mixed with 80% virgin ore (ratio 1:5). The light fittings and light bulbs originate from Philips and are recycled according to legal recycling procedures. EME conducted a circular match analysis to gather insights into the possibilities for higher value reuse of street lights.

Match Possibilities

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

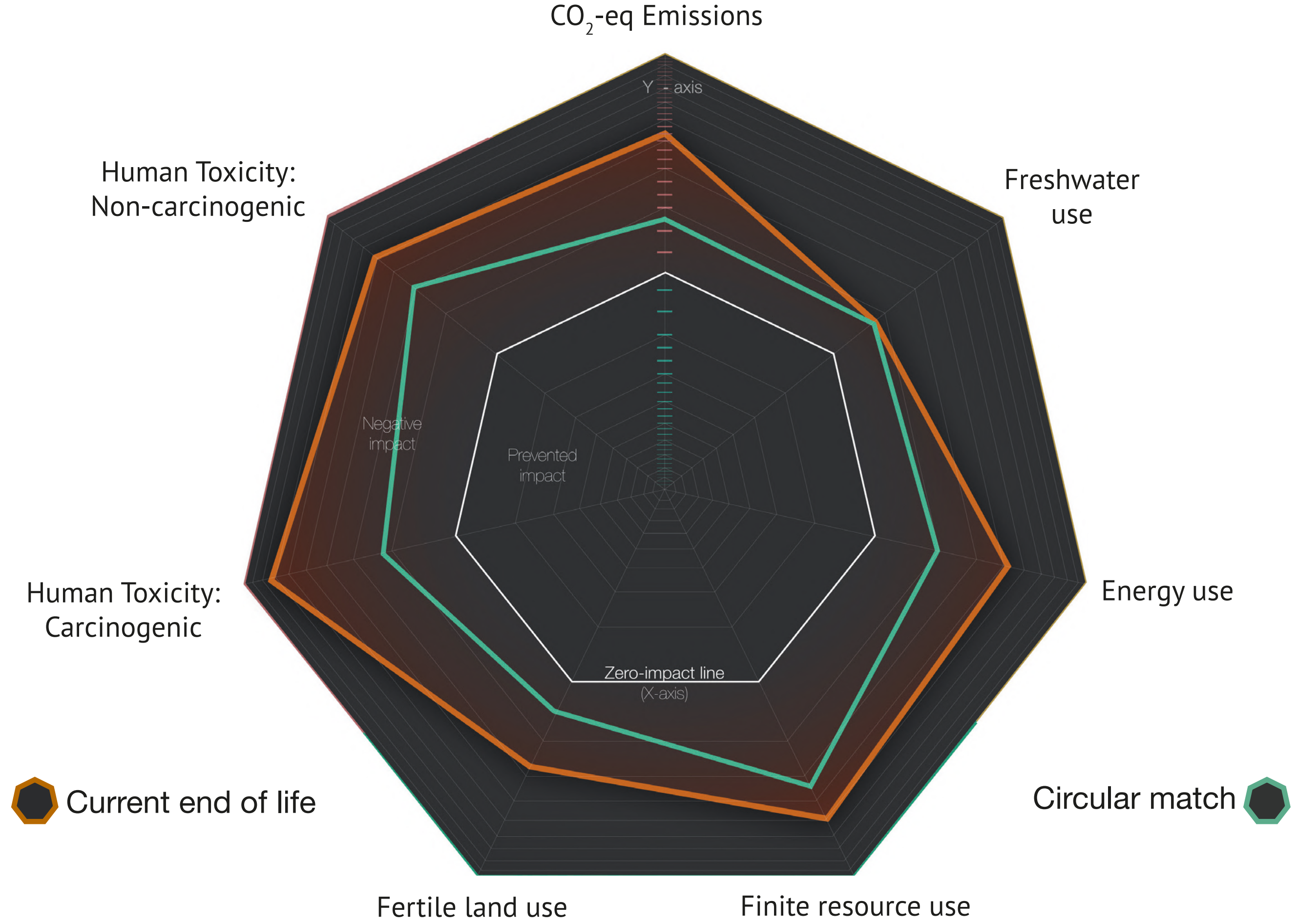
- Steel street lights can be reused as a channel bank reinforcement with innovation partner Arup;
- Steel street lights can be reused as construction element in buildings or infrastructure with innovation partner Arup;
- Steel street lights can be stored and refurbished in a circular resource depot with innovation partner GMP group or VolkerWessels.

Environmental Impact

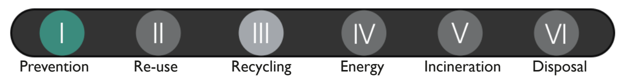
SGS Search conducted an LCA-study in 2014 to investigate the environmental impact of steel street lights. We have used the data from this study to calculate the embodied impact of the street lights. The street lights have a height of 8 meters, with the components weighing a total of 54 kg. Based on this impact profile, the impact was calculated for each street light. On the right side of this page, we have visualised, based on a selected set of parameters, the impact of our optimal circular match: channel bank reinforcement. Within the proposed circular match, the parameter "CO_2 emissions" shows the highest impact reduction (69.4%) compared to the current end-of-life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.

Impact Difference

Current end of life vs. Circular Match

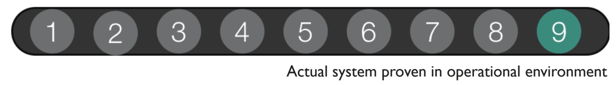


Waste Hierarchy



Currently, the steel street lights are being recycled. When the proposed circular match is applied, this product prevents the production of a new product. This is considered to be two steps higher in the waste hierarchy (in Dutch known as "Ladder van Lansink")

Technological Readiness Level



There is a fully developed system which is ready-to-use in an operational environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	693	212	kg CO_2-eq	69%
Freshwater use	0.4930	0.4883	m^3 water-eq	1%
Energy use	7,716	3,068	MJ	60%
Finite resource use	1.58E-02	1.26E-02	kg Antimony-eq	20%
Fertile land use	769	236	kg C Deficit	69%
Carcinogenic	1.37E-04	5.94E-05	CTUh	63%
Non-carcinogenic	5.35E-05	3.80E-05	CTUh	57%

Financial Impact

Currently, the scrap metal price is roughly €0.14 per kg of steel. Multiplying the scrap price with both the weight of steel street lights and the total amount of released street lights per year results in the following financial perspective: 100,000 steel street lights are worth €761,600, resulting in a financial value of €7.61 per street light. By finding a circular end-of-life scenario for these street lights this value could potentially be harnessed and even increased, while at the same time saving significant environmental impact. By repurposing steel street lights as channel bank reinforcers, the end-of-life value significantly improves. According to market research, a single street light could have a financial value of €37.80 when used as channel bank reinforcement.

Eco-Costs

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. As of yet, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in Figure 8. For steel street lights, the eco-costs of the current end-of-life scenario are €32.76. When subtracted from the financial value of €7.61, the Total Value per steel street light amounts to -€25.15. In comparison, when repurposing the street lights as channel bank reinforcements, an eco-cost of €30.48 per street light is generated. When subtracted from the financial value of the proposed circular match of €37.80 per street light, this results in a Total Value of €7.32. This is a positive increase in Total Value of €32.47 per street light.

Recommendations by EME

There is a significant potential for Rijkswaterstaat to prevent harmful emissions by reusing the steel street lights as channel bank reinforcers. Especially considering the current end-of-life scenario is to melt the metals used for the street lights, which is a very energy- and impact-intensive process. Moreover, there has been a recent concern regarding the degrading state of channel banks within the city of Amsterdam. The costs of repairing the channel

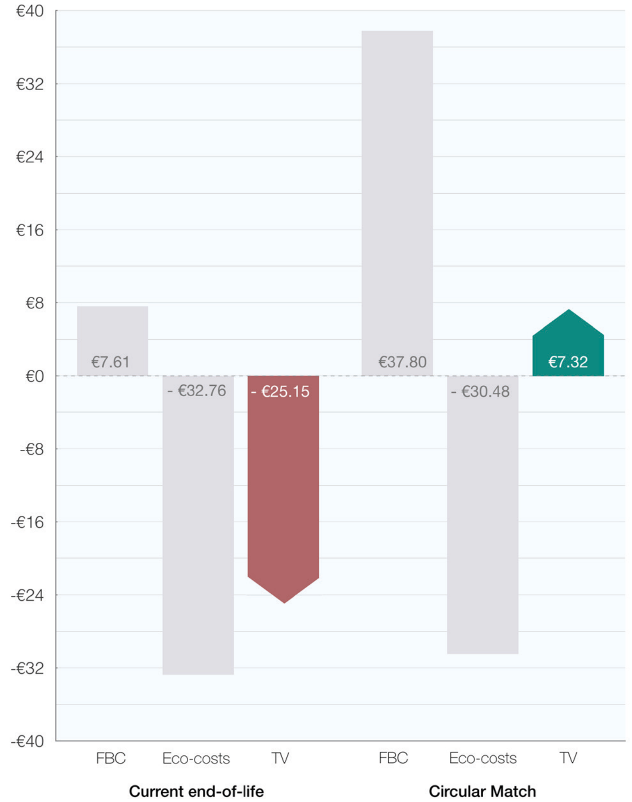


Figure 8: This graph visualises the financial business case (FBC) per street light, and shows the difference in "Total Value (TV)" of a product with eco-costs included.

banks can amount to €2 billion over the course of the reinforcement process. Moreover, all governmental tenders regarding construction have to be fulfilled in a circular manner by the year 2023. Herewith, there is a promising opportunity to address the previously described issues by implementing the proposed circular match.

We recommend Rijkswaterstaat to organise a meeting with Arup to further define the specifications for circular use. Together we can pinpoint the underlying impact-reduction scenarios and business case of this circular match. EME recommends Rijkswaterstaat to await the results of these meetings.

ALU STREET LIGHTS

A recent estimation of "VDL Groep" stated that there are roughly four million street lights stationed along Dutch roads, highways and biking paths. Of those four million street lights, around 60-70% is made out of zinc-layered steel (97% steel, 3% zinc) and 30-40% is made out of 100% aluminium. Rijkswaterstaat is transitioning from the use of halogen to LED in their street lights, leading to a yearly replacement of 150,000 street lights or 100,000 steel and 50,000 aluminium street lights. The following pages will show the analysis for the street light made out of aluminum.

Current End-of-life scenario

After an average lifetime of 30 years, nearly all street lights are recycled, which means they are either remelted for the production of new street lights or sold to international markets (mostly Asia) for a scrap price. Aluminium can be fully recycled by melting. The light fittings and light bulbs, which originate from Philips, are recycled according to legal recycling procedures. The EME conducted a circular match analysis for which we determined three high value matches for street lights.

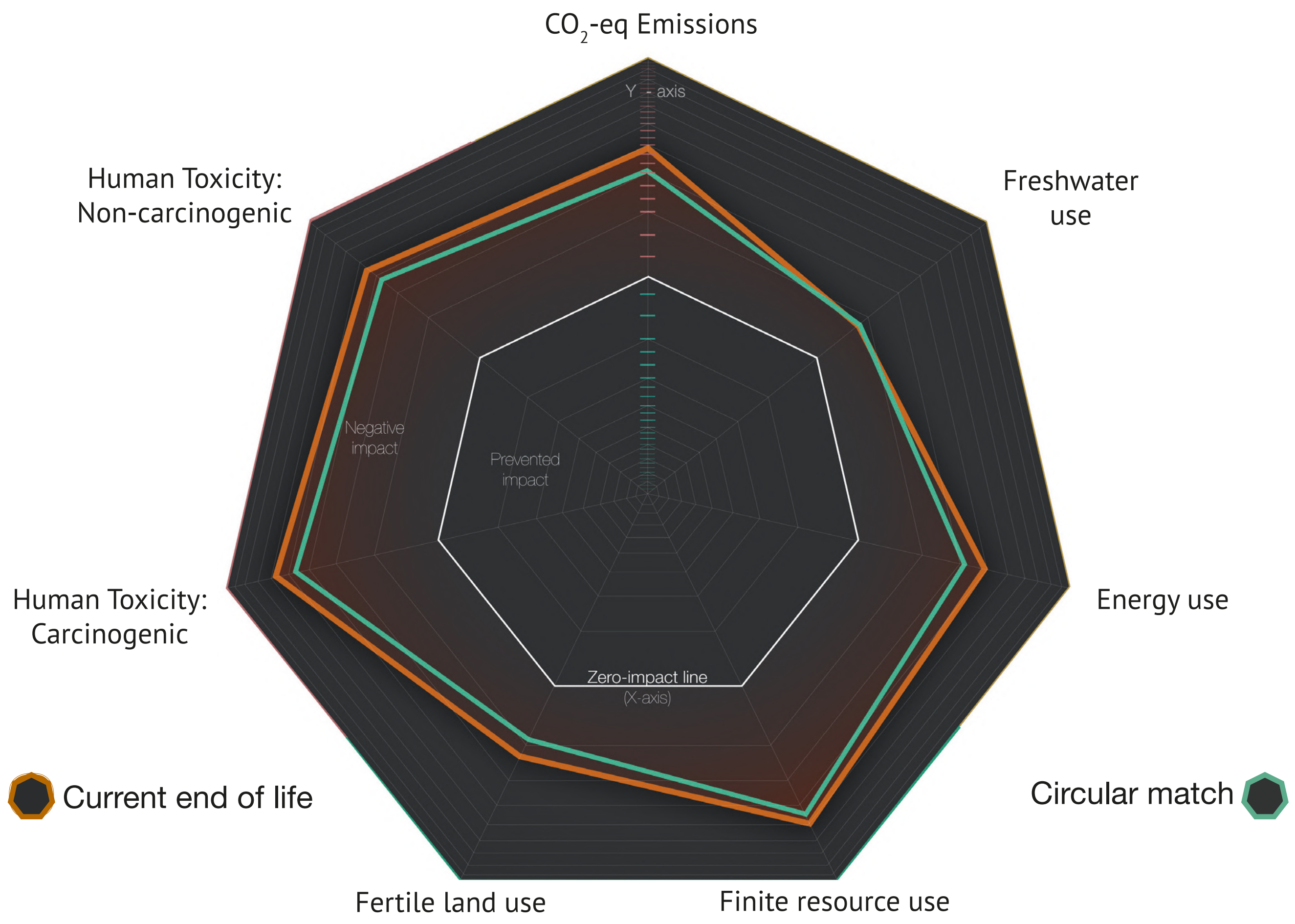
Match Possibilities

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

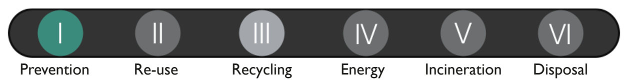
- Aluminium street lights can be reused as a soundwall for highways with innovation partner van Campen & Bayards;
- Aluminium street lights can be reused as construction element or in infrastructure with innovation partner Arup;
- Aluminium street lights can be stored and refurbished in a circular resource depot with innovation partner GMP group and/or VolkerWessels.

