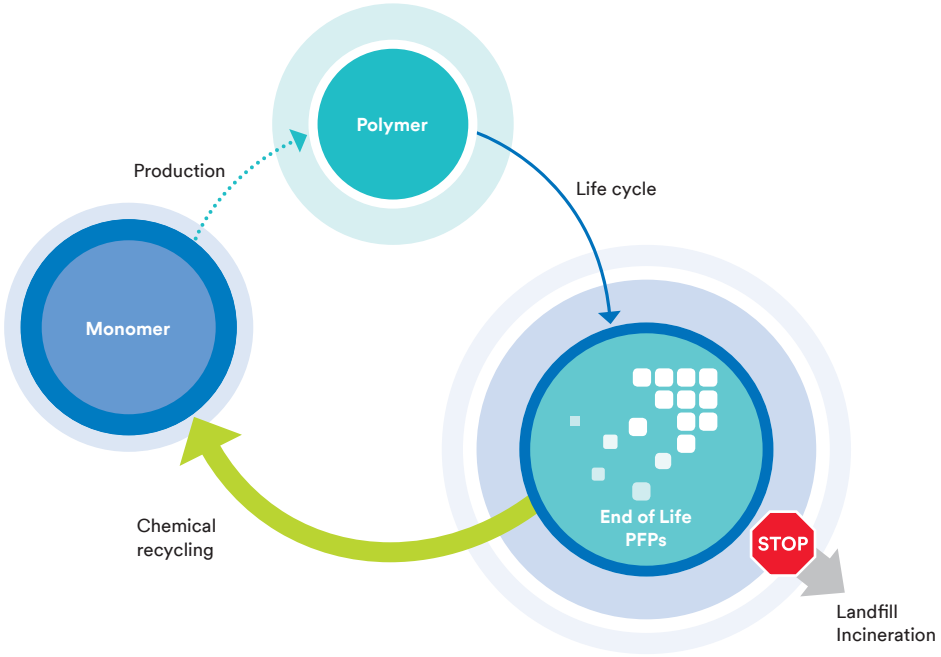
3M Science. Applied to Life.™

▶ 3M™ Dyneon™ Fluoropolymers

Up-Cycling.

Closing the loop.



Protecting the environment takes more than just good intentions.

Breaking new ground with clear goals.

In March 2015, Dyneon opened the world's first pilot plant for the recycling of fully fluorinated polymers in Gendorf Chemical Park, Burgkirchen, and thus established a milestone towards sustainability with a closed loop in fluoropolymer production. By regaining resources, this pilot project not only helps make production processes more efficient but also reduces the need for mining with chemicals and the transport of heavy loads, as well as the Industry's overall energy requirements, thereby having a positive impact on the environment.

From useless waste to valuable raw material.

In order to close the loop in fluoropolymer production, Dyneon uses a pyrolysis method: as perfluorinated polymers are decomposed, gaseous monomers are regained, cleaned first, and then fed back into production. As the product quality is not impacted in any way, the process is referred to as "Up-Cycling". The Up-Cycling plant in Burgkirchen is designed to handle up to 1,000 tonnes of fluoropolymer waste annually and is intended to help further develop the concept moving forward.

