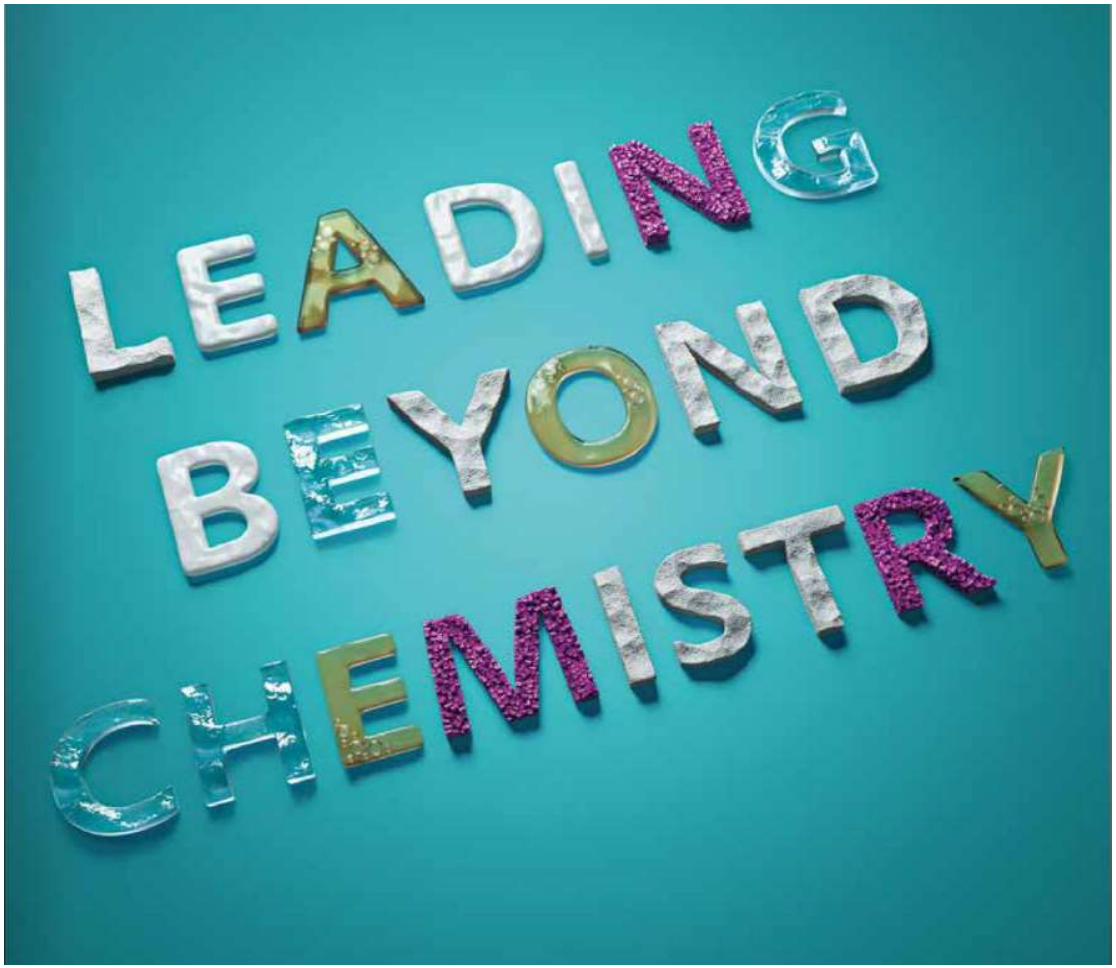
Circularity to Foster New "Value ~~Chains~~ NETWORKS" & Innovative Technologies

ProcessNet 2022

R. Kelle, Sustainability Strategy
Evonik Industries AG



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What is Circular Economy?

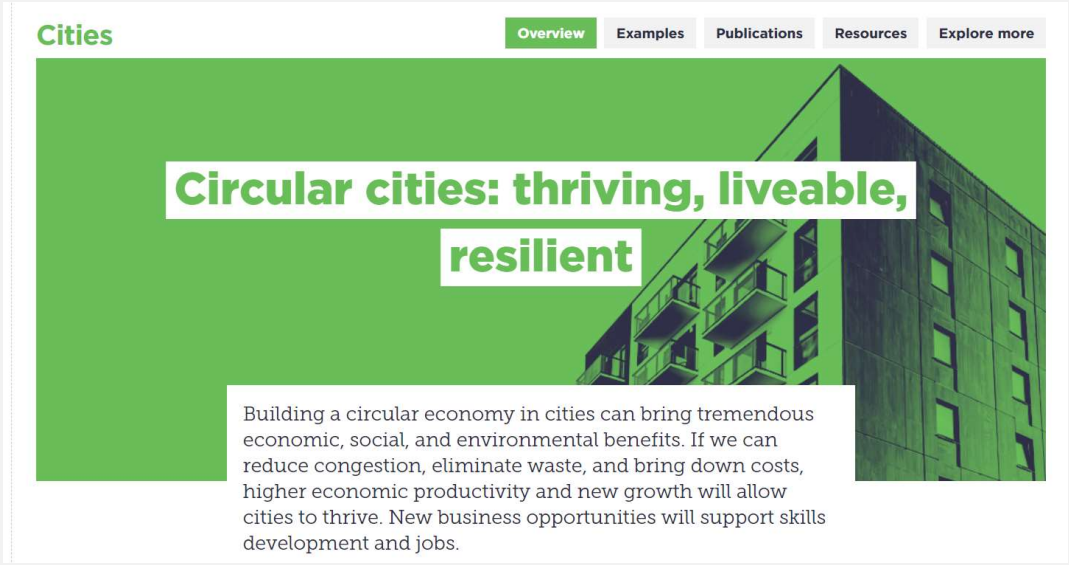
‘A systems approach involving industrial processes and economic activities along the whole value chain that are restorative or regenerative by design, aiming for a climate-neutral and resource-efficient economy by maintaining the value of products, materials and resources as long as possible.’

