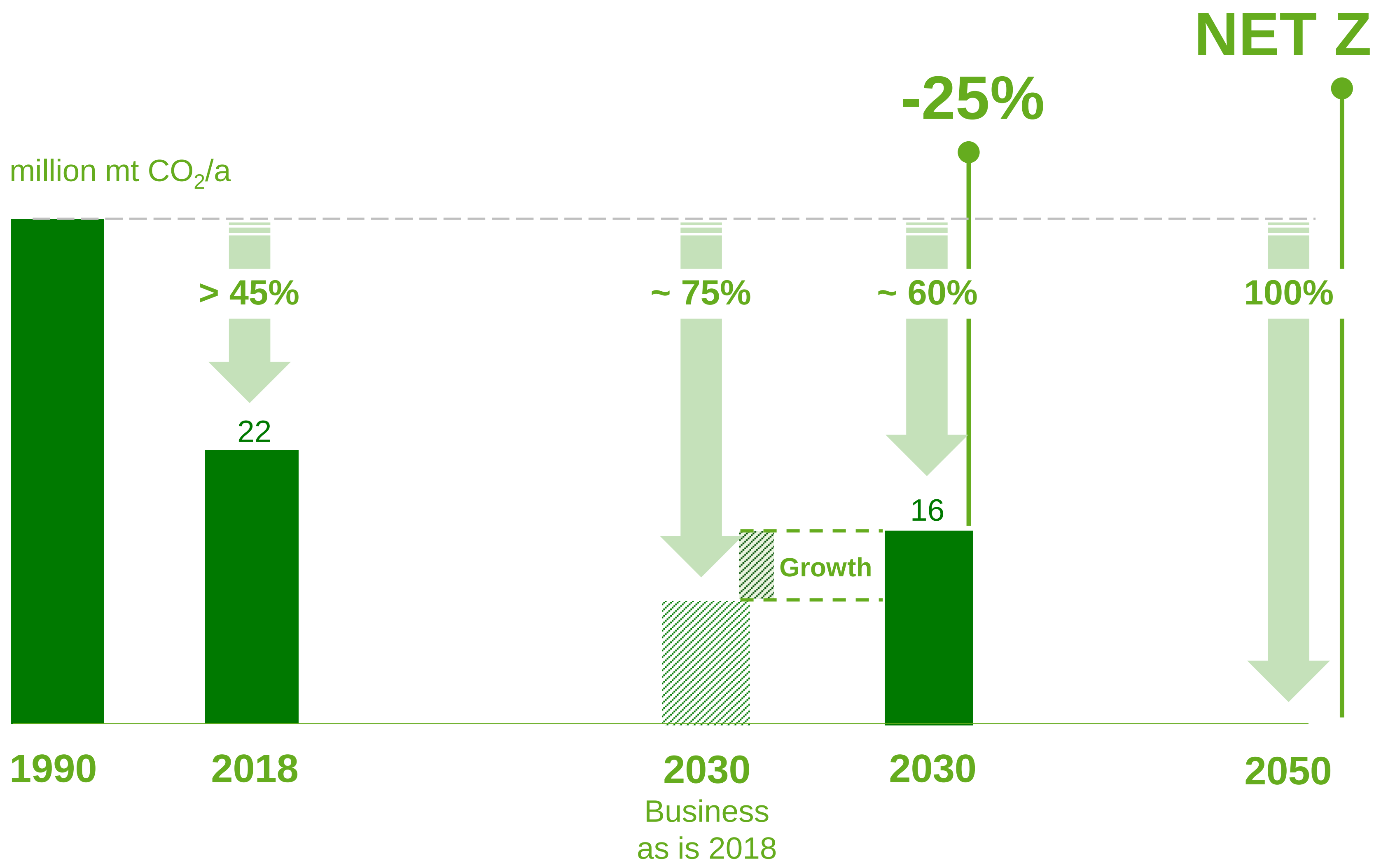
Harnessing energy from chemicals production: introducing HFOs as a Green Deal enabler

Bart Van Assche
Vice President Global Infrastructure Technology

OUR PATH TO REDUCE BASF EMISSIONS 2018-2050

BASF greenhouse gas emissions (Scope 1+2)