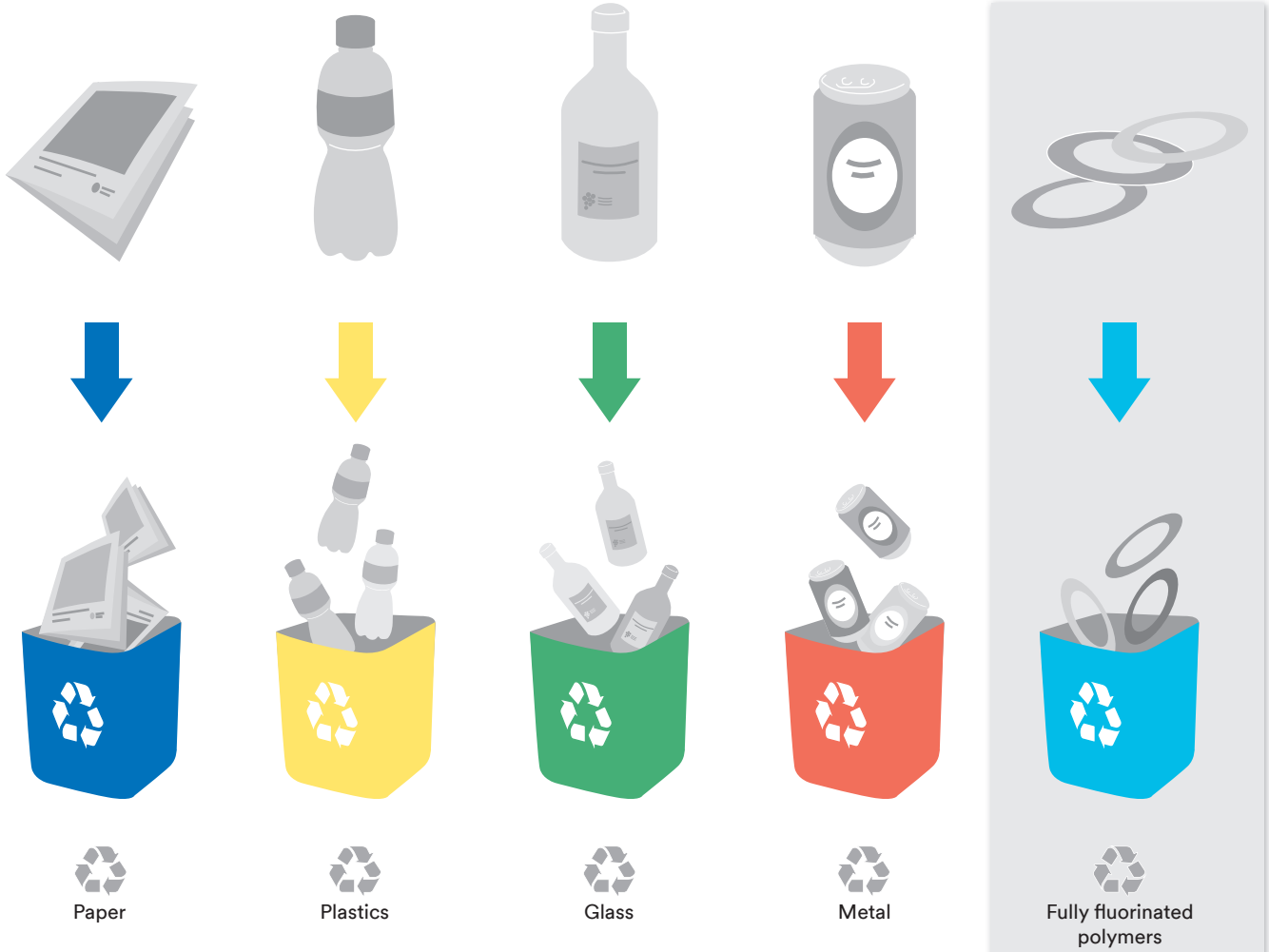
A long-term project for sustainable solutions.

It took 15 years to put the pilot plant into operation: from developing the methods and technology needed to building the plant and finally commencing operations. The result is an extraordinary project that addresses numerous economic and ecological necessities. In addition to the advantages offered by Up-Cycling mentioned before, it also helps to reduce waste volumes and CO_2 emissions as well as counter the rising demand for fluorspar as a base material in production processes.

Key message: sustainability

What is Up-Cycling?

- ✓ Up-Cycling is an R3 recycling process for turning waste flows into basic raw materials.
- ✓ More value – instead of lower value
- ✓ No compromises in product quality
- ✓ Conserving valuable non-renewable resources
- ✓ Avoiding disposal in landfill or incineration
- ✓ Reducing environmental impact