Definition of Circular Economy by the Circular Economy Network of Experts. Based on definitions of Ellen McArthur Foundation (EMF), the US Environmental Protection Agency (EPA) and the European Parliament.

Circularity as key enabler to address major sustainability challenges

With 68% of global population living in cities by 2050[1)]

Ellen McArthur Foundation Assessment 2019



UN Assessment in Preparation of COP27[2)]

…cities consume **78 per cent of the world's energy** and produce **more than 60 per cent of greenhouse gas emissions**. Yet, they account for less than 2 per cent of the Earth's surface.

...**1.8 billion children** breath air that is so polluted it puts their **health and development at serious risk**.

1) UN 2018: „today, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050"
2) UN 2022: https://www.un.org/en/climatechange/climate-solutions/cities-pollution

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Stakeholder ambitions translate circular economy into a framework

Can be summarized in five dimensions for circular economy

Business Pledges & Targets in Established Value Chains

Automotive Materials & Tires
Packaging & Service Ware
Durable Consumer Goods
Electronic Materials
Furniture & Household Appliances
Building Products
Construction Materials
Renewable Energy Production & Storage Materials

Regional, Country, State, and Local Policy

EU Circular Economy Action Plan
China 14th Five Year Plan for Circular Economy
California waste & recycling related bills
New York Circular City Initiative
Singapore's Inaugural Zero Waste Masterplan
and many more …

Circular Economy dimensions[1]

1. **Decoupled resource use from economic value**
2. **Reduced material waste**
3. **Increased non-virgin raw material share**
4. **Increased product longevity**
5. **Reduced emissions**

At no expense to overall sustainable development

1: based on B. Corona et al., 2019, Res. Cons. & Recycl. 151

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Buildings

drivers for change [1] calling for a system approach within a reliable policy frame

By 2025, 1 billion **new homes** are needed worldwide, costing USD 9-11 trillion overall

49% of owner-occupied **homes** in the UK are **„under-occupied“**, 60% of European **office space is unused** during working ours

Construction materials and the building sector are responsible for more than **one third of global resource consumption**

Up to 40% of urban solid waste is **construction and demolition waste**. Only 20-30% is recycled or reused, often due to **poor design and lack of information on building contents**

More than 80% of the total **energy consumption in a building‘s life** is consumed during its use

US cities may be 1-3°C warmer in the daytime and up to 12°C warmer in the evening than surrounding areas due to the **heat island effect**

1) From Ellen McArthur Foundation 2019: Circular economy opportunity & benefit factsheets

Mobility

drivers for change [1] calling for a system approach within a reliable policy frame

Traffic congestion cost 2-5% of global GDP annually in lost time, wasted fuel, and increased cost of doing business

50% of European inner-city **land is paved for roads and parking** leading to higher temperatures and higher risks of flooding. But even in rush hour, **cars use only 10% of urban roads**.

European **cars are parked 92% of the time** and when **in use only 1.5 out of 5 seats** are occupied

20% of average European and US **household gross income is spent on car ownership**

In India, electricity to power **street lighting and maintenance cost** can account for 5-10% of municipal budgets in larger cities and up to 20% in smaller cities

90% of **air pollution in cities** is caused by vehicle emissions. 90% of urban residents in Europe are exposed to harmful levels of air pollutants

1) From Ellen McArthur Foundation 2019: Circular economy opportunity & benefit factsheets

Products

drivers for change [1] calling for a system approach within a reliable policy frame

More than 80% of a product's **environmental impact is determined at the design stage**

75% of **urban solid waste** consists of discarded consumer goods; of which 80% is burned, landfilled or dumped. Up to 20% of municipal budgets are spend on waste management

Globally, customers miss out on up to USD 460 bn each year by **throwing away clothes.** In 2015, **CO_2e emission from textiles production** was 1.2 bn tons. **Mismanagement of chemicals** to cost EUR 7 bn a year by 2030 in illness and early mortality.

Worth $ 107 billion, **e-waste** is generated globally each year, of which only 20% is collected and recycled under appropriate conditions

19% of **European households' energy consumption** is used for lighting, electrical appliances and cooking. This could be reduced through better product design.

80% of household items are **used less than once a month**

1) From Ellen McArthur Foundation 2019: Circular economy opportunity & benefit factsheets

How to frame innovation to address these issues?