Environmental Impact

An LCA-study conducted by SGS Search, in 2014, investigated the impact for aluminium street lights. We have used the data from this study to calculate the embodied impact of the street lights. The street lights have a height of nine metres with the aluminium components weighing a total of 22 kg. We calculated the impact for each street light based on this profile. On the next page, we have visualised the impact of our optimal circular match based on a selected set of parameters; repurpose the street lights as a soundwall. Within this proposed circular match, the parameter "CO_2 emissions" shows the highest impact reduction (15.93%) compared to the current end-of-life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.



Waste Hierarchy



Currently, the aluminium street lights are being recycled. When the proposed circular match is applied, this product prevents the production of a new product. This is considered to be two steps higher in the waste hierarchy (in Dutch known as "Ladder van Lansink")

Technological Readiness Level

Fully developed system is ready-to-use in an operational environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	189	159	kg CO_2-eq	16%
Freshwater use	0.4874	0.4877	m³ water-eq	1%
Energy use	2,842	2,551	MJ	10%
Finite resource use	1.24E-02	1.22E-02	kg Antimony-eq	2%
Fertile land use	210	177	kg C Deficit	16%
Carcinogenic	5.56E-05	5.07E-05	CTUh	9%
Non-carcinogenic	3.72E-05	3.63E-05	CTUh	2%

Financial Impact

Currently, the scrap metal price is roughly €0.70 per kilogram of aluminium. Multiplying the scrap price with the weight of the street lights and the total amount of street lights per year results in the following perspective: 50,000 aluminium street lights are worth €770,000, resulting in a financial value of €15.40 per street light. By finding a circular end-of-life scenario for these street lights the financial value could potentially be harnessed and even increased, while simultaneously preventing a significant environmental impact. An aluminium sound wall has a value of €64 per m². 8.25 aluminium tubes can be transformed into one meter of soundwall covering 5 m². Therefore, the alternative end-of-life financial value of a single street light is set at €39.

Eco-Costs

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. Right now, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in Figure 9. For aluminium street lights, the eco-costs of the current end-of-life scenario are €59.10 per street light. When subtracted from the financial value of €15.40, the Total Value per aluminium street light results in -€43.70. When repurposing the street lights as a soundwall, an eco-cost of €30.48 per street light is generated. Subtracted from the financial value of the proposed circular match of €39 per street light, this results in a Total Value of €8.52. This is an increase in Total Value of €52.22 per street light.

Recommendations by EME

There is a significant potential for Rijkswaterstaat to prevent harmful emissions by repurposing the aluminium street lights. Especially considering the current end-of-life scenario is to melt the street lights, which is a very energy-intensive and therefore impactful process. As RWS is a governmental organisation. RWS aims to set an example concerning environmental engagement.

Figure 9: This graph visualises the financial business case (FBC) per street light, and shows the difference in "Total Value (TV)" of a product with eco-costs included.

The continuous circular application of aluminium street lights as a soundwall shows environmental dedication to the general public in regards to reducing environmental impact and honoring the Dutch climate goals.

We recommend Rijkswaterstaat to organise a meeting with both Arup and van Campen & Bayards to define the specifics for a circular match of aluminium street lights. Together we can pinpoint the underlying impact reduction scenarios and business case of the circular opportunities. EME recommends Rijkswaterstaat to await the results of these meetings.

Heembouw

Heembouw is a designing contractor: a construction company with its own architectural firm. Their vision is to create places where people want to be. The company offers integrated solutions for the built environment with a focus on business premises, offices and housing.

Circular economy goals

Heembouw is aware of the impact of its activities on the planet, and they sincerely strive to do it better: This is the compass of Heembouw in all their corporate activities. Circular designing and building is one of the strategic choices for the company. Together with their strategic partners Heembouw developes knowledge on circularity and implements circularity in all its activities from design to construction.

Progress

Heembouw is ISO 14001, uses 100% certified wood and has since 2012 Heembouw already reduced 45% of its CO_2 emissions. In the next two years Heembouw aims to reduce another 25% of their current CO_2 emissions. In addition, it cooperates with New Horizon and actively steers its projects towards circular designs. One example is the development of a proven concept for a circular distribution centre. Also the development of their own new office in Berkel en Roodenrijs will have many circular building solutions.

Partnership with EME

Heembouw's main motivation to join our pilot is the fact that we aim to exchange materials not just within but also between industries to turn waste into value. EME takes a holistic approach to the problem of transitioning from a linear to a circular model. We looked at the entire production and value chain to detect where currently resources are being wasted and which inputs could be replaced with secondary alternatives. EME identified fluorescent tubes, suspended ceiling systems and YMVK-cables as potential materials for exchange.

Going forward, Heembouw hopes to benefit from a vibrant marketplace and knowledge-sharing in their collaboration with EME.

CEILING TILES

Ceiling tiles are used to form ceilings in buildings. These specific modular ceiling tiles measure 60cm by 60cm and are made with a composition of minerals and fibres. The composition of these tiles is approximately: 40-50% mineral wool, 20-30% perlite, 1-10% starch, 5-10% recycled paper, 1-10% recycled tiles, 10-20% coating and 1-5% gauze. The majority of buildings in the Netherlands contain this type of modular ceiling, making this product an excellent option for urban mining. For this pilot we based our calculations on a unit of one tonne of wasted ceiling tiles. The tiles are wasted during the dismantling and transformation projects of Heembouw. An estimated 80% can be directly reused at its current end-of-life. The ceiling tiles that no longer meet quality standards are recycled.

Current End-of-life Scenario

Any ceiling tile produced before 1998 has to be incinerated by law, due to the possible contamination with asbestos. All ceiling tiles produced after 1998 are fit for recycling. From these tiles, 40% of materials can be recycled, while the remaining parts end up in the incinerator. In the current end-of-life scenario, innovation partner New Horizon harvests the valuable urban resources when buildings are dismantled. For our analysis we assume all ceiling tiles are incinerated, since most buildings currently being dismantled were constructed before 1998.

Match Possibilities

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

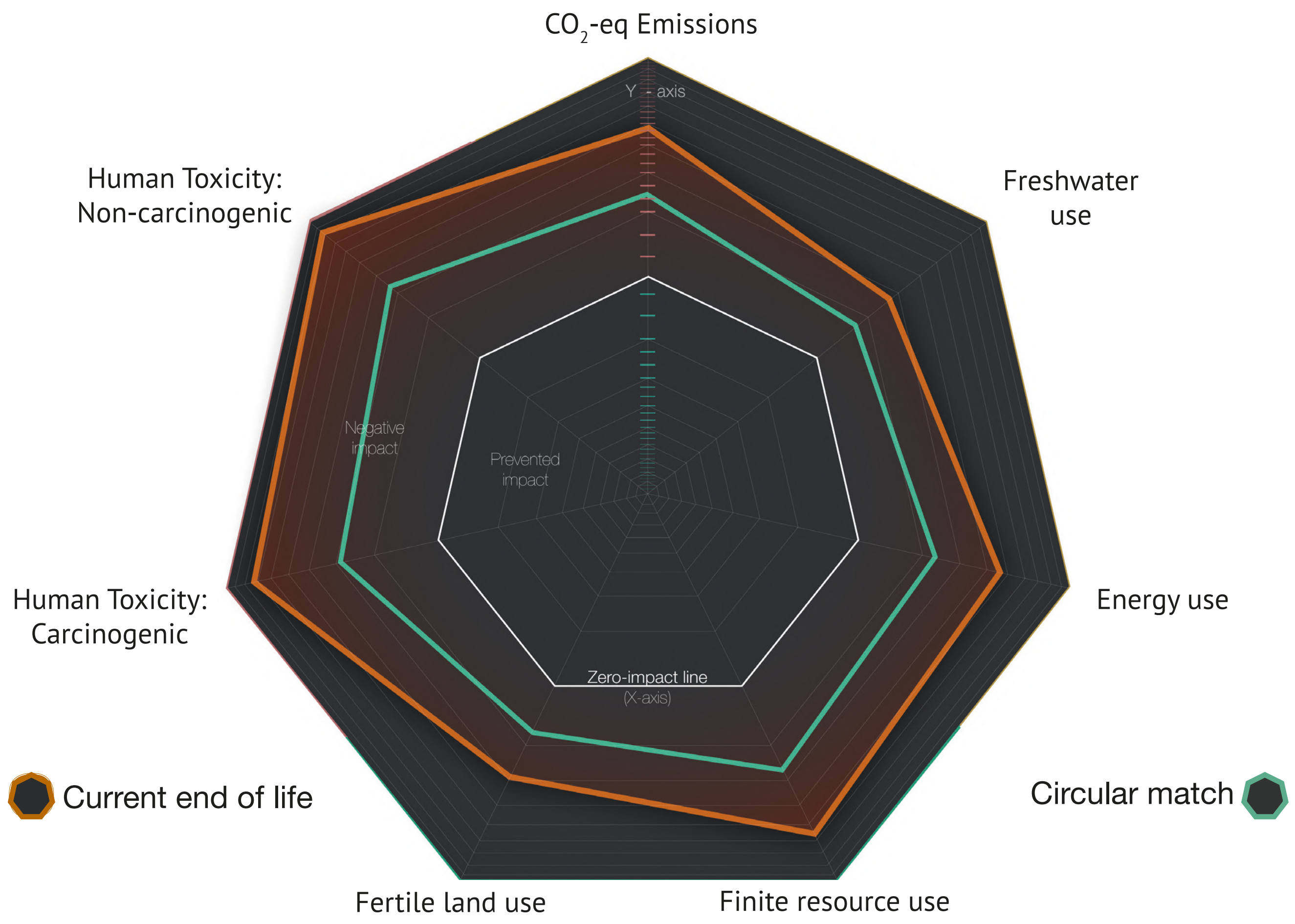
- Reusing the functional 80% of ceiling tiles directly in new buildings with guidance from New Horizon;
- Storage of ceiling tiles in circular hubs to be reused at a later time. GMP group and Volkerwessels are currently finishing the construction of their circular hub in Amsterdam, which can be used to store materials and resources harvested during urban mining;
- The production of syn-gas through pyrolysis of ceiling tiles, with innovation partner Pyrolyse in Amerfoort.

Environmental Impact

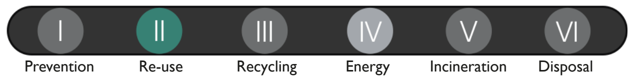
We calculated a total environmental impact based upon one tonne of ceiling tiles. We derived impact data from LCA software Simapro. On the next page, the impact of the optimal circular match is visualised based on a selected set of parameters. Within the proposed circular match, the parameter "water use" shows the most significant impact reduction (80,1%) compared to the current end-of-life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.

Impact Difference

Current end of life vs. Circular Match

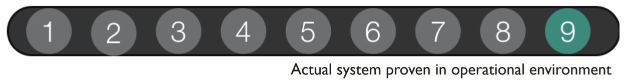


Waste Hierarchy



Currently, ceiling tiles are being incinerated to generate energy. When the proposed circular match is applied, this product will be reused. This is considered to be two steps higher in the waste hierarchy (in Dutch known as “Ladder van Lansink”).

Technological Readiness Level



There is a fully developed system, which is ready-to-use in an operational environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	2,962.07	595.88	kg CO_2-eq	79,88 %
Freshwater use	2.06	0.41	m^3 water-eq	80.10 %
Energy use	20,619.22	4,185.00	MJ	79.90 %
Finite resource use	1.56E-02	3.27E-03	kg Antimony-eq	79,04 %
Fertile land use	1,018.10	221.06	kg C Deficit	78.29 %
Carcinogenic	2.67E-04	5.43E-05	CTUh	79.67 %
Non-carcinogenic	1.52E-02	3.03E-03	CTUh	79.99 %

Financial Impact

The modular ceiling tiles have a value of €6.40 per m^2 and weigh about 1.38 kg. One tonne of ceiling tile consists of approximately 725 individual pieces, each with a surface area of 0.36 m^2. Due to the strict disposal legislation of the ceiling tiles containing asbestos, ceiling tiles are incinerated in a secure environment. Ceiling tiles containing asbestos are classified as “hazardous waste”. Therefore, cost of disposal is set at €300 per tonne based on industry standards. With current demolition practises, 80% of all ceiling tiles are fit for reuse. This results in a potentially saved financial value of €1,355 per tonne. We did not take into account the costs for harvesting and transportation in our scenarios.

Eco-Cost

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. Right now, the eco-costs are classified as ‘external costs’, since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the ‘Total Value’ (TV) of a product. This is visualised in Figure 10.

The eco-costs for ceiling tiles of the current end-of-life scenario are €239 per tonne. When added to the current end-of-life financial value of -€300, the Total Value per ceiling tile is -€539 per tonne of ceiling tiles. When reusing ceiling tiles, an eco-cost of €48.88 per tonne is generated. When subtracted from the financial value of the proposed circular match of €1,355, this results in a TV of €1,306.12. This is an increase in TVof €1,864 per tonne of ceiling tiles.