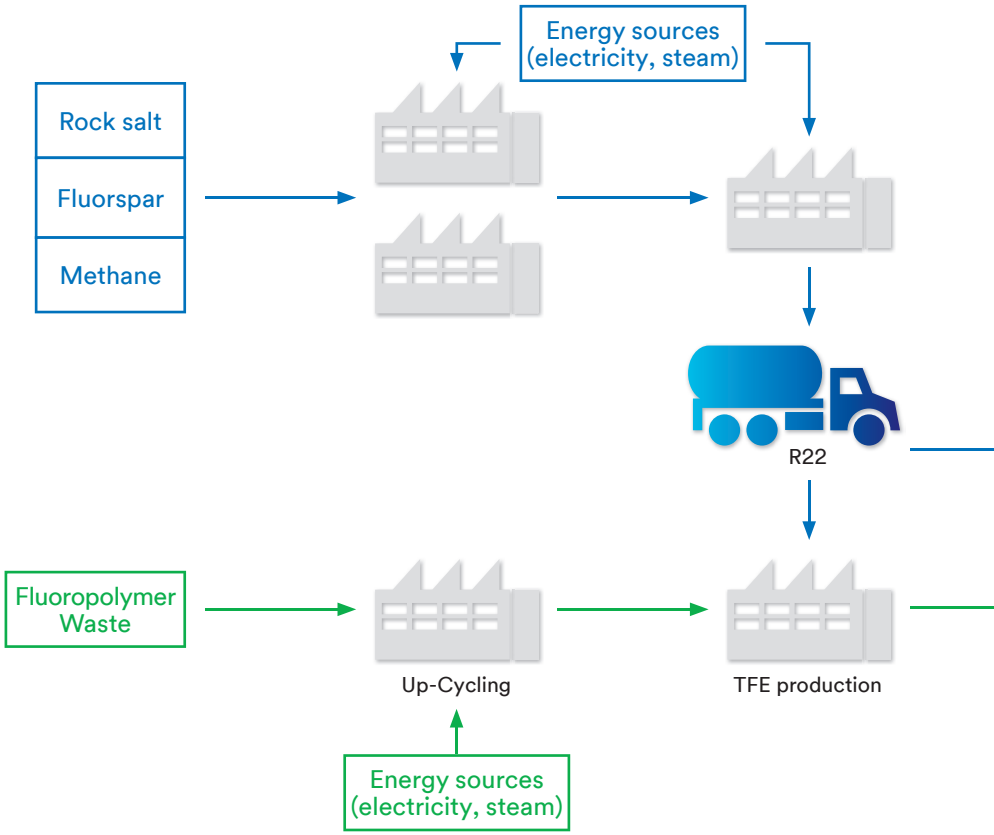


Extension of proven recycling concepts to include flully fluorinated polymers.

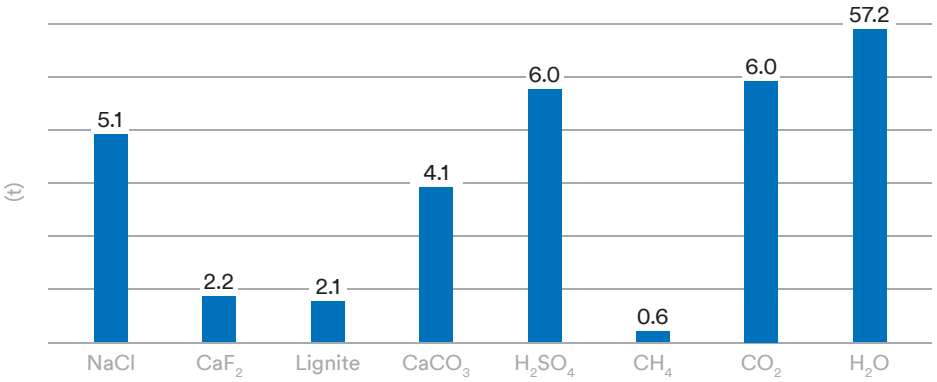
Environmental savings.

Numerous chemical transformation processes are required to produce the most important monomers for fluoropolymers, tetrafluoroethylene (TFE), and hexafluoropropene (HFP). The steps in this process are depicted in the diagrams to the right as well as the corresponding material flows based on the production of one tonne of TFE. Energy of 12 MWh is required for the conventional R22 Route. The waste flows generated by the R22 production process are also shown.

When producing TFE via the Up-Cycling process, large amounts of energy can be saved (diagram bottom right). These energy savings benefit the society as a whole: the energy conserved through Up-Cycling can supply around 2800 households with electricity for 1 year and less waste is generated.