1. Circular Raw Materials will help - but will not be able to resolve fundamental problems.
2. New, circular business models will (have to) shape and transform existing value chains.
3. Necessary investments and shift in employment will need reliable policy frameworks.
4. Design decision for products and services have much higher impact than manufacturing options. *How can process engineers, chemists, and biologists be part of these design discussions?*
5. „Technology“ is a key enabler of the transformation as it facilitates credible information to be shared between stakeholders to design and assess solutions for (sustainable) systems impact.
6. Process industry with asset lifetimes of several decades has to be aware of lock-in risks, both on the manufacturing / raw material / energy supply side and the product application & end of life side.

How is Circularity Anchored in Evonik's Sustainability Strategy ?

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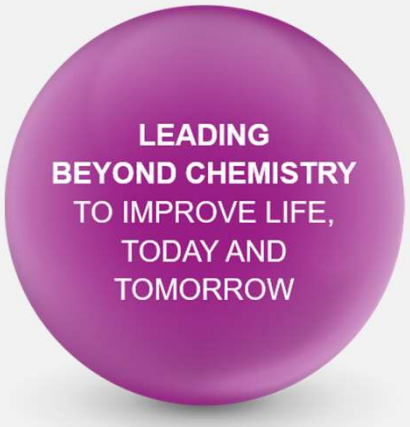
Evonik's Sustainability Strategy

Delivering on our purpose and an integral part of our strategy process

Sustainability is an integral part of our purpose



We drive profitable growth …

"**Sustainability is a key growth driver** and the cornerstone of our product portfolio, our investments and our innovation management."

… by fully accepting our responsibility

"We **take responsibility** to improve life by **caring about our resources**. We see profitable growth and accepting responsibility as **two sides of the same coin**."

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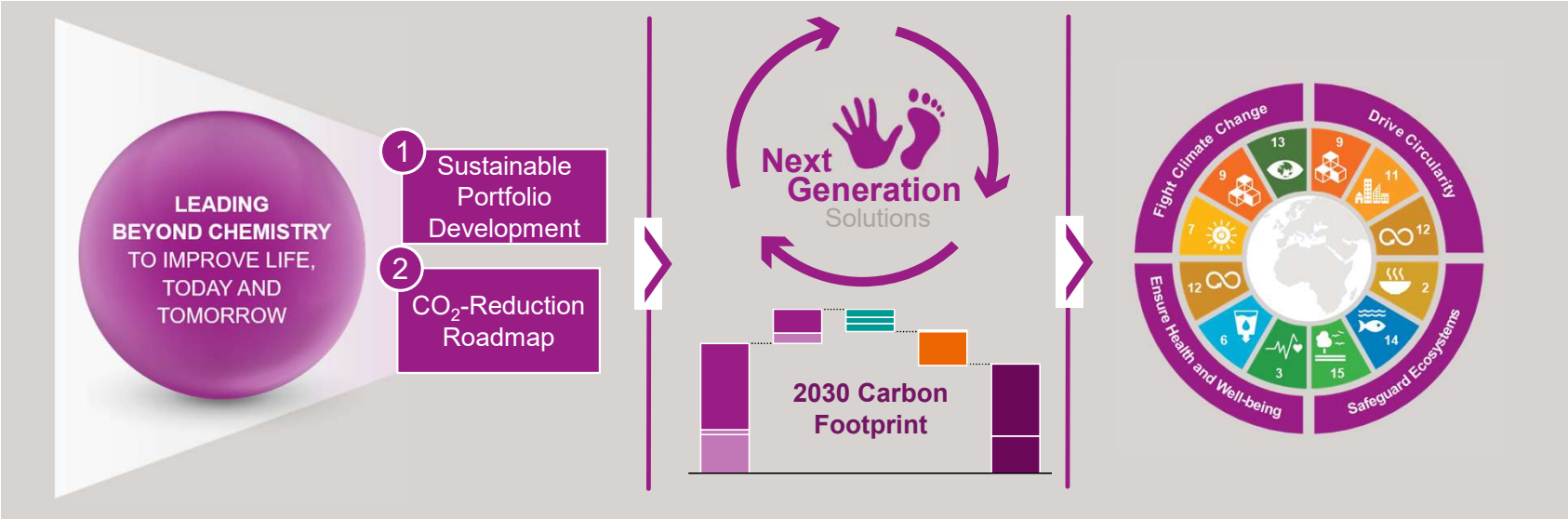
Evonik's Sustainability Framework
to measure our performance and to guide our activities



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Portfolio Sustainability Assessment (PSA)