Recommendations by EME

Considering the environmental impact and the financial perspective of reusing ceiling tiles, EME recommends the reuse of tiles over recycling. EME recommends Heembouw to set up a meeting with New Horizon to learn what they are currently doing with the ceiling tiles and how a collaboration could be started to reuse them in new construction projects. Due to the possible time gaps between dismantling of old, and construction of new buildings, we advise to further investigate the use of circular hubs to temporarily store the ceiling tiles until they can be reused.

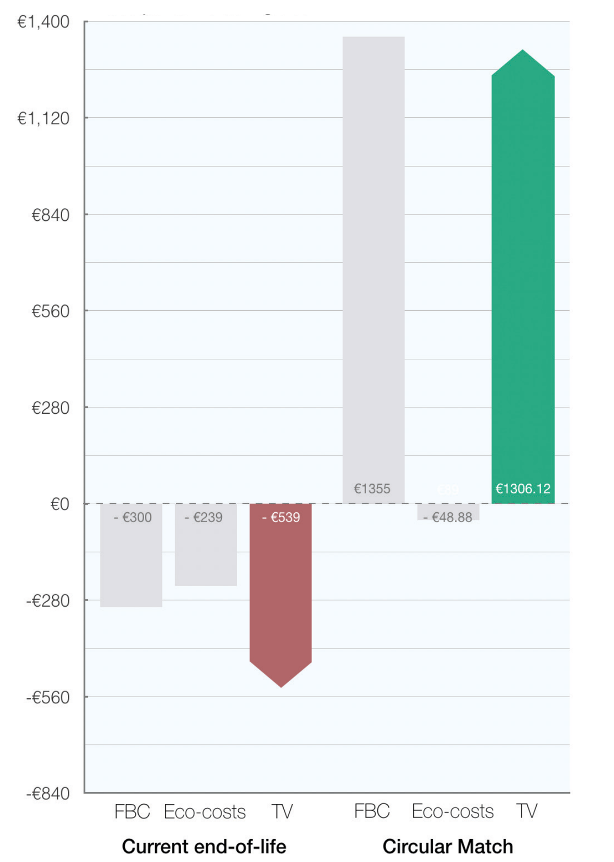


Figure 10: This graph visualises the financial business case (FBC) per tonne of ceiling tiles, and shows the difference in “Total Value (TV)” with eco-costs included.

Introduction
Excess Materials Exchange
Pilot
Results
Conclusion

YMVK CABLE

YMVK installation cables are used to power devices and provide electricity in buildings. These cables consist of a bundle of three inner copper cables: the phase wire, neutral wire and earth/ground wire. YMVK cables are covered by an insulation sheet made of cross-linked polyethylene (XLPE), which is then covered by a thin sheet of filler compound and a thick outer sheet of fire retardant polyvinyl chloride (PVC). We used an estimated output material of one tonne YMVK cable per year as a case study for this pilot.

Current End-of-life Scenario

When cables are removed from a building, the PVC-XLPE is stripped from the copper and grinded for incineration. The copper is sold as scrap and molten for reuse. What happens to these materials thereafter is unknown, since this depends on the contractor that collects the secondary resources during dismantling of a building.

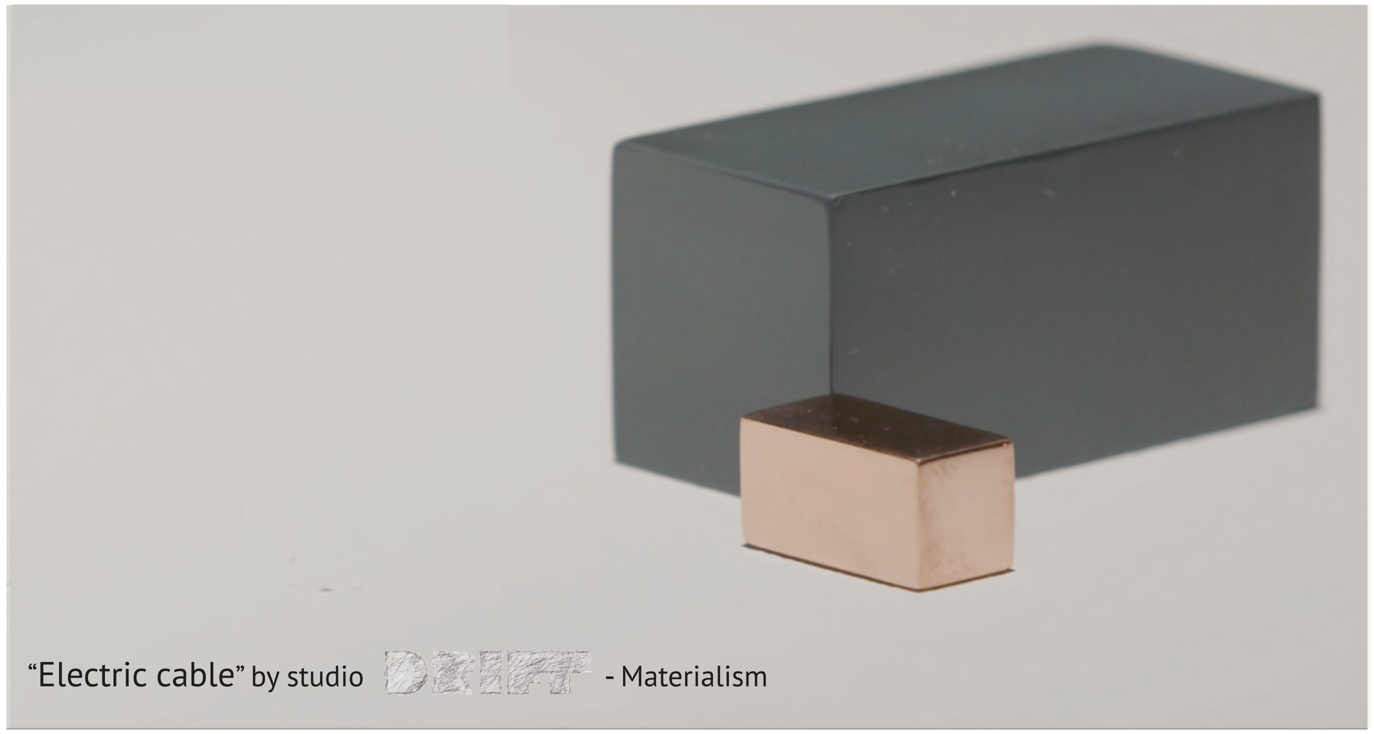
Possible Matches

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

- Reusing cables in new construction projects through the use of circular hub(s), for instance, with innovation partner GMP group or VolkerWessels;
- Production of synthetic gas out of the plastic components of the cable using pyrolysis with innovation partner Pryme (in Rotterdam).

Environmental Impact

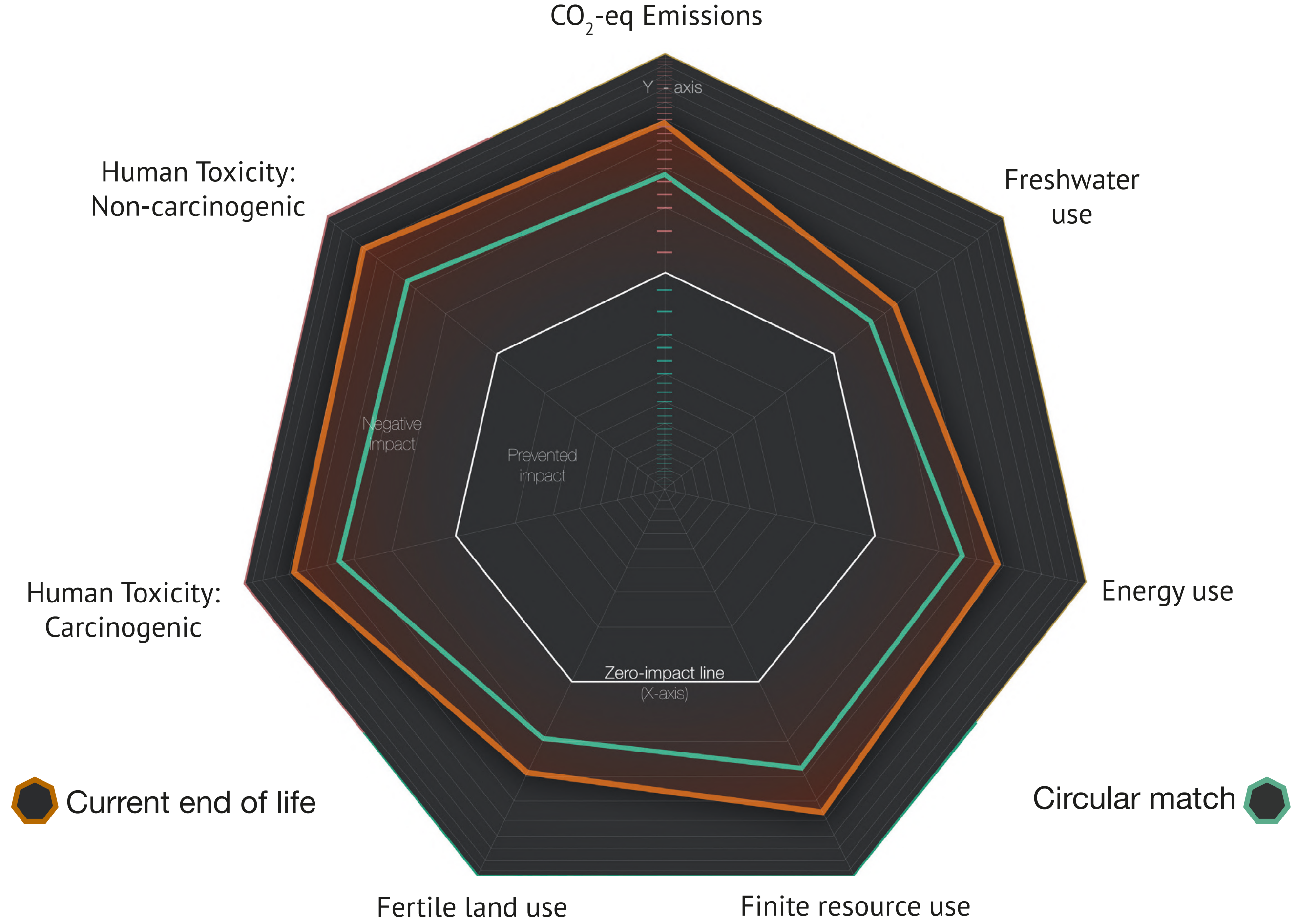
We calculated the environmental impact data of the YMVK installation cable using LCA software Simapro. On the right side of this page, we visualised the impact of our optimal circular match based on a selected set of parameters; Reusing cables in new construction projects. Within the proposed circular match, the parameter “water use” shows the most significant impact reduction (70%) compared to the current end-of-life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.



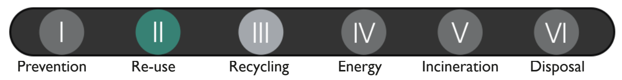
“Electric cable” by studio - Materialism

Impact Difference

Current end of life vs. Circular Match

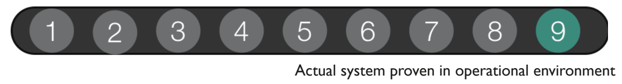


Waste Hierarchy



Currently, YMVK cables are being recycled and incinerated to generate energy. When the proposed circular match is applied, this product will be reused. This is considered to be one step higher in the waste hierarchy (in Dutch known as “Ladder van Lansink”).

Technological Readiness Level



There is a fully developed system, which is ready-to-use in an operational environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	2,660	820	kg CO_2-eq	69%
Freshwater use	77.28	23.19	m^3 water-eq	70%
Energy use	103,105	31,321	MJ	70%
Finite resource use	129	3.98E-02	kg Antimony-eq	69%
Fertile land use	2,960	999	kg C Deficit	66%
Carcinogenic	6.08E-03	1.83E-03	CTUh	70%
Non-carcinogenic	4.04E-04	1.22E-04	CTUh	70%

Financial Impact

YMVK cables cost around €1.45 per metre and weigh 1.85 kg/m. One tonne of cables equals a total 540 metres. The financial value of YMVK cables amounts to €1,450 per km. YMVK cables might therefore contain a considerable financial value at its end of life. The exact current disposal cost and practices are uncertain. We based the waste management costs on industrial standards, which are currently at €74 per tonne. We estimated disposal cost per km at €137 per km. If the YMVK cables were to be reused, they would prevent the procurement and therefore production of new cables. Within this analysis, we set the financial value of reusing YMVK cables at €1,450 per km. Since we expect only 70% of the cable reusable and the rest is sent to landfill, the proposed circular match generates a financial value of €993.

Eco-Cost

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. As of yet, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in Figure 11.

The eco-costs of the current end-of-life scenario are €1,646 per km YMVK cable. When added to the financial value of -€137, the TV per kilometre of YMVK cable amounts to -€1,783. When reusing the YMVK cables, an eco-cost of €500 per km is generated. Subtracting the financial value of the proposed circular match of €974 this amount to a Total Value of €474 (Figure 14). This is an increase in Total Value of €2,257 per km YMVK cable.

Figure 11: This graph visualises the financial business case (FBC) per kilometre of YMVK cable, and shows the difference in "Total Value (TV)" with eco-costs included.

Recommendations by EME

Considering the environmental impact and the financial perspective of reusing YMVK cable, EME recommends the cables are reused before opting for recycling. EME recommends Heembouw to set up a meeting with New Horizon to better understand the current end-of-life treatment of the cables. Due to the frequent time gap between the demolition and harvesting of old buildings and reusing the cables within new construction projects, we advise to further investigate the use of circular hubs to temporarily store the cables.