Raw material required for the R22 Route



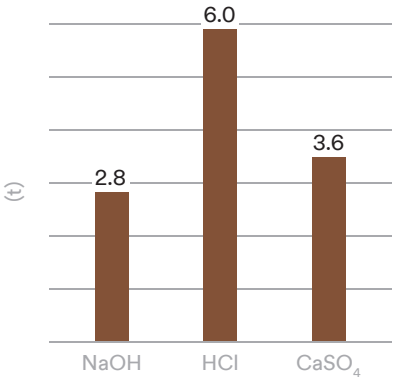
Based on the production of 1 t of TFE with an energy requirement of 12 MWh

R22 Route and energy flow

Up-Cycling materials and energy flow

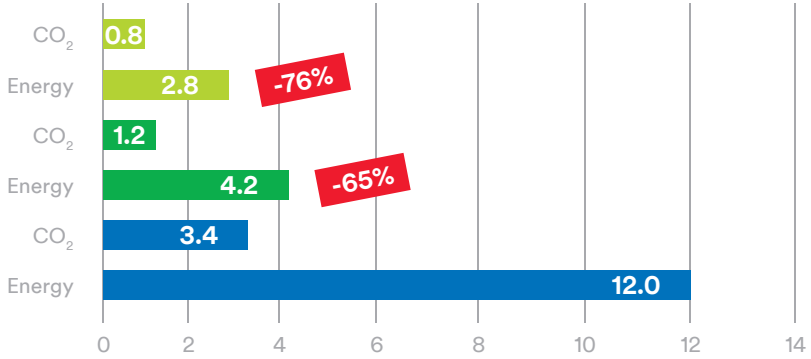
Savings equal the energy demand for 2800 households for one year at full utilisation of the pilot plant. The energy demand is based on average consumption per household. Consumption for a 3 Person household provided by German Statistisches Bundesamt.