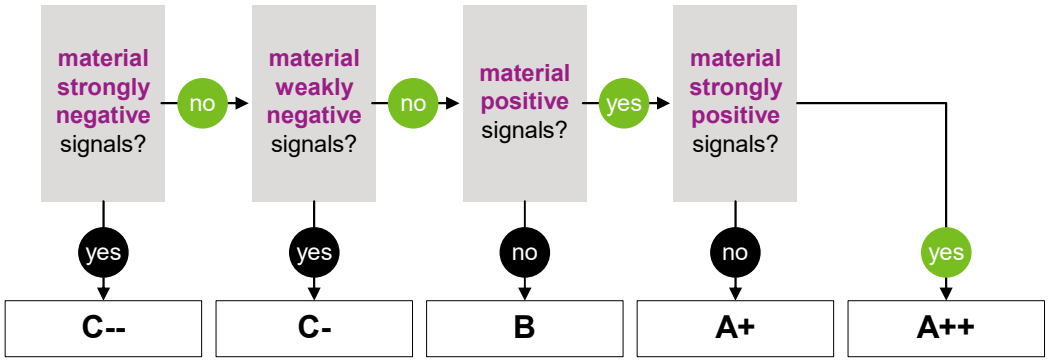
Allows us to identify market signals in time and integrate sustainability in strategy

WBCSD methodology[1]

Analysis of the product portfolio for meaningful combinations of product, application and region.

Considering following signal categories[2]:

1. Critical substances
2. Regulatory trends and global commissions
3. Sustainability ambitions along the value chain
4. Ecolabels, certification and standards
5. Relative environmental and social performance



Terms coined by Evonik

Challenged | Transitioner | Performer | Driver | Leader

NEXT GENERATION SOLUTIONS

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Consideration of Circularity in Portfolio Sustainability Assessment (PSA)

Questions to assess materiality of circularity

1) Does the product impact the circularity of the PARC?

YES, supports circularity

- Uses non-virgin or sustainably renewable raw materials (inflow circularity)
- Positively impacts durability/longevity, reusability, repairability, disassembly, remanufacturing/refurbishment, recycling or other optimization of the use of the resource like resource efficiency and recovery potential.
- Provides a 100% closed loop with 100% bio-based and 100% biodegradable materials.

Driver | Leader

NEXT GENERATION SOLUTIONS

if no other negative signals

YES, hinders circularity

- by negatively impacting the above mentioned circularity activities

Challenged | Transitioner

NO

- Does not hinder nor support circularity activities.

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Portfolio management: Adding sustainability as integral dimension

Alignment of sustainability clusters and strategic roles in strategy dialogues

Bringing together two approaches

Strategic roles in portfolio

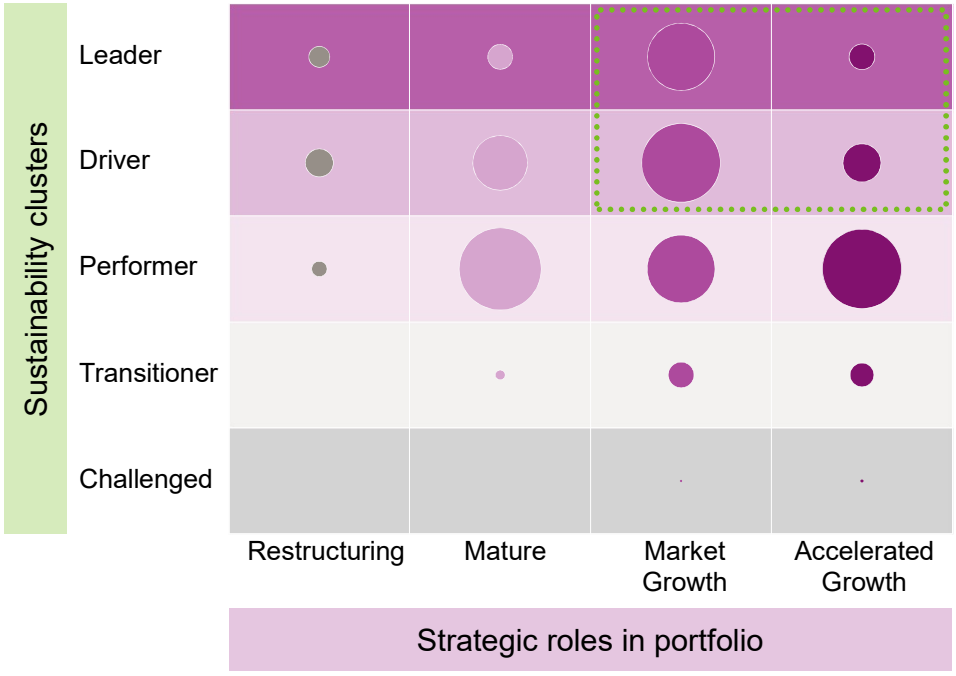
Traditional strategy matrix

+

"Portfolio Sustainability Analysis"

Sustainability clusters

To derive new strategic actions



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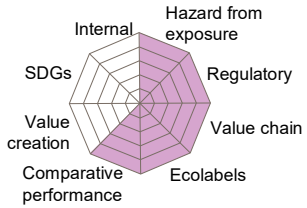
Sustainability fully integrated in corporate strategy

PSA and Emission Data Cube: core tools for strategy management process

"Portfolio Sustainability Analysis" (PSA)

Assessing products vs. market signals

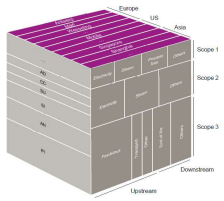


Categorization of product portfolio

- >500 PARC[1]s analyzed
- Classification into 5 product sustainability clusters with simple ranking from C-- to A++