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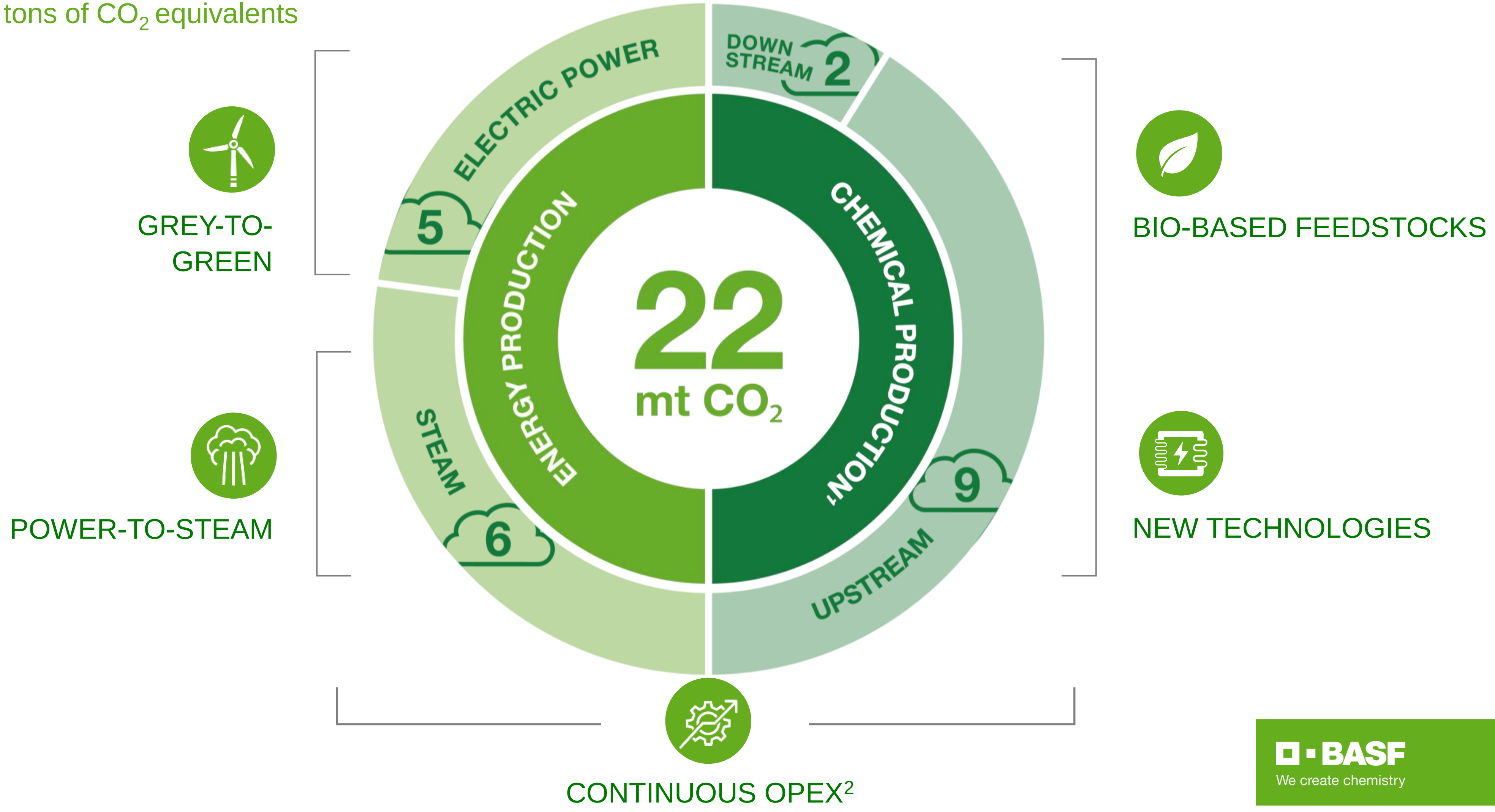
OUR CARBON MANAGEMENT PROGRAM TO REDUCE CO_2 EMISSIONS

BASF GREENHOUSE GAS EMISSIONS 2018 (SCOPE 1+2)

