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Smart Fridge Recycling (SFR)
Next step in eco efficiency

State of the Art fridge recycling

The **V**olatile **F**luoro **C**arbons (VFC) have a huge **G**lobal **W**arming **P**otential (GWP) and a huge **O**zone **D**epleting **P**otential (ODP). The VFC were used in fridge production as a foam blowing agent and as gas/liquid in the cooling circuit.
Since 1995 Cyclopentane (**V**olatile **H**ydro**C**arbons VHC)) replaces the massive environmentally damaging VFC's as a blowing agent.

The average environmental damaging impact (GWP) of a VFC domestic fridge is equivalent to about 2800 kg CO2. This means, that you could drive 16'000km in an average car with the same environmental impact.
The environmentally damaging impact from a new VHC domestic fridge is only 1 kg CO2 equivalent, which means, that you could drive in an average car for only 5.4 km.
Furthermore, the foam blowing agent cyclopentan is not stable in the atmosphere and is decomposing in 24 to 48h.

Conclusion:

1. **It is very important to dispose and recycle all VFC fridges**
2. **VHC as foam blowing agent has a very low environmental impact**

Since 1995 VFC are forbidden in fridge production and substituted with VHC. The European VHC fridges are already between 50 – 70% in the return streams in 2013 which is increasing fast and strongly.
Nowadays all fridges are brought to fridge recycling plants through complex logistics. These plants recycle the VFC and VHC fridges together in one step. This makes sense when having more than 50% VFC fridges.

The challenge
To optimise recycling efficiency and reduce carbon footprint.

1. Logistics
The next ecological step in fridge recycling is the optimisation in logistics. An average domestic fridge has a volume of 0.5 m3. The material fractions after recycling have only a volume of 0.07 m3. That means, that there is a huge additional efficiency potential of over 85% in logistics.
2. Treatment of mixture of blowing agent VFC and VHC
In a State of the Art recycling plant all fridges are treated together. These plants recover a mixture of VFC and VHC and this mixture needs to be be destroyed. This process requires a huge amount of thermal energy.
3. Resource efficiency in the recycling process
Because of the mixed fridge (VFC and VHC) treatment the recycling process is very complex. Most of the State of the Art fridge recycling processes need cryogenic nitrogen for inertisation and for VFC/VHC condensation. The production and the use of cryogenic nitrogen results in a huge carbon foot print impact.
One of the major needs is beside a reduction of the carbon foot print also an ecologic better and a cost saving recycling solution.

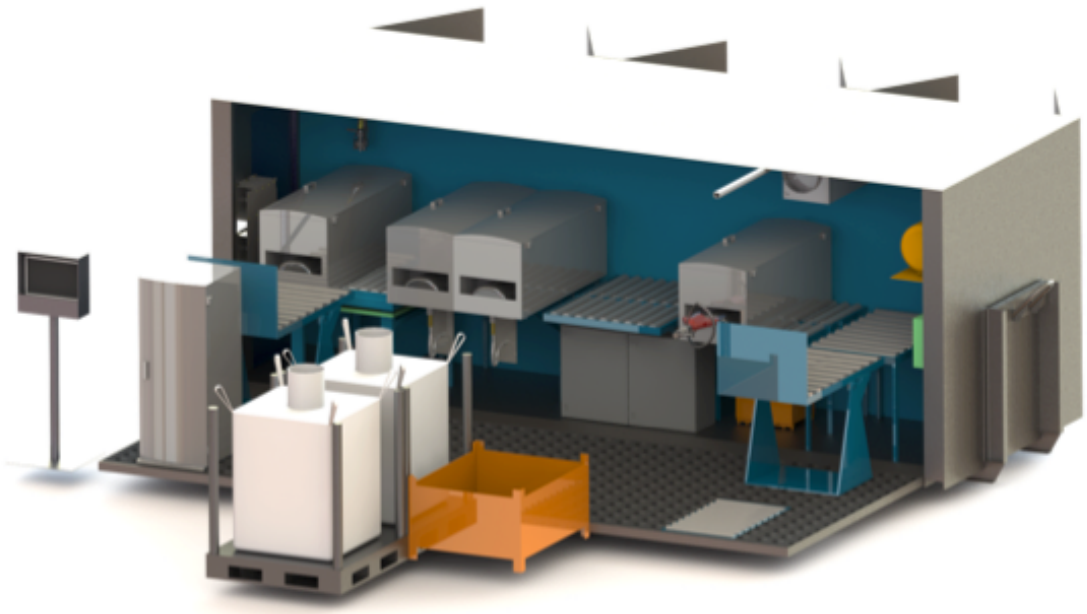
4. What happens when the quantity of VHC fridges is over 70%?
State of the Art fridge recycling plants are not very efficient if the ratio of VHC fridges moves over 70%. The main reason is the higher risk of explosion and the increasing consummation of liquid nitrogen. That means, that efficiency is massively decreasing and that cost and carbon footprint are increasing.