"Emissions Data Cube" (Evonik GHG summary)

Emissions' analysis



3-dimensional emission data

- By business lines and divisions
- By type: scope 1-3 emissions, up- & downstream
- By sites and region

Outcomes for Strategic Management Process

- Portfolio circle with sustainability clusters, to be aligned with strategic roles of product groups
- Portfolio guidelines for product and innovation steering

- Targets considered in asset strategy and accounted for in resource planning
- Simulation of scenarios in all dimensions (e.g. portfolio moves, regional choices)

Portfolio management | **Innovation management** | **Capital allocation**

1. PARC: product-application-region combinations

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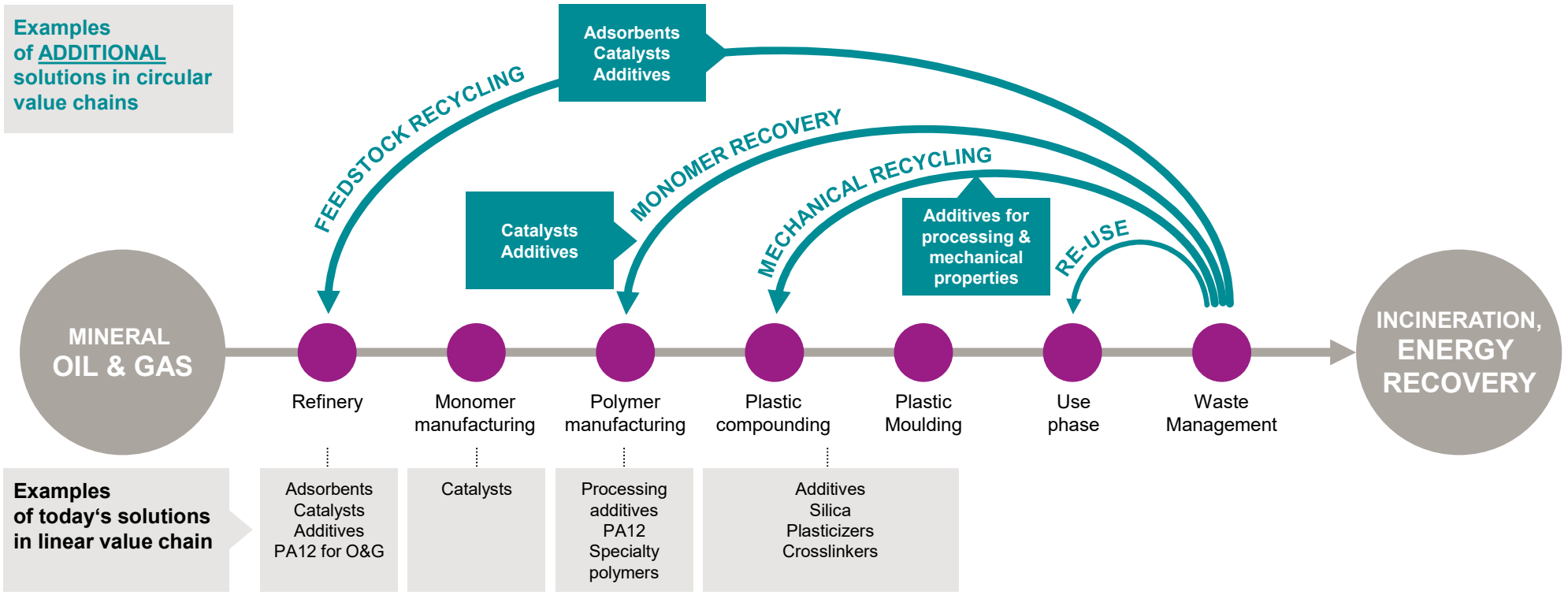
Evonik provides solutions along the entire Circular Plastics Value Chain