Million metric tons of CO_2 equivalents

[1] Includes emissions from process energy [2] Operational excellence measures



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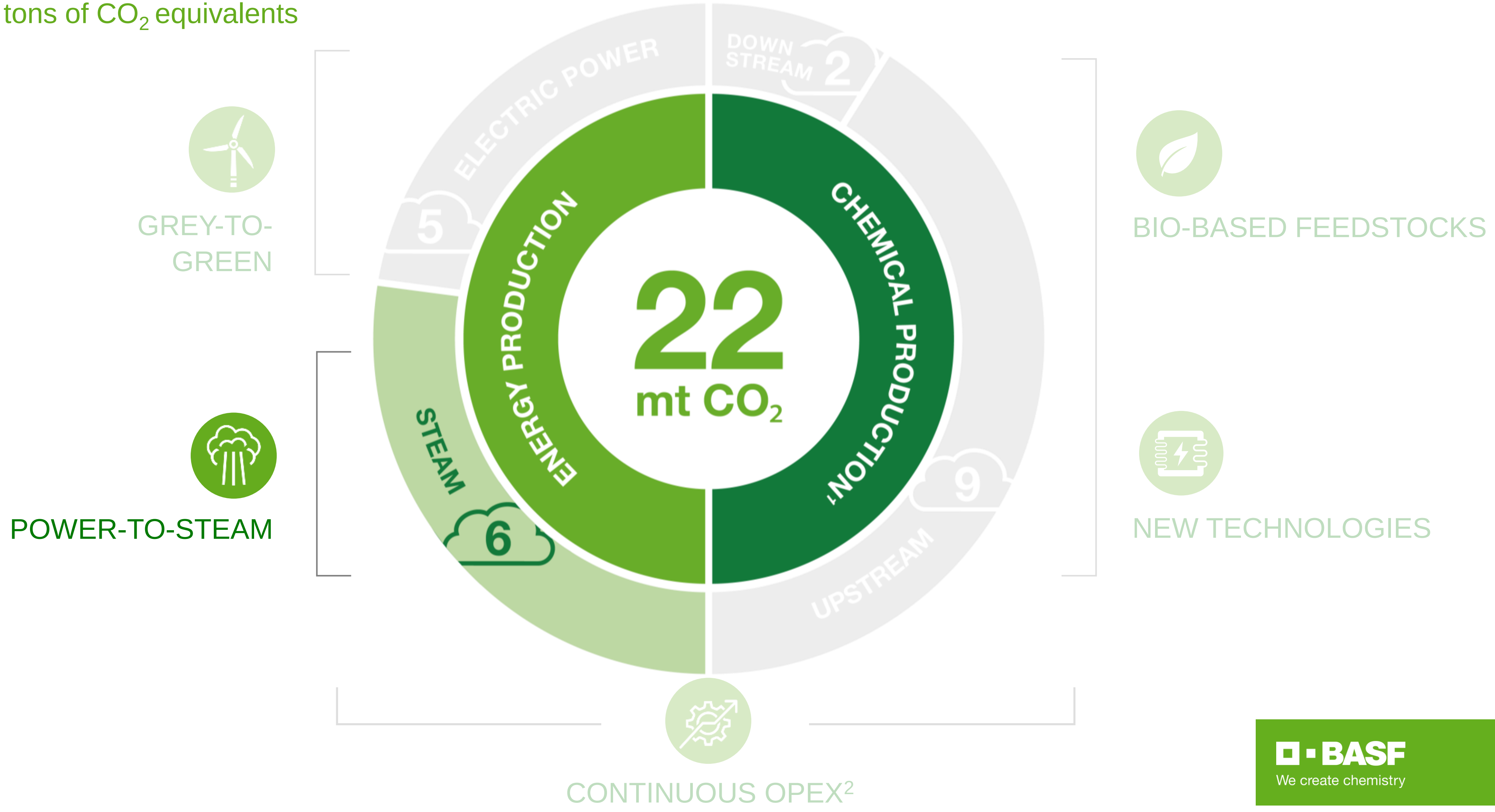