FLUORESCENT LIGHTS

Fluorescent lighting is used in buildings worldwide to produce light. The lamps used by Heembouw are mainly produced by Philips lighting in Europe. Fluorescent lighting tubes are tubes of glass filled with argon gas and mercury drops that vapourize and luminisce upon the release of electrons. These electrons are emitted by a cathode placed at the fitting filled with bromine ions. The fitting is mostly made out of aluminium and placed at the end of one side of the tube, which is connected to the grid. The other side has an aluminium cap placed over the tube to enclose the elements within the product. EME used a functional unit of one tonne of fluorescent lighting for this pilot.

Current End-of-life Scenario

The procedure for recycling fluorescent lighting tubes is subject to strict legislation. The glass is broken in a contained environment after which the released mercury is safely processed and collected. The broken glass is recycled into glass cullet. The electrical components are subsequently sent to a recycler who strips the metal and plastics and sells it as scrap.

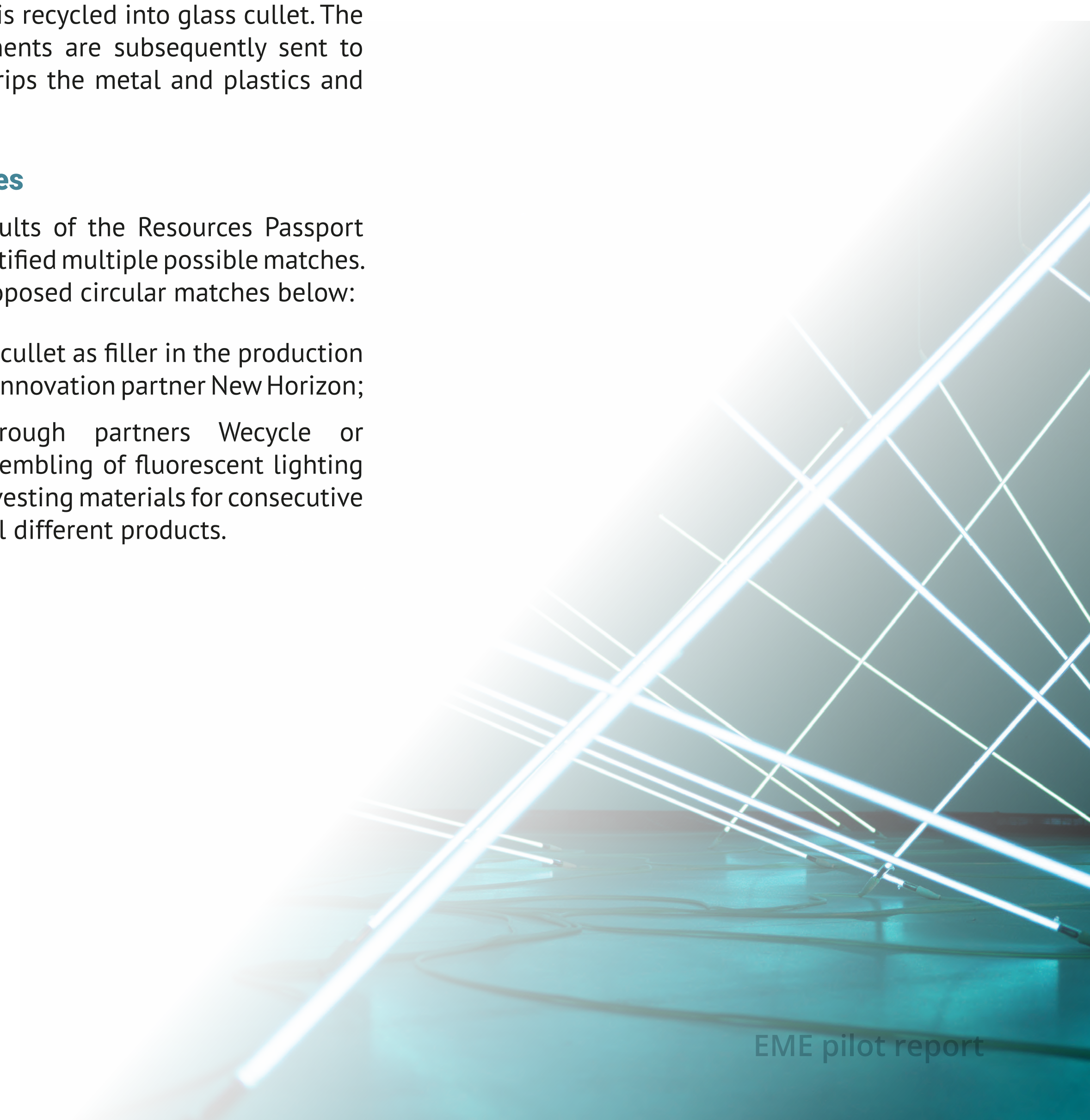
Possible Matches

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

- Reusing glass cullet as filler in the production of bricks with innovation partner New Horizon;
- Recycling through partners Wecycle or Indaver; reassembling of fluorescent lighting tubes and harvesting materials for consecutive uses in several different products.

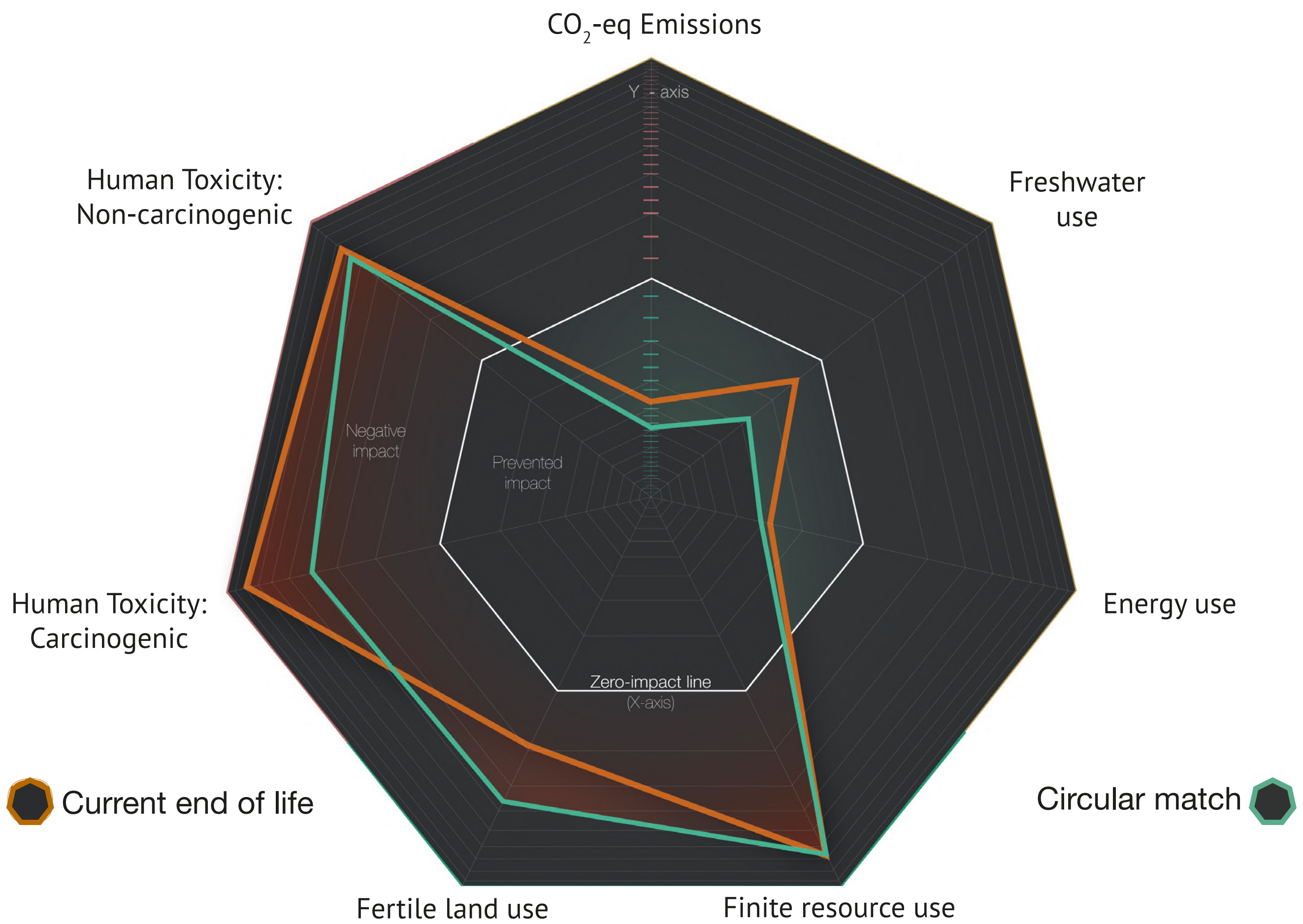
Environmental Impact

Using impact data from the Ecoinvent database, LCA results and Simapro software, EME calculated the impact of 1 tonne of fluorescent lighting tubes. On the next page, we visualise the impact of our optimal circular match based on a selected set of parameters: use of glass cullet in bricks. Within the proposed circular match, the parameter "water use" shows the most significant impact reduction (over 1000%) compared to the current end-of-life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.

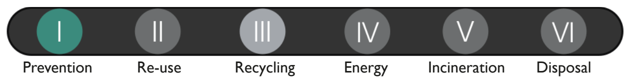


Impact Difference

Current end of life vs. Circular Match

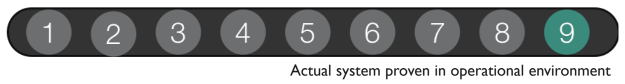


Waste Hierarchy



Currently, Fluorescent lights are being recycled. When the proposed circular match is applied, this product prevents virgin materials from being used. This is considered to be two steps higher in the waste hierarchy (in Dutch known as "Ladder van Lansink").

Technological Readiness Level



There is a fully developed system, which is ready-to-use in an operational environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	499.56	791.16	kg CO_2-eq	58%
Freshwater use	0.09	4.96	m^3 water-eq	5,411%
Energy use	1,927	2,311	MJ	20%
Finite resource use	5.35E-01	5.48E-01	kg Antimony-eq	2%
Fertile land use	151.08	353.58	kg C Deficit	134%
Carcinogenic	3.40E-04	3.04E-04	CTUh	11%
Non-carcinogenic	1.10E-04	1.04E-04	CTUh	6%

EME

Financial Impact

Fluorescent lighting tubes cost about €1.20 per piece when bought in bulk. One tube weighs 1.40 kg. This means one tonne contains 715 fluorescent lighting tubes. The total worth of these lighting tubes equals to €858. Current disposal cost of fluorescent lighting are unknown. Therefore, we based current end-of-life disposal costs on industrial standards, which are €74. In the proposed circular match, a tonne of glass cullets replaces 0.9 tonne of cement. With an estimated price of €55 per tonne of cement, we estimate the alternative end-of-life value at €49,50.

Eco-Cost

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. Right now, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in Figure 12.

The eco-profit per tonne fluorescent lighting for the current end-of-life is €60.25. When added to the financial value of -€74, the Total Value per tonne of fluorescent lighting tubes amounts to -€13.75. When repurposing the glass cullets in cement, an eco-profit of €88.92 is generated. Adding the financial value of the proposed circular match of €49,5, this amounts to a Total Value of €138.42. This is an increase in Total Value of €152.17 per tonne.

Recommendations by EME

Preventing the production of cement through recycling the glass of fluorescent lamps has a high potential to save environmental impact and prevent a loss of financial value from the current end-of-life scenario. Therefore, EME recommends setting up a meeting with New Horizon, the current handler of this waste stream, to discuss the end-of-life situation of the lighting tubes. EME also recommends Heembouw to investigate the options of storing lighting tubes for possible reuse, as this is likely to save even more impact, while retaining the value of the lighting tubes.

Figure 12: This graph visualises the financial business (FBC) case per ton of fluorescent lights, and shows the difference in "total value (TV)" when eco-costs are included.

EME can also investigate the match possibility of making use of circular hubs for the storage and circular reuse of lighting tubes.

> *"EME aims to exchange materials not just within but also between industries to turn waste into value.*
>
> *- Heembouw -"*

aqua minerals

AquaMinerals is a partnership between organisations in the water sector, ranging from drinking water companies to water authorities. The aim of the partnership is to give resources from (waste) water treatment a second life.

Circular economy goals

AquaMinerals actively tries to find secondary materials to replace high-value primary raw materials. Their activities are modelled to the Waste hierarchy: at least 99.9% of the residual materials received should find a useful application, and only 0.1% ending up in landfills.
A little less than one-fifth is used as construction material in infrastructural works and the remainder is upcycled.

Progress

AquaMinerals embraces the Cradle to Cradle® philosophy and avoids, whenever possible, having residuals being dumped after single usage. At the moment, about 40% of the residuals are directed to applications in which the material flows back into the resource cycle. For instance, lime pellets are incorporated into the biological cycle in the form of consumer-use lime, and lime pellets for the glass industry ultimately end up in recycled glass (technical cycle).

Partnership with EME

AquaMinerals partnered with EME to help identify better destinations for their excess materials. Given the cross-sector nature of EME's activities, the marketplace together with the matching tool could help AquaMinerals introduce their used resources to new markets.

For the pilot two resources were identified. Together with EME, AquaMinerals then began searching for better markets to offload those resources in a way that would be both financially and environmentally sustainable. Going forward, AquaMinerals hopes to benefit from the platform EME is creating, as well as the Resource Passport that would help to identify new opportunities for its excess materials.

PAC SLUDGE

Powder Activated Carbon (PAC) sludge is a waste stream primarily made out of porous carbon. The composition of this sludge is 52.7% water, 37% carbon, 20.4% organic matter, 3.7% iron, 2.7% calcium and <1% other materials. The production process of PAC in which charcoal is made porous to absorb pollutants has a considerable impact on the environment. Therefore, investigating a circular end-of-life scenario is likely to have a significant positive impact. We used a functional unit of one tonne PAC sludge for this analysis.

Current End-of-life Scenario

Currently, PAC sludge is used as a foundation ('Immobilisaat') for infrastructural works, such as sound barriers, road elevation and others. For this process, the sludge is mixed with other secondary resources, such as sand and mixed granulates. However, there end-of-life solution, able to reclaim more value, can be realised.