With our Specialties we help our clients to keep plastic in the loop



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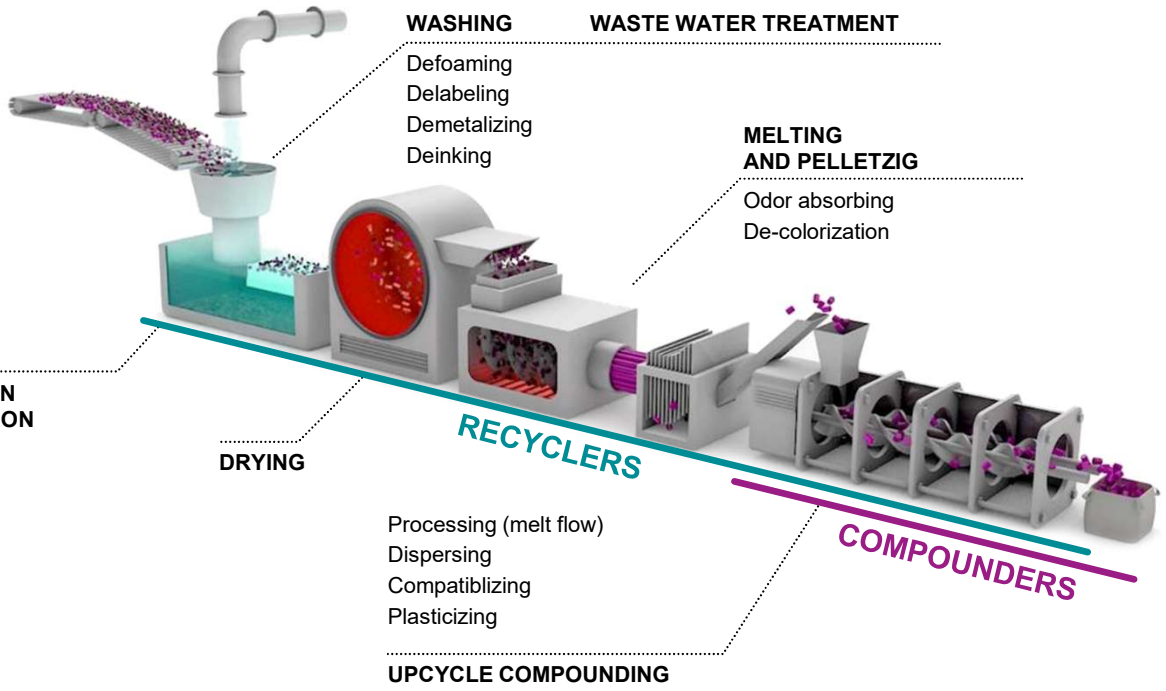
Our technologies help along the entire mechanical plastic recycling process



Mechanical Recycling

- During separation/washing, **our additives help to make recycling processes more efficient** resulting in higher quality of recyclates
- During compounding, **our additives improve processing** leading to competitive costs and quality

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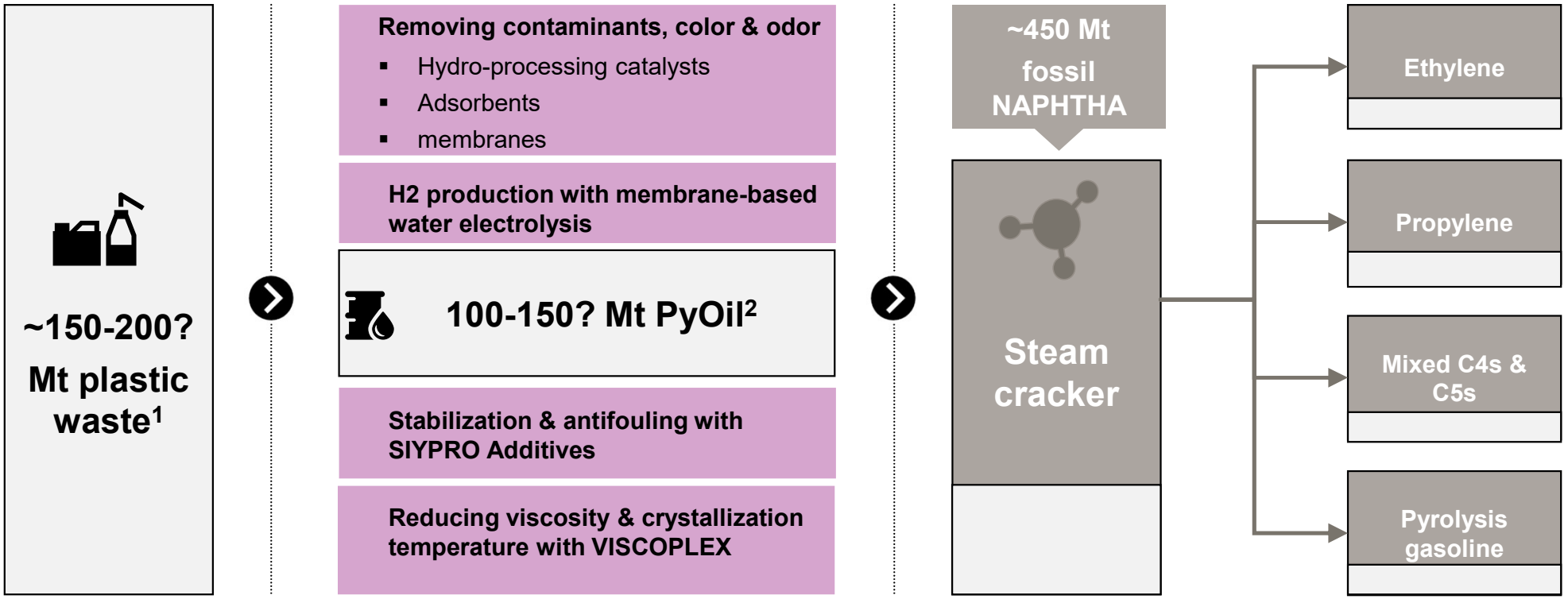
Pyrolysis of mixed plastic waste: We help with expertise & enabling technologies to make plastic waste a suitable feedstock to substitute fossil NAPHTHA



[1]not suitable for mechanical recycling

[2]purification and upgrading technology of off-gases available, potential of py oil from if plastic waste would be fully converted. Wide range of yields reported in Papari, S.; Bamdad, H.; Berruti, F. Pyrolytic Conversion of Plastic Waste to Value-Added Products and Fuels: A Review. Materials 2021, 14, 2586. https:// doi.org/10.3390/ma14102586