The solution: Smart Fridge Recycling - the mobile recycling plant

A best available technology recycling facility is brought as a mobile plant to the fridges which are processed on the spot.

Recycling Step 1
In a first step, the fridges are separated into containing VFC or non VFC (measured with secure industrial process by infrared spectroscopic analysis). In the next step all gases and liquids (oil, VHC or VFC) are removed from the cooling circuit. Then the compressor and the inserts are removed.
As a result you have a fridge body with blowing agent VHC, VFC insulated with rock wool or expanded polystyrene (EPS). All the VFC marked fridges will be separated and delivered to a State of the Art VFC fridge recycling plant.
All other fridges will go directly in the mobile Smart Fridge Recycling plant in step 2.

Input: Domestic fridges
Output: Compressor, inserts (glass, polystyrene), cooling circuit, oil, VHC and VFC, VHC and VFC fridge bodies



Picture 1: SFR mobile fridge recycling plant Step 1

Recycling Step 2

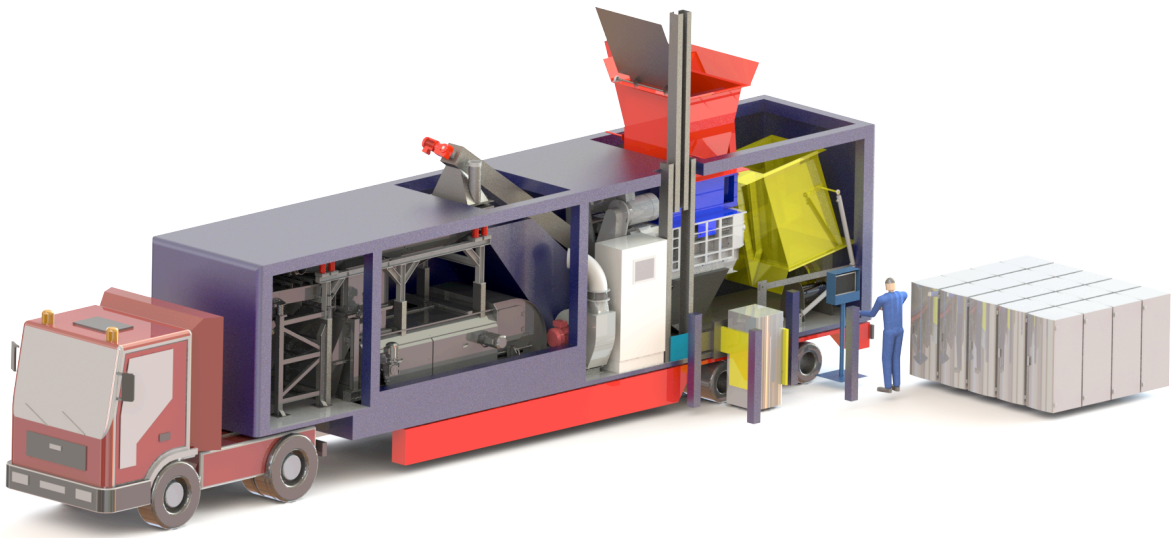
All separated VHC fridge bodies will be fed into the second recycling stage. The whole recycling equipment is installed on a truck trailer. The VHC fridge bodies are treated by a four shafts shredder. The shredding the sorting technology and the put through is the same as you will find in a stationary State of the Art fridge recycling plant.
Together with an air stream part of the cyclopentane will be blowed direct into the atmosphere. Another part of the cyclopentane will stay in the Polyurethane (PUR) and will go as substitute fuel to the combustion facility.

Is it reasonable to blow the cyclopentane in the atmosphere?

- cyclopentane is a cycloalkane => Alkane
- cyclopentane (CP) has no Ozone Depleting Potential (ODP)
- cyclopentane has a very low Global Warming Potential (GWP)
- cyclopentane in in the atmosphere not stable and is decomposing in 24 to 48 h
- In a few hot summer days, the CP has a photochemical ozon creation potential. This is less than the effect from the off-gases created by transport of the same amount of fridges.

So the answer is yes, it is reasonable, it is most eco efficient to blow the cyclopentane into the atmosphere.