Possible Matches

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We rank the proposed circular matches below:

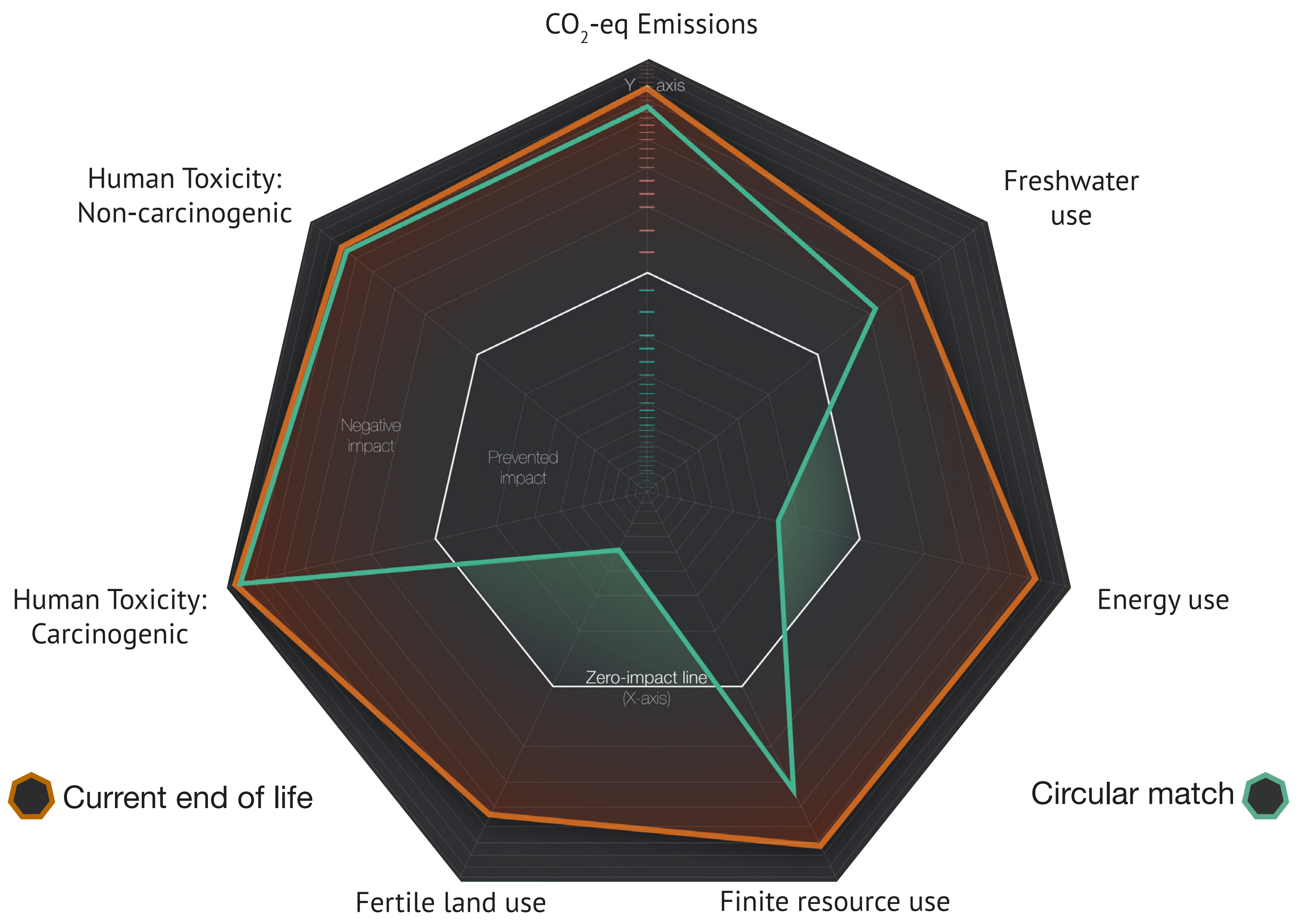
- Recycling the carbon inside the sludge as a replacement for bitumen in the production of asphalt;
- Making use of supercritical gasification to process the wet material flow of PAC for the production of biogas (hydrogen and methane), with innovation partner SCW systems;
- Using pyrolysis to convert the carbon sludge into fuel and energy, with innovation partner Pyrolyze.

Environmental Impact

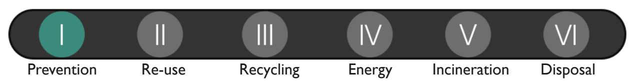
The impact for 1 kg of carbon has been retrieved from the Ecoinvent database using Simapro LCA software. Herewith, the total annual environmental impact of 1 tonne sludge is calculated. On the next page, the impact of the optimal circular match is visualised based on a selected set of parameters: the use of PAC as a replacement of bitumen in asphalt production. Within the proposed circular match, the parameter "land use" shows the most significant impact reduction (707%) compared to the current end-of-life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.

Impact Difference

Current end of life vs. Circular Match



Waste Hierarchy



Currently, PAC prevents the use of other materials. When the proposed circular match is applied, this product stays on the same spot within the waste hierarchy (in Dutch known as "Ladder van Lansink").

Technological Readiness Level

Prototype models proved to be successful and are being implemented in a relevant environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	2,658.48	2,323.64	kg CO_2-eq	13%
Freshwater use	3.61	1.81	m^3 water-eq	50%
Energy use	40,832	-11,252	MJ	128%
Finite resource use	5.30E-03	3.76E-03	kg Antimony-eq	29%
Fertile land use	1,387.61	-8,426.45	kg Carbon Deficit	707%
Carcinogenic	3.81E-04	3.20E-04	CTUh	16%
Non-carcinogenic	1.00E-04	7.81E-05	CTUh	22%

EME

Financial Impact

The market value of activated carbon lies at €900 per tonne for virgin PAC and €450 per tonne for regenerated PAC. The PAC sludge coming from drinking water production and exists for 85% of regenerated PAC and 15% virgin PAC. After use the primary function of PAC is lost. However AquaMinerals is able to retrieve some of its original value by recovering the carbon sludge for infrastructure. Based on the market values of both regenerated PAC and virgin PAC and the content of PAC present in the sludge we calculated the virgin value of the PAC sludge lies at €190 per tonne. For the use of PAC sludge in infrastructural works as 'Immobilisaat' we estimate 20% of original value can be retained,, making the current end-of-life value of the sludge €40 per tonne.

Alternatively we expect the replacement of bitumen to have a sales price of €150 per tonne corrected for the drying and transporting costs of the PAC sludge and the market value of bitumen in asphalt.

Eco-Cost

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. Right now, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in Figure 13.

The eco-costs of PAC at the current end of life are €116 per tonne. When subtracted from the current end-of-life financial value of €40 per tonne, the Total Value equals -€76 per tonne PAC. When using PAC as replacement for bitumen, an eco-profit of €833 per tonne is generated. Adding the financial value of the proposed circular match of €150 per tonne amounts to a Total Value of €983 per tonne. This is an increase in Total Value of €1,059 per tonne.

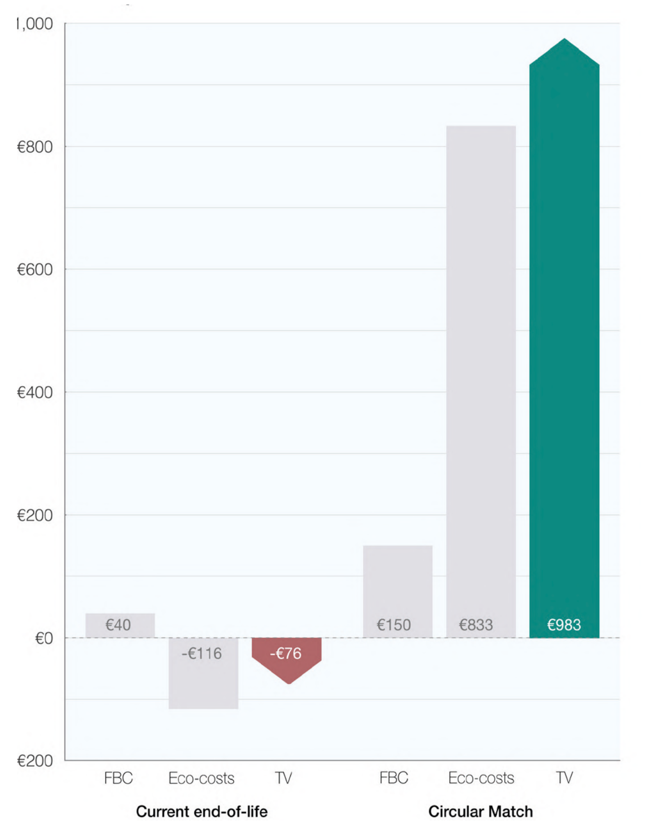


Figure 13: This graph visualises the financial business case (FBC) per tonne of PAC, and shows the difference in "Total Value (TV)" with eco-costs included.

Recommendations by EME

Considering the results of the Resources Passport and the match possibilities, EME sees a significant potential for impact reduction. The most beneficial match is to reusing dried PAC in the construction of roads as a replacement of bitumen. Alternatively, AquaMinerals could create biofuels from the PAC sludge in collaboration with SCW Systems. Herewith, impact savings can be realised for the remaining waste stream as well. We advise to internally use of PAC as replacement of bitumen until SCW systems can process sufficient PAC.

Sodexo delivers Quality-of-Life services to more than 80 countries around the world. As a facility management provider they deliver a total package of services from cleaning and maintenance to food services.

Circular economy goals

Sodexo's ultimate goal is to be totally circular. The first step is to have 100% plastic waste free restaurants in 2019.

Progress

To achieve their goals, Sodexo is collaborating with start-ups, changing their business model and organising innovation challenges to encourage employees to come up with solutions. In addition, the company started eliminating waste streams by giving waste a new purpose.

Partnership with EME

Sodexo joined our pilot out of belief a better tomorrow requires a focus on waste reduction. Together with EME they set out to explore how our platform could facilitate matchmaking waste flows to achieve their aims.

For the pilot we focused on residual plastics, coffee grounds and orange peels. Sodexo generates large quantities of all three materials. During the pilot we made a successful match for orange peels and coffee grounds. Sodexo hopes to receive help with all their other waste flows in the future. The company looks forward to seeing the marketplace in action.

ORANGE PEELS

Sodexo NL generates 77 tonnes of orange peels daily. with considerable financial potential. Orange peels exist of two different organic components: the orange outer layer known as the flavedo and the white inner layer known as the albedo. The flavedo contains fragrances and oils, whereas the albedo contains cellulose and fibres. These materials possess a significant value in the production of new products.

Current End-of-life scenario.

Waste management company Renewi collects the orange peels at end-of-life to produce biogas through anaerobic digestion.

Match Possibilities

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

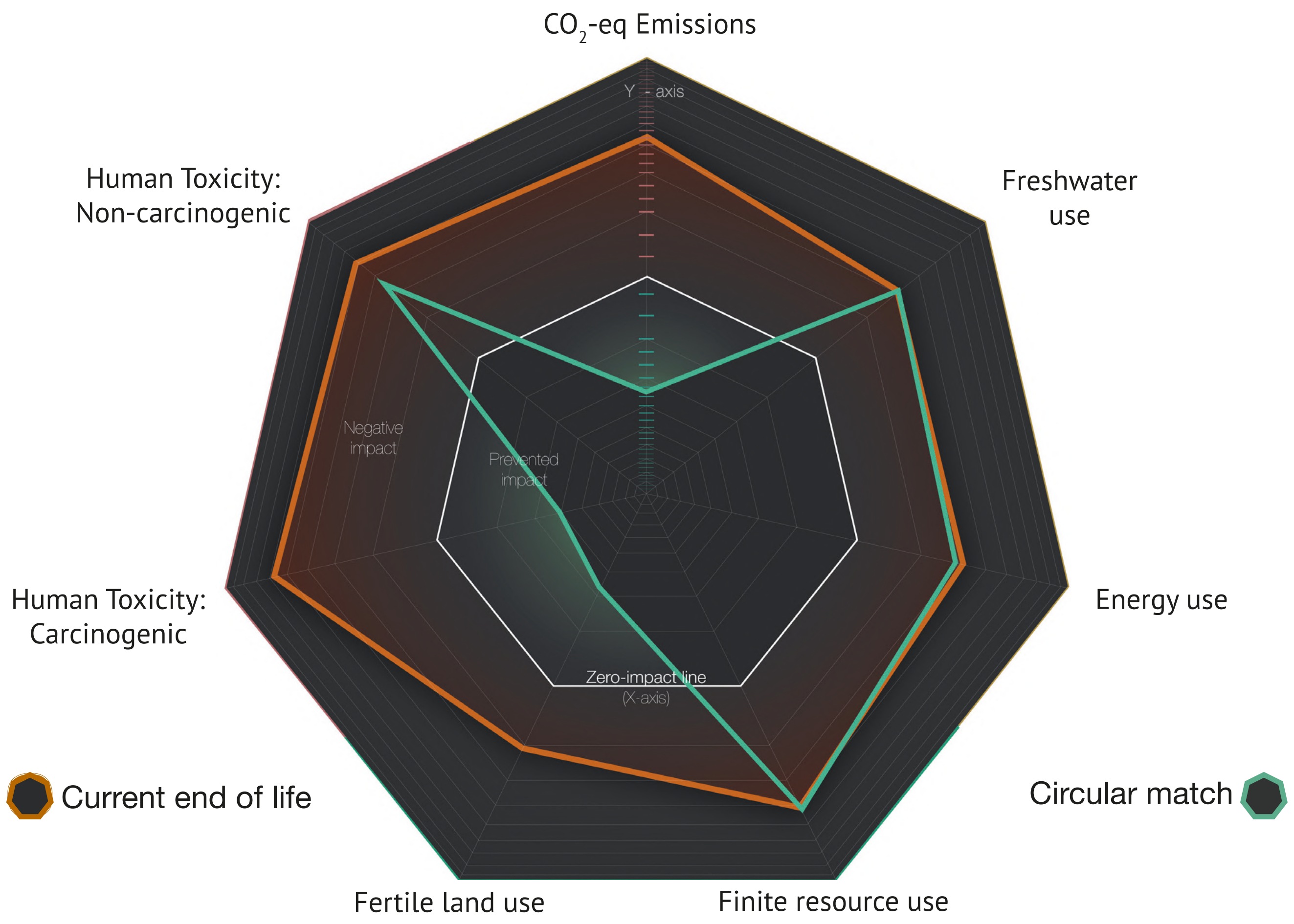
- Innovation partner Spaak uses supercritical CO_2 gasification to extract limonene, 10-fold citrus oil and pectin from orange peels. The waste stream of this process can be sold as high quality cattle feed.
- Peel pioneers uses supercritical H_2O gasification to extract 10-fold citrus oil and limonene. The waste stream of this process can be sold as high quality cattle feed.
- A company called Orangefiber in Italy extracts cellulose from citrus fruits to create polymers. These polymers can be spun into yarn from which clothing can be produced.