Waste stream out of the R22 Route



Based on the production of 1 t of TFE with an energy requirement of 12 MWh

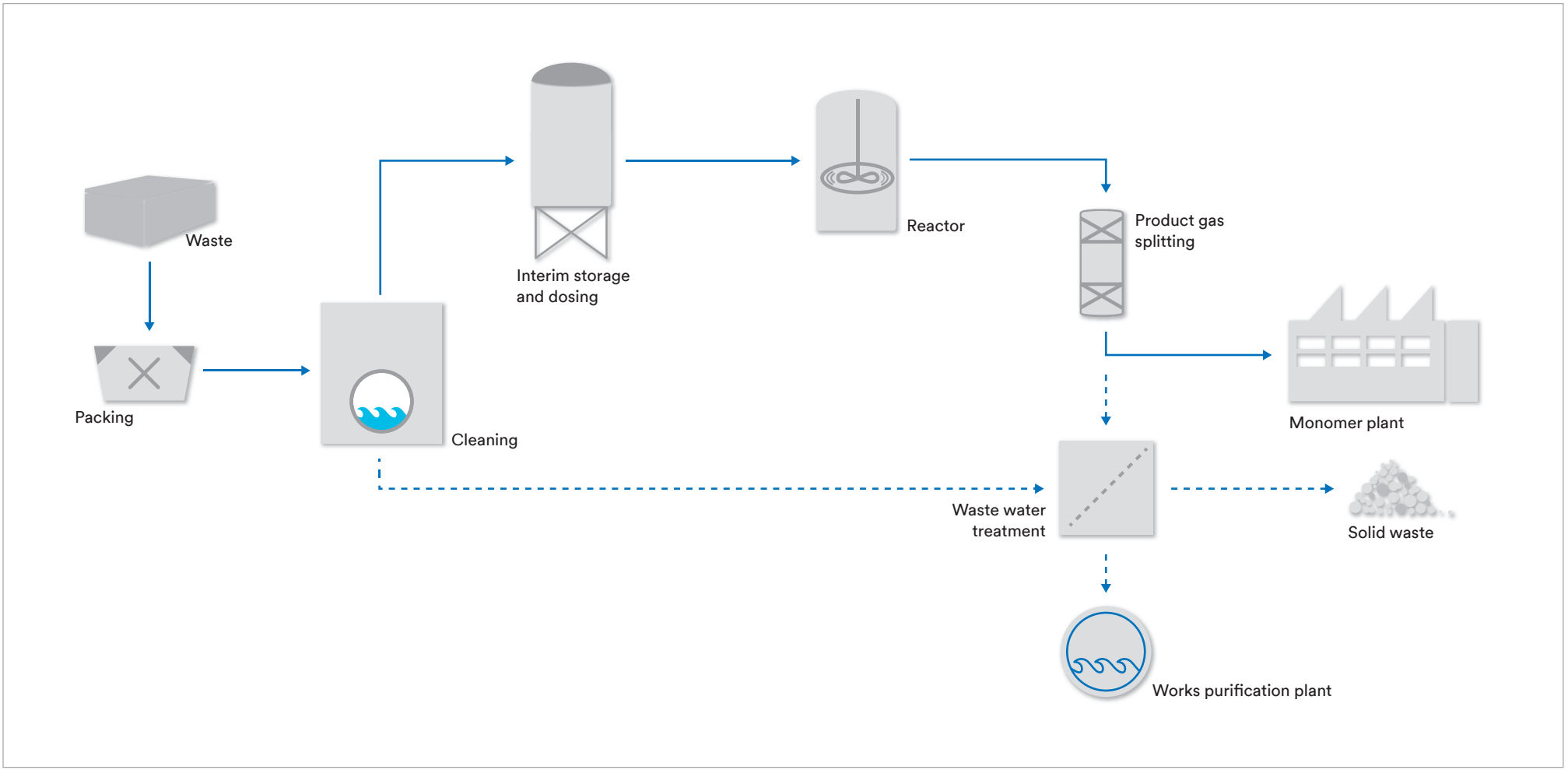
Comparison R22 Route vs. Up-Cycling



Energy (MWh) and CO_2 equivalent (t)

- Up-Cycling yield 90%
- Up-Cycling yield 60%
- R22 Route

How does Up-Cycling work?



What types of waste can be processed at our pilot plant?

Waste and waste products are not homogeneous material flows! Each fraction can always be slightly different from the one before. Once it is operating, a pilot plant continuously evolves over time in line with the new and ever-changing tasks with which it is faced.

Various types of fully fluorinated waste flows are contributed, and the reactions and ideal parameters during processing are evaluated.

Therefore, every new fraction must be checked and assessed in order to achieve the best results possible.

What

- ✓ Virgin PTFE
- ✓ Virgin TFM
- ✓ PFA
- ✓ FEP
- ✓ Compounds with
  - Carbon fibre
  - Carbon
  - Graphite