Input: VHC fridge bodies
Output: PUR from the insulation, aluminium, iron, copper, polystyrene and cyclopentane



Picture 1: SFR mobile fridge recycling plant Step 2

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Smart Fridge Recycling eco efficiency

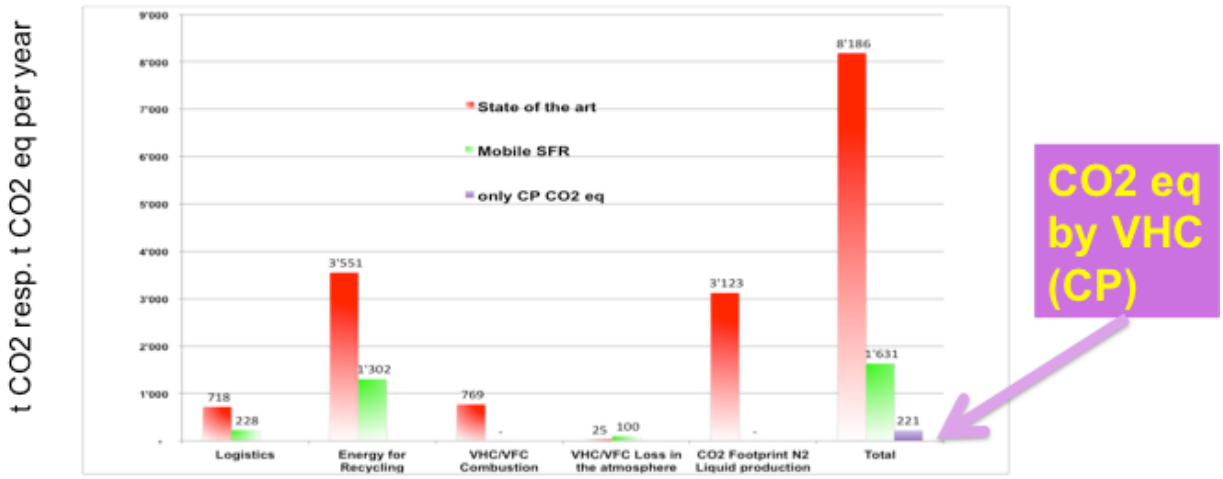
Smart Fridge Recycling provides a massive reduction of the carbon foot print by a factor 5.

Case Switzerland with 400’000 fridges to be recycled per year

CO2 emission State of the Art recycling plant	8‘200 t/a
CO2 emission Smart Fridge Recycling mobile plant	1‘650 t/a
CO2 reduction	**6‘550 t/a**
Logistics reduction potenzial	**1‘000‘000 km/a**

CO2 Foot Print Reduction > Factor 5

Good to know:
The CO2 eq from the blowing agent cyclopentane in 400’000 fridges is only 221t CO2 eq per year



Picture 3: Comparison carbon foot print step 2, 400’000 fridges per year in Switzerland (SMART Firdge Recycling, International Electronic Recycling Congress, Jan. 2014, Dr. Viktor Haefeli)

Case EU with over 16 Mio fridges per year

The potential reduction of the carbon foot print is 40x higher than Switzerland
40 x 6‘550t/a CO2 eq => 262‘000t/a CO2 eq
40 x 1‘000‘000 km/a => 40‘000‘000km/a

Cost Savings
The Smart Fridge Recycling brings four major cost savings effects

1. Cost savings in logistics
2. Cost savings in energy consumption over 50%

3. No use of (liquid) nitrogen
4. No use of a stationary plant infrastructure

CENELEC Standard

In the Draft Technical Specification CENELEC, a mixed VFC and VHC fridge recycling treatment is described. But the VHC input in the Smart Fridge Recycling plant is 100%. About 40% of the VHC goes in the atmosphere and is fully decomposed within 24 - 48 h.
The rest of the VHC is contained in the foam and goes directly as substitute fuel into the incineration plant. Therefore a recovery rate of cyclopentane as described in the CENELEC standard brings no additional value, nor better environmental impact.

Conclusion

Smart Fridge Recycling accomplishes

- **One step Material recovery and VHC decomposition**
- **Same capacity as stationary plants**
- **Same output fraction quality**

Smart Fridge Recycling benefits

- **Huge transport distance reduction**
  - **over 1‘000‘000 km per year in Switzerland**
  - **over 40‘000‘000 km per year in the EU**
  - **huge logistics cost savings**
- **Huge reduction in energy consumption**
- **Huge Carbon Foot Print reduction by factor 5**
- **Huge reduction of total cost of ownership**

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