Environmental impact

Last year, Sodexo the Netherlands used 139 tonnes of oranges for squeezing fresh orange juice, resulting in an organic waste flow of roughly 70 tonnes of orange peels. Sodexo imports cooled oranges from Egypt. We retrieved impact data per kg of oranges from the Ecoinvent database using Simapro software. On the next page, we visualise the impact of our optimal circular match based on a selected set of parameters: extraction of nutrients by supercritical gasification. Within the proposed circular match, the parameter "human toxicity" shows the most significant impact reduction (190.89%) compared to the current end-of-life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.

Impact Difference

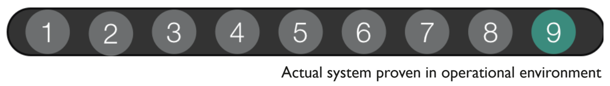
Current end of life vs. Circular Match



Waste Hierarchy

Currently, orange peels are being used to generate energy. When the proposed circular match is applied, this product prevents virgin materials from being used. This is considered to be three steps higher in the waste hierarchy (in Dutch known as "Ladder van Lansink").

Technological Readiness Level



There is a fully developed system, which is ready-to-use in an operational environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	896.11	-45.54	kg CO_2-eq	105%
Freshwater use	359.73	358.11	m^3 water-eq	1%
Energy use	15,269	12,723	MJ	17%
Finite resource use	5.49E-02	5.38E-02	kg Antimony-eq	2%
Fertile land use	4,875.39	-1,449.03	kg C Deficit	130%
Carcinogenic	2.09E-04	-1.90E-04	CTUh	191%
Non-carcinogenic	7.33E-05	4.69E-05	CTUh	36%

Financial Impact

Currently, processing costs of one tonne of orange peels ranges between €40 and €50. With our proposed circular match an instant cost reduction of 50% can be realised, as our innovation partner charges €20 per tonne of orange peels. Our innovation partner expects to process the orange for free in the coming years. Spaak even indicated it will pay Sodexo up to €20 per tonne in the future.

Eco-Cost

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. Right now, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in Figure 14.

The eco-costs of one tonne orange peel at the current end-of-life are €232.19. When added to the waste management cost (financial value) of €45, the Total Value per tonne orange peel amounts to -€277.19. The eco-costs of the proposed circular match are €93.08. When combined with the lower waste management fee of Spaak, the new Total Value is -€113.08 per tonne (figure 14). This is an increase in Total Value of €164.11 per tonne orange peel.

Recommendations by EME

EME recommends Sodexo to start working with innovation partner Spaak and PeelPioneers to implement the circular opportunities. The first step towards realising a high-value circular match for the orange peels of Sodexo is to initiate a pilot project to determine the actual potential of this match. Making internal use of tangible upcycled products created from its own waste flow such as soap (limonene), jam (pectin), biogas (sugars), perfume (10-fold citrus oil) and paint (pigment) improves the sustainable image of Sodexo's brand. Since sustainable waste management is increasingly important to customers of Sodexo, implementing this pilot project is likely to have a positive influence.

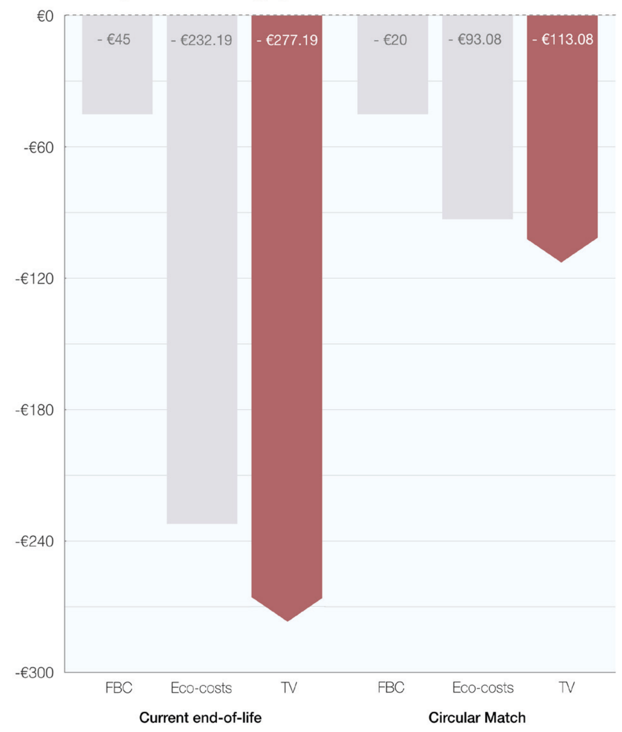


Figure 14: This graph visualises the financial business (FBC) case per ton of orange peels, and shows the difference in "total value (TV)" with eco-costs included.

EME offers its services to help map the logistical landscape and overcome barriers to fully transition towards a circular method of processing this organic waste stream.

COFFEE GROUNDS

Customers of the Sodexo facilities in the Netherlands consume large quantities of coffee. As a result, large quantities of spent coffee grounds are generated each year. These spent coffee grounds are currently labeled as an excess flow, even though they contain organic materials with a considerable high-value and circular potential. We examined alternative methods of waste management that retain the value of spent coffee grounds at end of life.

Current End-of-life Scenario

Waste management company Renewi currently collects the spent coffee ground at end-of-life to incinerate for energy. Additionally, Renewi converts the spent coffee grounds into fertiliser for mushroom production. Although using spent coffee grounds for the production of mushrooms is favourable over energy recovery, improvements can be made by finding higher-value uses with a lower environmental impact and a stronger business case.

Match Possibilities

Based on the results of the Resources Passport analysis, EME identified multiple possible matches. We ranked the proposed circular matches below:

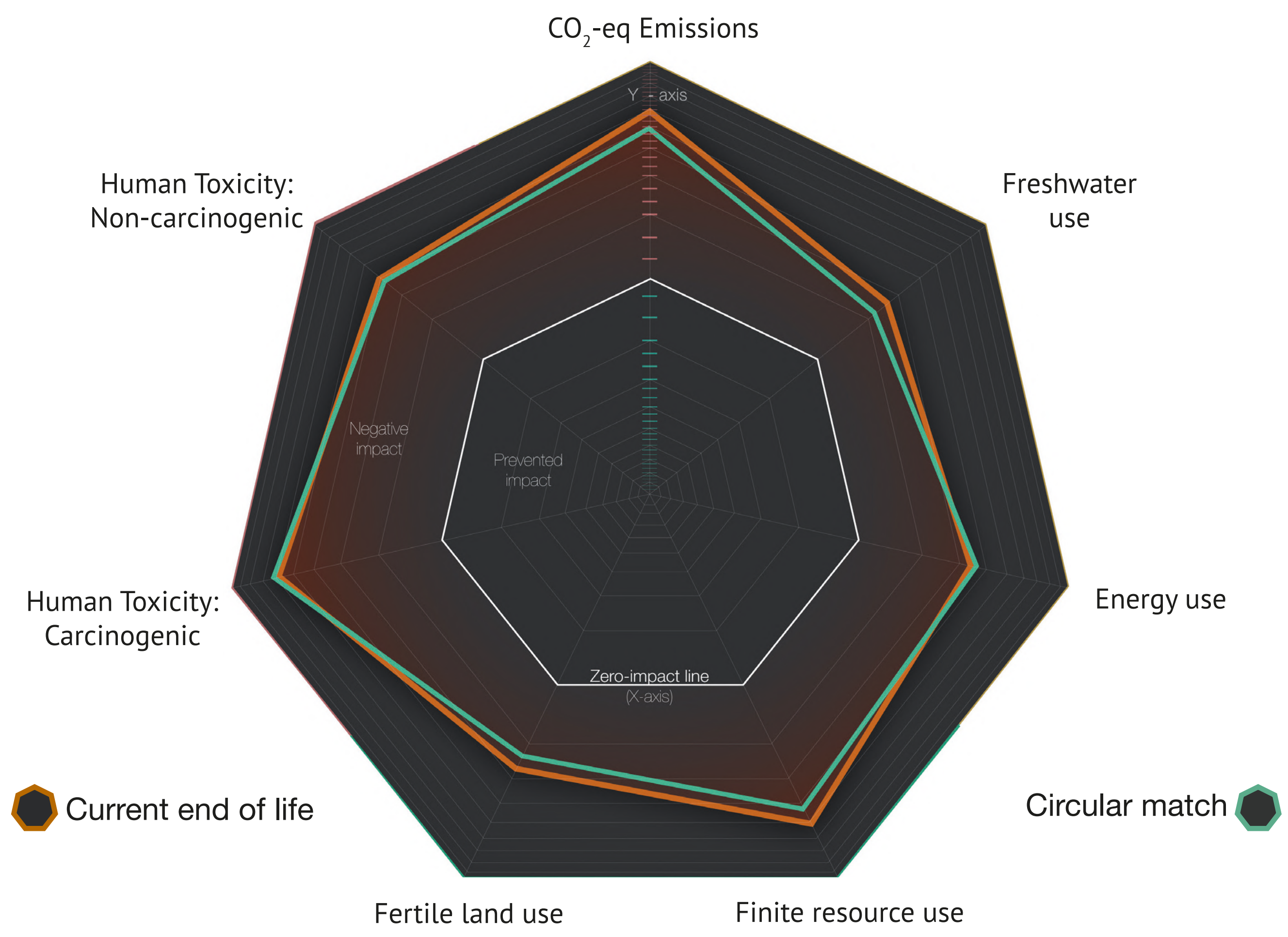
- Extracting black pigments for the production of ink for the printer industry with CafeInk and innovation partner Spaak;
- Extracting cellulose for the production of (coffee) cups with innovation partner Spaak;
- Extracting palmatine acid for the production of soap with CafeInk and innovation partner Spaak;
- Extracting linoleic acid for the production of cosmetics with innovation partner Spaak.

Environmental Impact

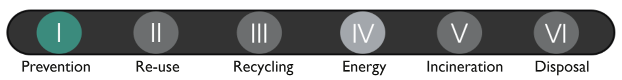
Last year, the cumillated coffee consumption of all facilities of Sodexo in the Netherlands resulted in an estimated 68 tonnes of spent coffee grounds. Coffee is not a local product and possesses a considerable environmental impact. The coffee beans used by Sodexo are shipped by cooled cargo from all around the world. We calculated the impact using data from the Ecoinvent database of LCA-programme Simapro. On the right side of this page, we have visualised the impact of our optimal circular match based on a selected set of parameters: printer ink production. Within the proposed circular match, the parameter "toxicity (human carcinogenics)" shows the most significant impact reduction (15.56%) compared to the current end-of-life scenario. More detailed information on the avoided impact and the impact categories can be found in the table below the radar chart.

Impact Difference

Current end of life vs. Circular Match



Waste Hierarchy



Currently, coffee grounds are being incinerated to generate energy. When the proposed circular match is applied, this product prevents virgin materials from being used. This is considered to be three steps higher in the waste hierarchy (in Dutch known as "Ladder van Lansink").

Technological Readiness Level

Prototype models are being placed and tested in an operational environment.

	Current end of life	Circular match	Unit	Percentage Change
CO_2-eq emissions	6,924	6,485	kg CO_2-eq	6%
Freshwater use	99.08	91.01	m^3 water-eq	8%
Energy use	87,156	87,619	MJ	1%
Finite resource use	8.35E-01	7.80E-01	kg Antimony-eq	7%
Fertile land use	45,651	45,461	kg C Deficit	1%
Carcinogenic	1.32E-02	1.35E-02	CTUh	2%
Non-carcinogenic	8.44E-04	8.20E-04	CTUh	3%

Financial Impact

Renewi charges Sodexo €45 per tonne spent coffee grounds. This material flow is currently being used for the purpose of energy recovery. With our proposed circular match an instant cost reduction of 50% can be realised, as our innovation partner charges €20 per tonne of coffee grounds. Spaak is able to extract valuable materials from the coffee grounds, resulting in an improved business case. Our innovation partner indicates to process the spent coffee grounds for free in the coming years. Spaak also indicates to pay its suppliers up to €20 per tonne spent coffee grounds in the future.

Eco-Cost

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. Right now, the eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs, however, can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product. This is visualised in figure 15.

The eco-costs for spent coffee grounds of the current end-of-life scenario are €2,128. When added to the waste management cost (financial value) of €45, the Total Value per tonne of spent coffee grounds amounts to -€2,173. When applying supercritical gasification to the spent coffee grounds, an eco-cost of €2,082 per tonne is generated. Adding the alternative disposal costs of €20 results in a Total Value of -€2,102. This is an increase in Total Value of €71 per tonne.

Recommendations by EME

Considering the business case and the possibility to reduce considerable environmental impact, EME recommends Sodexo to work together with innovation partner Spaak. By implementing the circular match, Sodexo strongly improves its current waste management model. Making internal use of tangible upcycled products created from Sodexo's own waste flow such as ink made from black pigment improves the sustainable image of Sodexo's brand. Since sustainable waste management is increasingly important to customers of Sodexo, implementing this pilot project is to have positive influence on decision makers. EME offers to map the logistical landscape and create insights into barriers that need to be overcome to fully transition towards a more circular model.