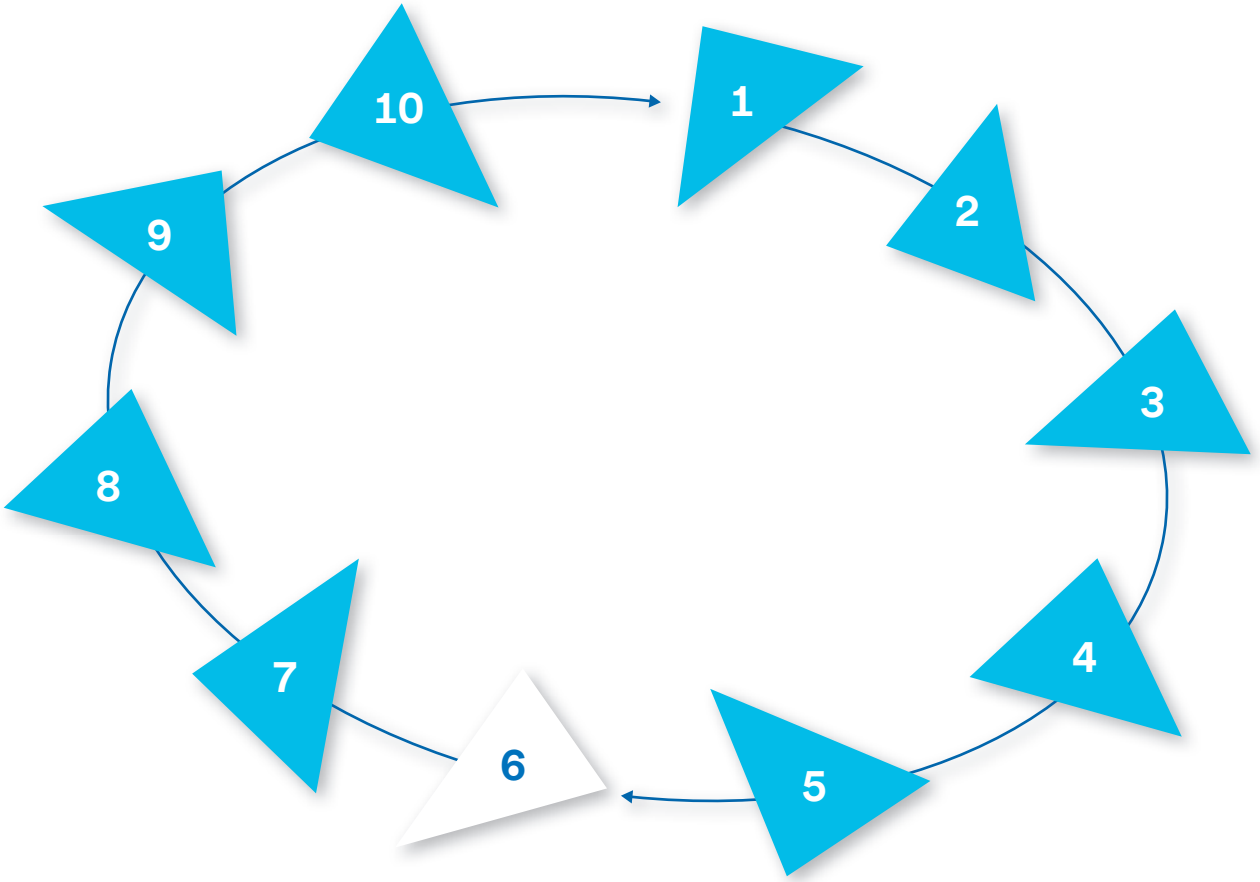
How

- ✓ Blocks
- ✓ Pellets
- ✓ Liner
- ✓ Semi-finished goods
- ✓ Machining waste
- ✓ Chips
- ✓ ...

First steps towards Up-Cycling.

Would you like to contribute?

1. Contact with Dyneon initiated
2. Waste declaration form from waste producer with photo
3. Review of information by Dyneon
4. Samples requested for reference testing
5. Testing and analysis of samples by Dyneon
6. Feedback – possible assumption of waste fraction
7. Planning – coordination of logistics required
8. Packing and transport
9. Processing
10. Record of disposal for the waste producer



Up-Cycling – a European idea.

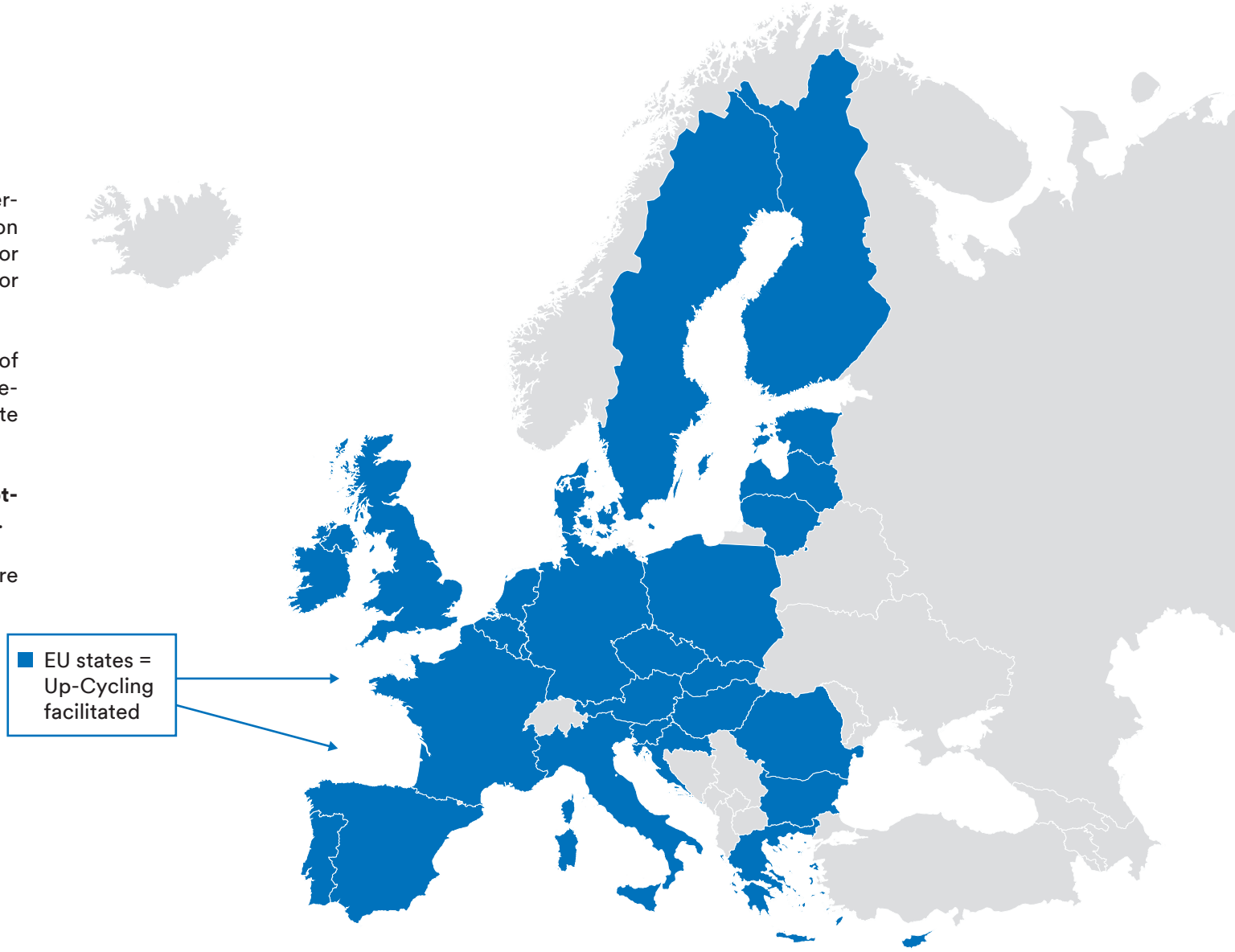
Fully fluorinated polymer waste flows that are generated in the members states of the European Union and which comply with the criteria/requirements for Up-Cycling can by recycled at Dyneon following prior consultation.