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Linerless labels have up to 40% reduced material usage

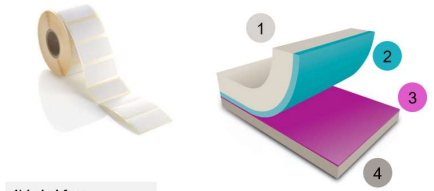
Challenge

- Every day >275m parcels are delivered, consuming 4.3 Mm^2 labels
- Liner make up to 40% of the weight of traditional labels
- **Causing unnecessary waste, emissions, material and logistics costs**

Solution

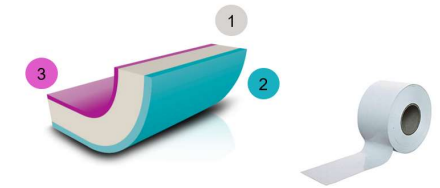
- A silicone coating ensures that the windings separate cleanly and quickly before dispensing the individual label
- **Linerless labels can save ~75 kg of CO_2 per 1,000 m^2 of label**
- More efficient logistics and handling

Standard Label



Weight: 140-180 g/m²

Linerless Label



Weight: 80-100 g/m²

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Becoming circular in performance polymer production

Challenge

- Production of performance polymers requires fossil resources
- Only 9% of plastic waste today is recycled[1)]
- High end applications such as sun-glass lenses require high quality materials
- Applications like that cannot be served by mechanical recycling

Solution

- Chemical recycling to monomer can access a significant part of app. 150 Mt of plastic waste, presently not accessible for mechanically recycling
- Monomers can be fed into existing manufacturing assets
- At the same time quality level can be assured

VESTAMID® eCO E40

TROGAMID® eCO

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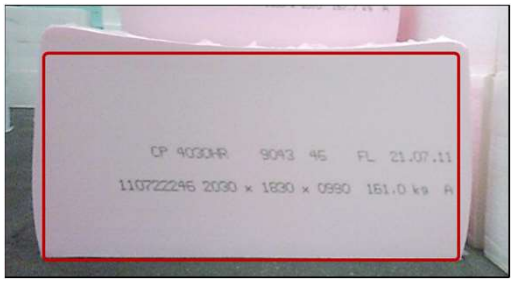
Reduced formation of PU foam waste at our customers
simulation of a production line creates perfect production settings

Challenge

In the production of globally 5 million tons flexible PU foam[1] approx. 10% of the raw materials are converted into foam that can not be used as intended (foam defects)[2]

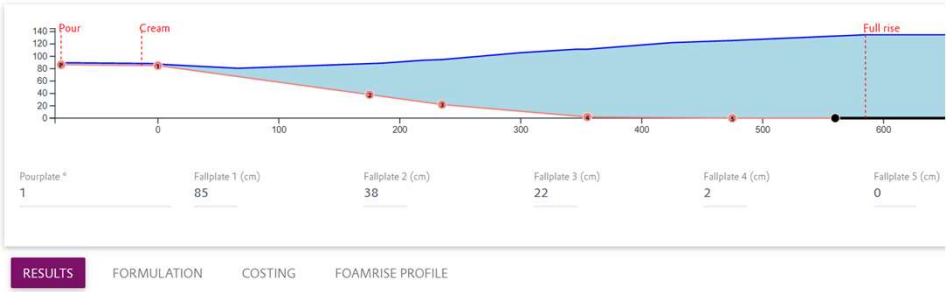
- Non-optimal production line settings cause the defects
- Consequences are: avoidable cost, waste of raw materials, poor sustainability profile



Foam defects: splits, form not rectangular

Solution

- The SaaS-solutions TEGO® RISE enables our customers to find perfect settings of their production line → 2% reduced scrap
- Deep understanding of PU chemistry & applied data science was needed to create the tool
- Customers get the required additives and know-how how to use them in an optimal way



Visualization of the foam building process in the production line

1) https://europur.org/flexible-pu-foam/elementor-4539/ (Europe only)

2) Internal know-how. Differences between various foam types.

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PU waste becomes circular feedstock

Depolymerization through direct catalytic hydrolysis results in high quality raw materials with better carbon footprint

less waste

Pre-treatment → Reaction → Downstream processing

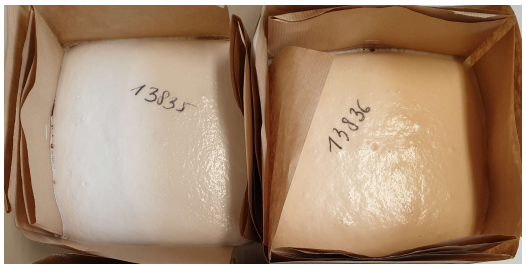
Polyurethane foam	Catalytic hydrolysis in alkaline solution	RePolyol	Amine (TDA)*

*Carbon Footprint was calculated using the CML2001 - Aug. 2016, Global Warming Potential (GWP 100), incl bio. C, incl LUC, no norm/weight; cradle to gate, economic allocation between polyol and TDA; basket approach