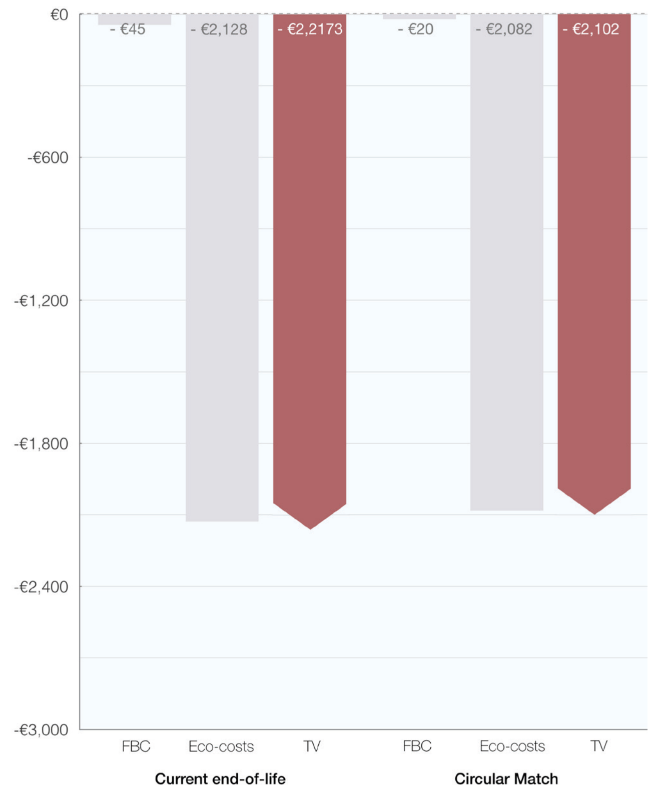


Figure 15: This graph visualises the financial business (FBC) case per ton of coffee grounds, and shows the difference in "total value (TV)" with eco-costs included.

Schiphol Group

Royal Schiphol Group is an airport with an important socio-economic task to provide high-quality aviation infrastructure. As an airport operator, they are responsible for the infrastructural capacity and processes that facilitate passengers, airlines, cargo and luggage. Royal Schiphol Group aims to achieve zero waste by 2030 and to be fully circular by 2050. Currently, Schiphol Group is in the process of integrating circular economy designs and building philosophy into the company's mindset and operational processes.

The company has embarked on various pilots, strategic partnerships and design experiments to accelerate this process. Schiphol's participation in the EME pilot is part of a larger research effort into how to design, procure and build circular assets and infrastructures, how to convert residual streams into materials or products and how to match material supply and demand. Schiphol sees EME as a possible solution for the procurement and offloading of secondary materials. During the pilot we analysed one material flow that turned out to be a prime candidate for sale on our exchange. Schiphol is currently investigating how to upcycle this material flow. When this is definitive, Schiphol will share the results of the pilot and environmental benefits.

With more than 130 years of experience, Tarkett is a worldwide leader in innovative flooring and sports surface solutions. Tarkett offers one of the widest ranges of flooring solutions in the industry. With experienced teams and sales in more than 100 countries, the Group has acquired extensive knowledge and an excellent understanding of customer cultures, tastes and requirements, local regulations, and the use of flooring in each country. Respect for the environment and the health of people at every stage of the product life cycle is at the heart of the Group's virtuous circuit design approach, applied to all of its activities around the world. By offering innovative products with low Volatile Organic Compound (VOC) emissions or phthalate-free plasticisers, Tarkett positions itself as a pioneer, influencing industry standards, encouraging a collaborative circular economy, involving all stakeholders in this sustainable approach.

Within the EME pilot, Tarkett identified three key resources that could be made more circular at the end of their lifecycle. We helped the company better understand how these resources could be reused by potential buyers and calculated the financial, environmental and social impacts of each option. In addition, we actively explored various match possibilities. Tarkett decided to not share the results of the pilot publicly because they contain sensitive information.

GLOSSARY

Eco-costs

Eco-costs represent the costs associated with prevention of the environmental burden of a product. This burden consists of e.g. environmental pollution and material depletion related to the production, transportation and end-of-life treatment of a product. Eco-costs are classified as 'external costs', since they are not yet integrated in the current costs of production chains (Life Cycle Costs). The eco-costs can be added to the financial business case. When combined, we can determine the 'Total Value' (TV) of a product.

Total Value

In order to assess the value creation of a process or product, an approach is needed that incorporates all dimensions of sustainability and externalities. The concept Total Value represents the sum of the financial business case combined with the environmental and social values expressed as eco-costs. This measurement offers transparency and enables better decision making.

Radar Chart

The radar chart visualises the change in environmental impact between the current end-of-life scenario ('business as usual' in orange) and the circular matches (in dark green) proposed for the products. We selected a key set of six impact categories (listed below) in which we express environmental impact. These categories are divided over the different y-axes of the radar chart. The unit of measurement per category differs and is listed in the table below the radar chart. However, in order to correctly compare the different impact categories, the data presented in the radar chart is normalised for relevance on a global scale[6]. Circular solutions aim, other than mitigating the negative environmental impact of a product, to create a net positive impact by preventing emissions from other value chains. In the radar chart, positive impact is visualised making use of the zero-impact line (x-axis). Data points exterior of the zero-impact line represent a negative impact on the environment, while solutions that fall within the zero-impact line have a positive impact on the natural environment. This is highlighted by a red-coloured fill for negative impact while a green fill displays prevented impact.

Impact Categories

For the radar chart, we selected a key set of six impact categories with which we express environmental impact. These categories are as follows:

1. CO_2 emissions (expressed in kg CO_2-equivalents
2. Freshwater depletion (expressed in m^3 fesh water)
3. Energy use (expressed in MJ)
4. Finite resource use (expressed in kg antimony-equivalents)
5. Land use (expressed in kg C deficit)
6. Human toxicity (expressed in comparative toxic unit for humans)

Kilograms of CO_2-equivalents (CO_2 emissions)

During production, transport and end-of-life management of products a wide variety of greenhouse gases are emitted. A CO_2-equivalent is a metric measurement and useful tool to take into account the varying intensities of impact of different greenhouse gas emissions expressed in one unit. Although CO_2 is known as the characteristic greenhouse gas, by use of conversion, the effect of other greenhouse gasses can be converted to that of CO_2 emissions and summed up as one value.

Fresh water use in m^3 (Freshwater depletion)

Water depletion refers to the amount of freshwater used in relation to the local availability or scarcity of water, and the ability of water bodies to replenish sustainably. Water depletion is expressed in cubic metres of water-equivalents from ground water, river water and lake water. The availability of freshwater at location of extraction is taken into account, as the environmental impact of water extraction differs between locations rich or scarce of water.

MJ (Energy use)

Energy use is calculated using the method of Cumulative Energy Demand (CED) and is expressed in megajoules. The CED of a product represents the direct and indirect energy use throughout the life cycle of a material/product, including the energy consumed during the extraction, manufacturing, and disposal of the raw and supplemental materials.

Antimony-equivalent in kg (finite resource use)

Finite resource depletion indicates an amount of finite resources extracted beyond the natural rate of recovery for that resource reserve. This results in a net loss of the available reserves. Finite resource depletion is expressed in kg of antimony equivalents extracted during the production, transportation and end-of-life management of a product. Antimony, also known as the element stibium (Sb), is a commonly used rare earth mineral applied in, for instance, batteries needed for devices such as laptops and phones. Since the available natural reserves of antimony have been mapped extensively it is used as a reference for other finite resources such as other rare earth minerals and fossil fuels. For the available reserves of these resources characterisation factors have been developed that allow comparing these reserves to that of antimony. Based on this comparison and the conversion factor, the amount of resource depletion for any finite resource is expressed in kg of antimony equivalents.

Comparative Toxic Unit for Humans in CTUh (Human toxicity)

Human toxicity is expressed in a unit called the Comparative Toxic Unit for Humans abbreviated as CTUh. CTUh is a measurement for the estimated increase in morbidity (the rate of disease) for the total human population per kg of product produced. The increase in morbidity level per kg of product is calculated based on the amount and types of chemicals emitted during the extraction, manufacturing and disposal of the raw and supplemental materials. A distinction is made for carcinogenic and non-carcinogenic cases of morbidity, which depend on the type of chemicals emitted during a product's life cycle. For example, the emittance of benzene (a carcinogenic substance) during the production of a material has an effect of 1 CTUh per kg. This means that for the production of 1 kg of that material it is expected that there will be one more incident of cancer among the total population.

Carbon deficit in kg (land use)

Trees, plants and the land itself store carbon. For example, forests contain large amounts of carbon stored in roots, trunks and branches. Once this forest is converted to agricultural land and the forest is cut down, the stored organic carbon is emitted as CO_2. Land use is expressed in this loss of stored organic carbon called carbon deficit. In turn, land use changes can also result in a net accumulation of soil organic carbon, which is sequestered from air.

For more info, please visit the following document and the ILCD handbook. http://eplca.jrc.ec.europa.eu/uploads/LCIA-characterization-factors-of-the-ILCD.pdf

In the pilot, EME created a potential water saving of 860 Olympic-size swimming pools.

Technological Readiness Level

Technological Readiness Level (TRL) is a concept used to estimate the maturity of a developing technology. We use TRL to categorise each match option on a scale ranging from 1 to 9. The scope of the TRL reaches from the fundamental research phase to advanced scenarios in which a technology is technically and commercially market ready. The different levels of technological readiness are categorised as follows:

Level 1: Basic principles observed

The theory supporting the technology is being developed and future research agendas are established.

Level 2: Technology concept formulated

The basic theory supporting the technology has been researched and reported.

Level 3: Experimental proof of concept

The technology has abundantly been researched and a system which could harness the potential of the envisioned technology is being tested in analytical and experimental manners.

Level 4: Technology tested in lab

The system has proven to be operational, based on laboratory-conditions, but needs higher levels of validation.

Level 5: Technology tested in relevant environment

The technology is being tested in scenarios mimicking the operational environment.

Level 6: Technology demonstrated in relevant environment

The designed system, mimicking the operational environment which could harness the potential of the envisioned technology has been proven operational. Prototype models are being developed.

Level 7: System prototype demonstration in operational environment

Prototype models are being placed and tested in an operational environment.

Level 8: System complete and qualified

Prototype models have proven to be successful and are being implemented in the relevant environment.

Level 9: Actual system proven in operational environment

Fully developed system is ready-to-use in an operational environment.

Waste Hierarchy

Waste hierarchy (also know as the "Ladder van Lansink in Dutch) indicates a preferential order for the treatment and processing of waste. The different categories rank the various waste treatment methods based on environmental impact, energy use and resource consumption. We use the waste hierarchy to assess our circular matches. In order to make a circular match, we found alternative uses for the product or material flow. Therefore, the end-of-life scenario of a circular match is considered a prevention of the production process of a new product rather than a waste process. The specific waste treatment level of the match is listed on the passport page. The following levels are part of the waste hierarchy:

I Prevention

Waste is prevented by design. For example, by designing the production process in such a way that no waste is created in the first place or by making sure that waste can be used as input for another process and thereby preventing materials from being used.

II Reuse

The product can be reused by fulfilling its original purpose in another location, thereby preventing the production of a new unit of this product.

III Recycling

Recycling is the process of recovering and converting waste materials into raw materials and objects.

IV Energy

Energy recovery from waste is the conversion of waste materials into usable heat, electricity or fuel through a variety of processes. This process is often called waste to energy.

V Incineration

Incineration is a waste treatment process that involves the combustion of substances contained in waste materials without recovering energy.

VI Disposal

Disposing of waste materials by landfilling.

Assumptions

As with all methodologies, we had to make assumptions to simplify reality. For further details, do not hesitate to contact us.

Chapter 5

CONCLUSION

CONCLUSION

Over the course of the pilot, we analysed the waste flows of ten organisations, among which: ProRail, Rijkswaterstaat, Schiphol, Aquaminerals, Heembouw, Sodexo and Tarkett and found new high-value matches for them. We will highlight the general conclusions of this pilot project first. Thereafter, we will share details about the aggregated impact this pilot.

General pilot results

Through the pilot we were able to validate our hypotheses and come to the following conclusions:

- Data alone or a single digital tool will not solve the challenge of collaboration, transparency and data security. A holistic approach is needed to guide companies in the transition towards a circular economy.
- A clear and unified data format to collect material characteristics is an essential tool to exchange excess material flows at their highest value. Only when information on alternative options is available can a comparison be made between various alternatives across sectors and industries.
- Tracking and tracing of materials, components and products enables the actual closing of loops by being able to locate materials. At the moment, many valuable materials are lost because their location is unknown.
- Quantifying the value of excess materials is essential in creating solid business cases to redefine waste as a valuable material. When a material is sold via EME, a cost is turned into an additional source of revenue.
- A (digital) tool that assesses the environmental and societal impact of high-value reuse is essential in creating a circular economy.
- The current legal framework provides room for the cross-sectoral exchange of materials at their highest value.
- We have sparked organisational change and furthered conversations about circular economy within our clients' organisations. Some have created dedicated task forces, multidisciplinary teams and set more ambitious targets for themselves to speed up the transition to a circular economy.

Impact of the EME pilot

During the pilot, 18 different materials made their way through our platform. With the help of the Resources Passports we created together with the pilot participants, we were able to calculate the possible financial costs, water, CO_2 emissions and energy savings that could be achieved by implementing high-value alternative uses for the - currently wasted - resource flows. We found high-value reuse options for each of these flows, as described in the matchmaking pages. We also aggregated these environmental and financial impact calculations to get an indication of the extent to which the exchange of secondary materials can contribute to achieving the Paris Climate Agreement.