Dyneon adheres to the regulatory requirements of the German Closed Substance Cycle Waste Management Act (KrW-AbfG) as well as the European Waste Code.

Waste that is **declared hazardous cannot be accepted** and **cannot be recycled** in the Up-Cycling plant.

Producers and manufacturers from six countries are already participating in the Up-Cycling project.

You, too, can become our partner.



Up-Cycling in the Closed Substance Cycle Waste Management Act.

Paragraph 6: Waste hierarchy

1. Waste avoidance
2. Preparation for reuse
3. Recycling yields higher quality than
4. Other exploitation or
5. Disposal

Up-Cycling ←

Other exploitation and disposal →

Paragraph 8, sect. 1: Improved protection of people and the environment

- Conservation of landfill space for the future
- Avoidance of hazardous waste from incineration plants
- 1 kg PFP* results in 3 kg toxic waste for final disposal

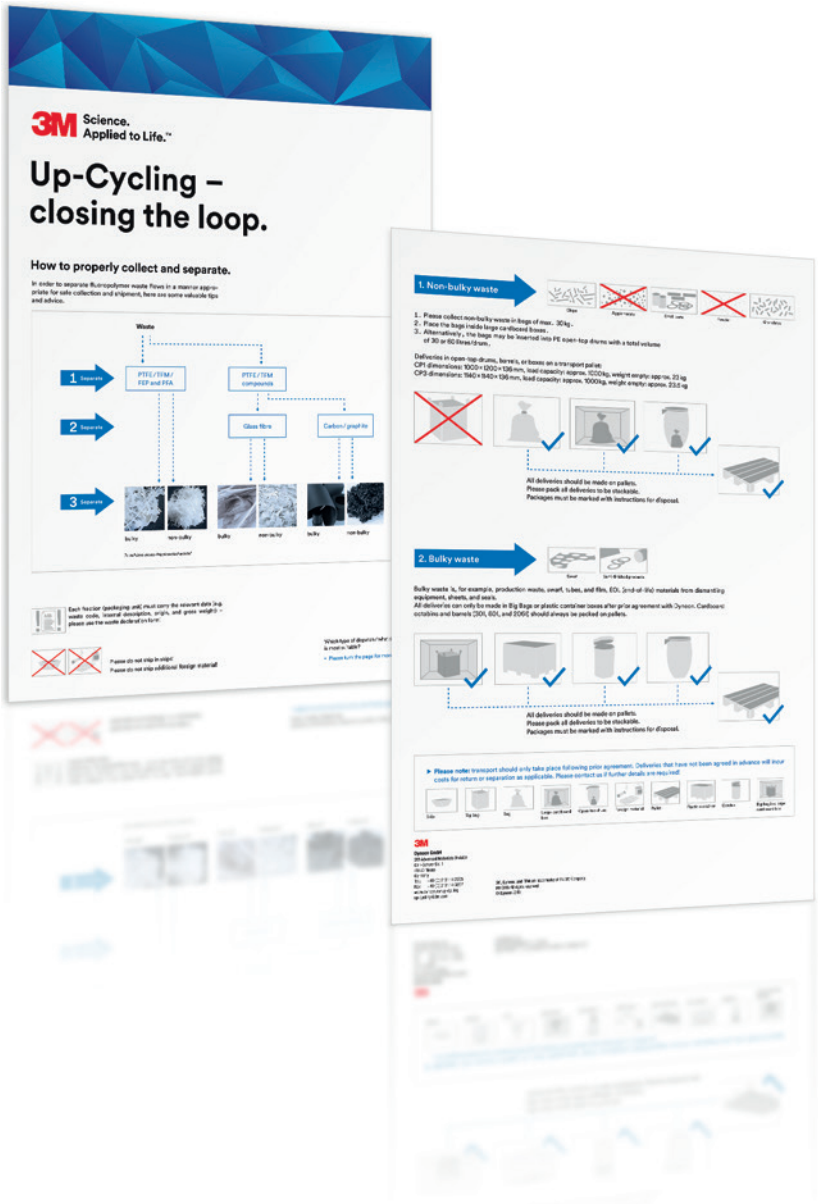
Paragraph 14: Promoting recycling, sect. 1 and sect. 2