Lower GWP*

Foam production

100% Virgin Polyol | 100% Evonik RePolyol



- Foams made with 100% of Evonik RePolyol only slightly colored
- Foam processing and cell structure fully comparable to reference foam

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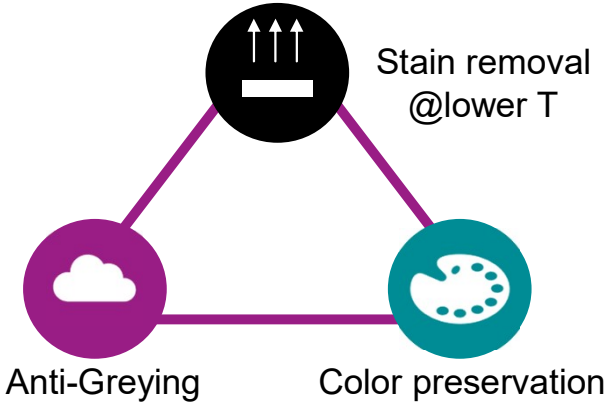
Washing performance with circular carbon-based REWOFERM® formulations

Challenge

- Limited lifetime of clothing due to greying and color fading. The average American has been estimated to throw away 37 kg of clothes each year[1)]
- Energy and water consumption in washing process
- Aquatic burden of household waste-water[2)].
- Fossil based surfactants as state of the art for price sensitive market in cleaning & laundry products

Solution

- Reformulated cleaning and laundry products to avoid fossil resources, to reduce greying, and to preserve color
- Collaboration is key element for market success and impact
- Biodegradable and lowest aquatic toxicity for reduced aquatic burden
- Rhamnolipid based biosurfactant in a competitive manufacturing process with renewable energy at scale and a carbon source not connected to deforestation



1) https://www.bbc.com/future/article/20200710-why-clothes-are-so-hard-to-recycle
2) From German private households, some 630.000 tons of chemicals from cleaning agents and detergents enter waste-water systems annually https://www.umweltbundesamt.de/en/topics/chemicals/cleaning-agents-laundry-detergents

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Partnering along the value chain is key to closing the loop

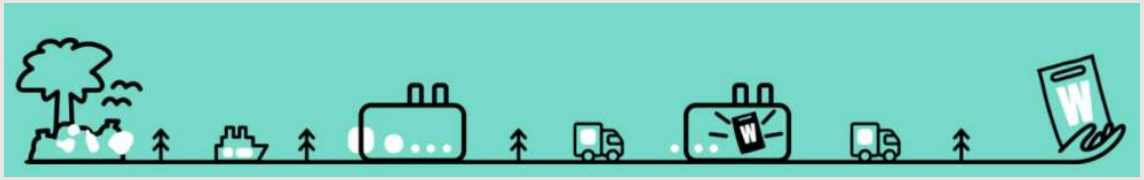
Creating showcases enabled by high performance additives

Harvesting plastic waste from nature

Collaboration started to

- Improve efficiency and robustness of the recycling process
- Improve the recycle quality
- Provide access to Evonik global network

WILDPLASTIC
RECOVERED FROM NATURE



WILDBAG

The first trash bag that actually cleans up the planet.

+ Made of WILDPLASTIC
+ Prevents Virgin Plastic
+ Cleans up the planet
+ Reduces poverty
+ Saves up to 60% CO2

Shipping bag*

Trash bag

*collaboration with OTTO

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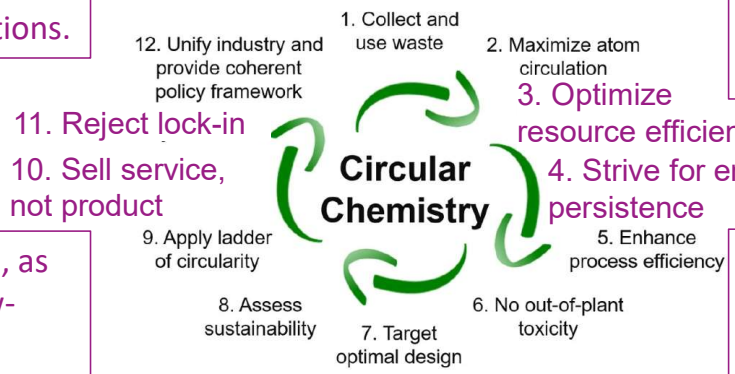
Circular Chemistry Principles[1)] for (Bio)Process Engineering

Failing on anyone will endanger future market success

Promote transitions and overcome lock-ins to realize market opportunities for long-term sustainability ambitions. Business and regulatory environment need to be flexible and allow the implementation of innovations.

Currently renewable resources offer the chemical industry an opportunity to diversify its raw materials base, but often bio-based materials are created in a linear production process without sustainable end-of-life options.



A service-based chemical industry is vital, as companies have the assets and the know-how to retrieve and repurpose chemical products and are equipped to target the management of molecule-circulating loops.

It is important to realize recirculation of molecules and materials of the highest bond energy, thereby retaining as much of their renewable energy input as possible to maximize energy efficiency.

1) C. Slootweg 2019, Nature Chemistry, https://hims.uva.nl/content/news/2019/02/the-twelve-principles-of-circular-chemistry.html

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