> "*EME does look promising as an example of a new approach that might help unlock the full potential of the circular economy.*
>
> *- HRH the Prince of Wales -*
> *At Business in the Community 'Waste-to-Wealth' Summit*"

Box 1: potential impact of the 18 material flows in the pilot

A CO_2 emissions reduction of 123 kilotonnes CO_2, which equals the emission of all citizens of Amsterdam (862,987) driving from Amsterdam to Milan.

An energy saving of 2,883 TJ, equal to the energy consumption of the public lights in Paris for at least five years.

A potential creation of €64m in financial value and a reduction of €54m in environmental damage (eco-cost), resulting in a Total Value creation of €118m. The potential savings on waste treatment cost add up to €5.4m annually.

Organisational changes: One of the participants put together a special team to oversee the matching of the materials. Another embarked on new collaborations with garbage disposal companies.

Water savings equal to the content of 860 Olympic-size swimming pools.

The summed weight of the streams analysed in the pilot is 70,000 tonnes, which is equal to the weight of seven Eiffeltowers.

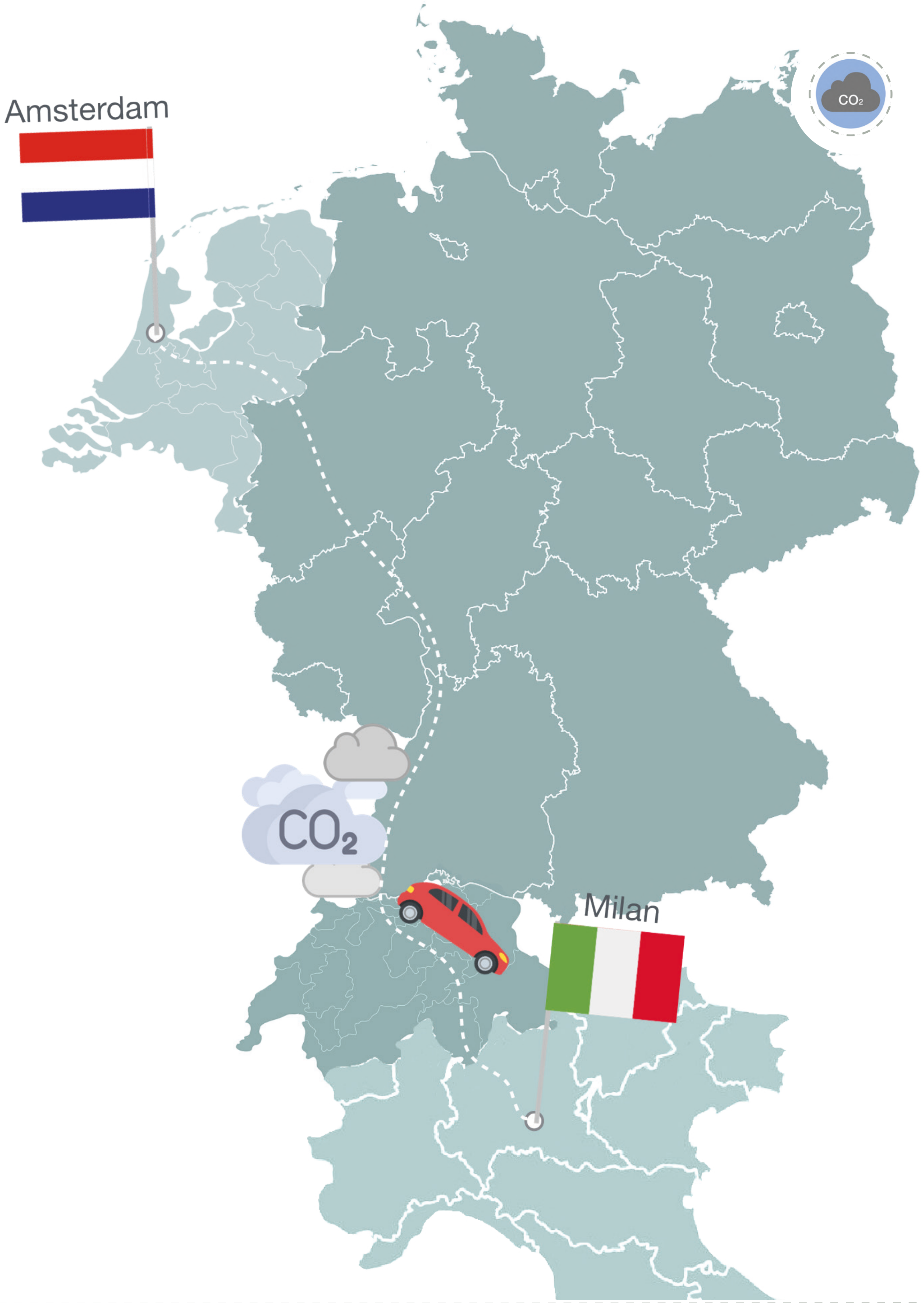


Figure 16: The CO_2 emissions we calculated throughout the EME pilot are equal to 862,987 car rides from Amsterdam to Milan. This represents all inhabitants of Amsterdam driving 1,180 km.

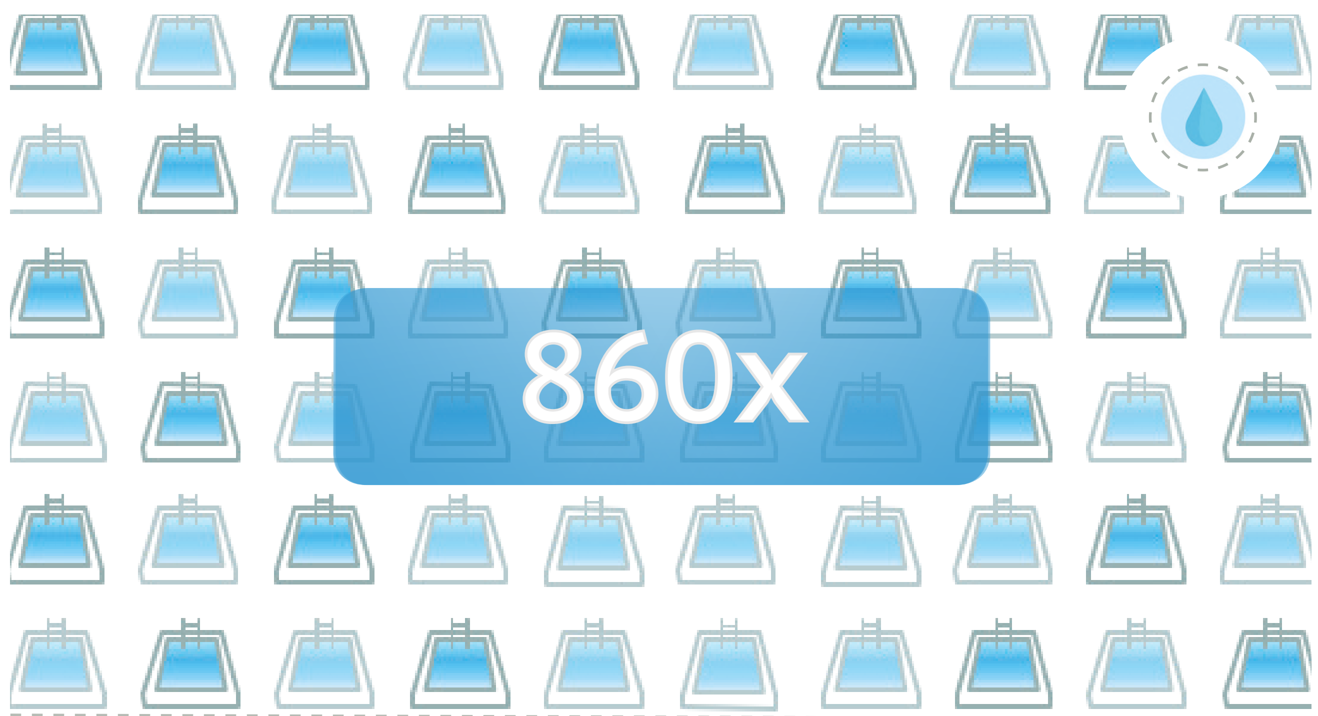


Figure 17: The potential water use savings throughout the EME pilot would equal the content of 860 Olympic-size swimming pools

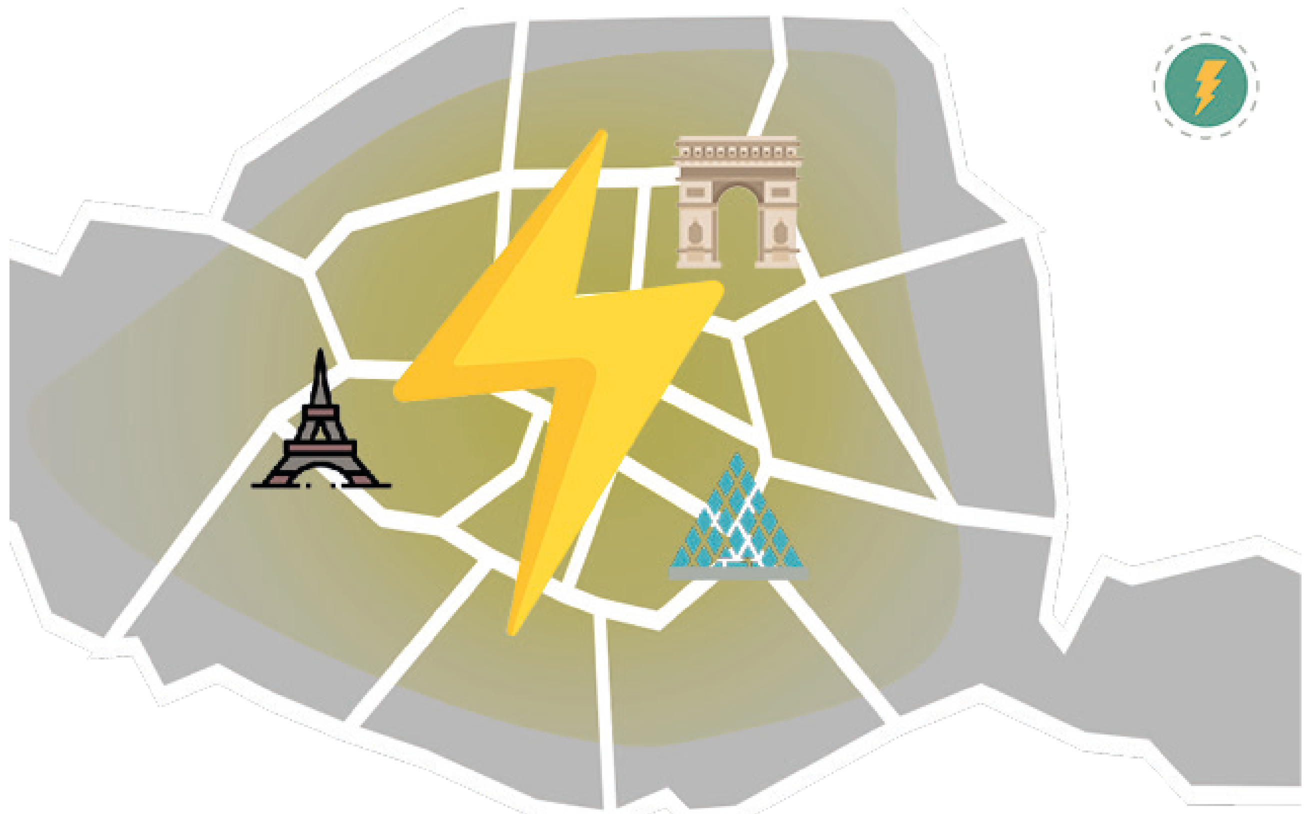


Figure 18: The matches derived from the EME pilot create a potential energy saving equal to the energy use of the city lights in Paris for up to 5 years.

Next Steps

During our pilot we successfully analysed our clients' excess material flows with the help of our tools. Together with the participants it is now the time to implement the matches we made and update our clients' operations to accommodate these excess materials exchanges. During the next phase our impact will move from the hypothetical to the tangible.

Moreover, we aim to integrate the insights obtained throughout this pilot into the next phase of EME. The coming period we will be focusing on:

- Further development of our tools;
- Digitizing our tools on the marketplace;
- Start training our matchmaking algorithms;
- Onboard more organisations on the EME platform;
- Reduce the environmental footprint of companies;
- Help speed up organisations in the transition to a circular economy and turn their waste into wealth.

These efforts will first and foremost culminate in us rolling out the EME platform in the Amsterdam Metropolitan Region (MRA). Our lessons learned from the pilot helped us win the competition "Digital and Circular". Our work in the MRA will be done with Copper8 and Alba Concepts. For us, this is a fantastic opportunity to help make this region more circular while further developing our platform.

Finally, we aim to contribute to the circular economy ecosystem at large. There are a multitude of external factors outside our immediate control that impact the speed of the transition to a circular economy. They include accounting rules, Product-as-a-Service (PaaS) models, official waste definitions and EU legislation. We try to positively contribute to all these areas by sharing our knowledge and experience with our network and by organising working groups around specific topics.

If you also want to transition to a circular economy and would like to join our journey, please contact us for more information at: info@excessmaterialsexchange.com

Figure 19: The potential financial value created and the environmental damage saved expressed in euros once the identified circular matches have been implemented.

Accolades

EME won the Metropool Region Amsterdam call called 'Digital and Circular';

Maayke was listed as one of the MIT 'Innovator 35 under 35';

Maayke was selected for the DJ100;

Maayke was recognized as a FD Top Talent 2019;

EME: Accenture Innovation Award Finalist;

EME: Ellen MacArthur CE100 Emerging Innovator;

Highly commended in The Circulars Awards;

EME: Winner Katerva award 2019 category Economy;

Christian was recognized as High Potential 2019 by PropertyNL;

EME: Supported by Stichting DOEN;

FOOTNOTES

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6. Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127, 221-232.
7. Sala, S., Crenna, E., Secchi, M., & Pant, R. (2017). Global normalisation factors for the Environmental Footprint and Life Cycle Assessment.