Improvement of recycling ratio (65% by weight) of municipal waste/plastic fractions by 2020 through Up-Cycling →

EU resource efficiency and recycling programme since 2011

- Measures for conserving valuable raw materials and resources
- Specifications from Paragraph 14 KrWG are to be implemented in the EU as an official directive by 2020.

The overview shows the German Closed Substance Cycle Waste Management Act, and how it relates to Up-Cycling.
* PFP = perfluorinated polymers



Collecting and separating correctly.

Up-Cycling can only be as good as the upstream fractioning of waste flows. But what exactly is “fractioning”?

Fractioning is the separation of various types of waste flows as uniformly as possible. Or to say it another way: collect and separate.

To give a few examples:

- A PTFE compound with carbon fibre must be separated from a PTFE compound with glass fibre as the two fractions are not both suited for Up-Cycling.
- An unblended PFA does not need to be separated from an unblended FEP.
- An unblended PTFE does not need to be separated from an unblended TFM.

Initial helpful information on correct collection and separation of waste can be found in the insert with this brochure or online at **www.dyneon.eu/up-cycling**

Technical information and test data

Technical information, test data, and advice provided by Dyneon personnel are based on information and tests we believe are reliable and are intended for persons with the knowledge and technical skills sufficient to analyse test types and conditions, and to handle and use raw polymers and related compounding ingredients. No licence under any Dyneon or third-party intellectual rights is granted or implied by virtue of this information.

General recommendations on health and safety in processing, on work hygiene, and on measures to be taken in the event of accident are detailed in our material safety data sheets.

You will find further notes on the safe handling of fluoropolymers in the brochure »Guide for the Safe Handling of Fluoropolymer Resins« by PlasticsEurope, Box 3, 1160 Brussels, Belgium, tel. +32 (2) 676 17 32.

Important notice

All information set forth herein is based on our present state of knowledge and is intended to provide general notes regarding our products and their uses. It should not therefore be construed as a guarantee of specific properties of the products described or their suitability for a particular application. Because conditions of product use are outside Dyneon's control and vary widely, user must evaluate and determine whether a Dyneon product will be suitable for user's intended application before using it. The quality of our products is warranted under our General Terms and Conditions of Sale as now are or hereafter may be in force.

Where to go for more information?

Dyneon Customer Service
Europe
Phone: 00 800 395 366 27
Fax: 00 800 396 366 39
Italy
Phone: 800 791 018
Fax: 800 781 019

Technical Service Fluoropolymers
Dyneon GmbH
Industrieparkstr. 1
84508 Burgkirchen
Germany
Phone: +49 (0) 8679 7 4709
Fax: +49 (0) 8679 7 5037

3M Advanced Materials Division
6744 33rd Street North
Oakdale, MN 55128
USA
Phone: +1 800 810 8499
Fax: +1 800 635 8051

dyneon.europe@mmm.com
www.dyneon.eu

Dyneon GmbH
Advanced Materials Division
Carl-Schurz-Straße 1
41453 Neuss
Germany
Phone +49 (0) 2131 14 2265
Fax +49 (0) 2131 14 3857
www.dyneon.eu