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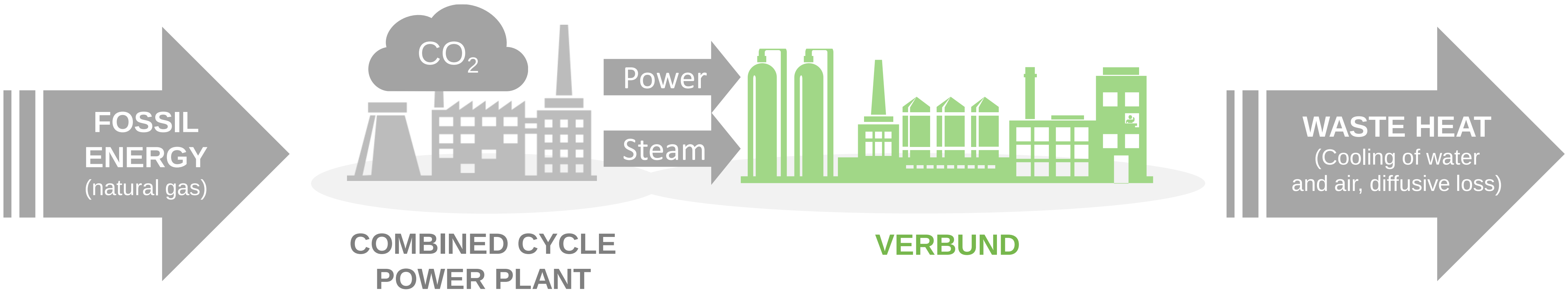
STEAM PROVIDES MOST EFFICIENTLY HEAT FOR OUR PRODUCTION PROCESSES

STATUS TODAY:

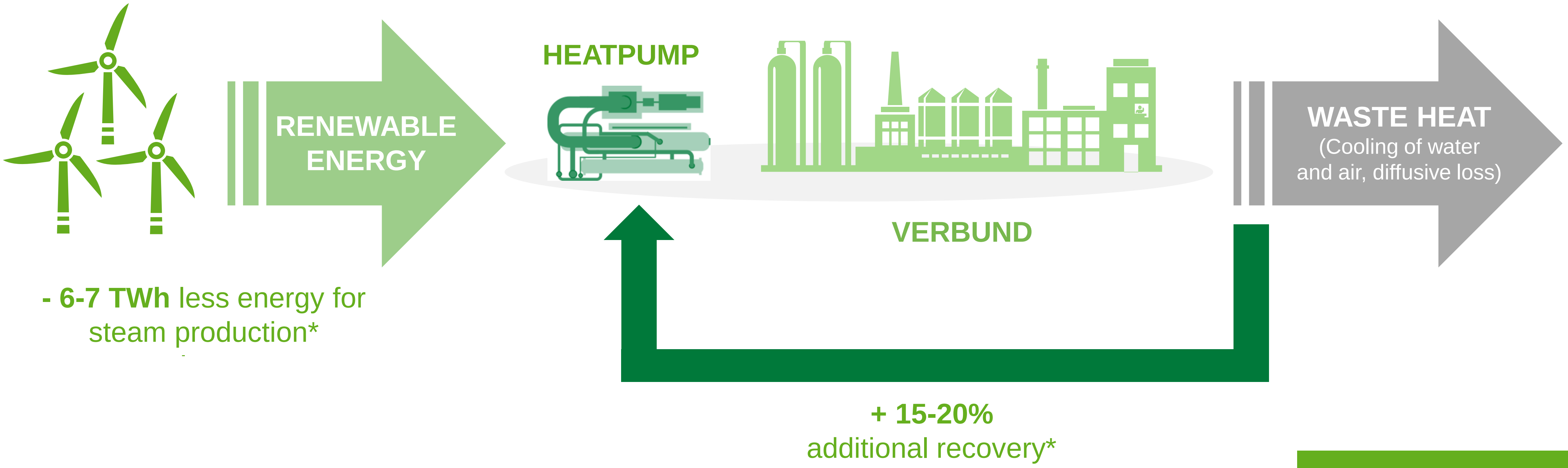
Steam generation by combustion of natural gas in highly efficient combined cycle power plants.



STEAM PROVIDES MOST EFFICIENTLY HEAT FOR OUR PRODUCTION PROCESSES

FUTURE:

Electrification of steam generation by heat pumps with advanced heat recovery and energy efficiency.



*Example Ludwigshafen

FUTURE STEAM SUPPLY CONCEPT FOR LUDWIGSHAFEN: HEAT PUMPS TO REPLACE FOSSIL-GENERATED STEAM

Overview of projected heat pumps at Ludwigshafen site

- Heat pump (hub)
- Off-heat
- Power plant
- Grid connection

Potential to replace up to **1,100 tons per hour** of fossil-generated steam

Comprehensive set of technologies

Incineration of by-products	Gas boiler technology
High-pressure steam	Cogen or gas boiler technology Heat pump technology
Medium-pressure steam	E-boiler technology Heat pump technology
Freeing up steam for use in central grid by replacing steam drives	E-drives

Potential to reduce **1,5 million tons of CO2 emissions per year** for steam generation

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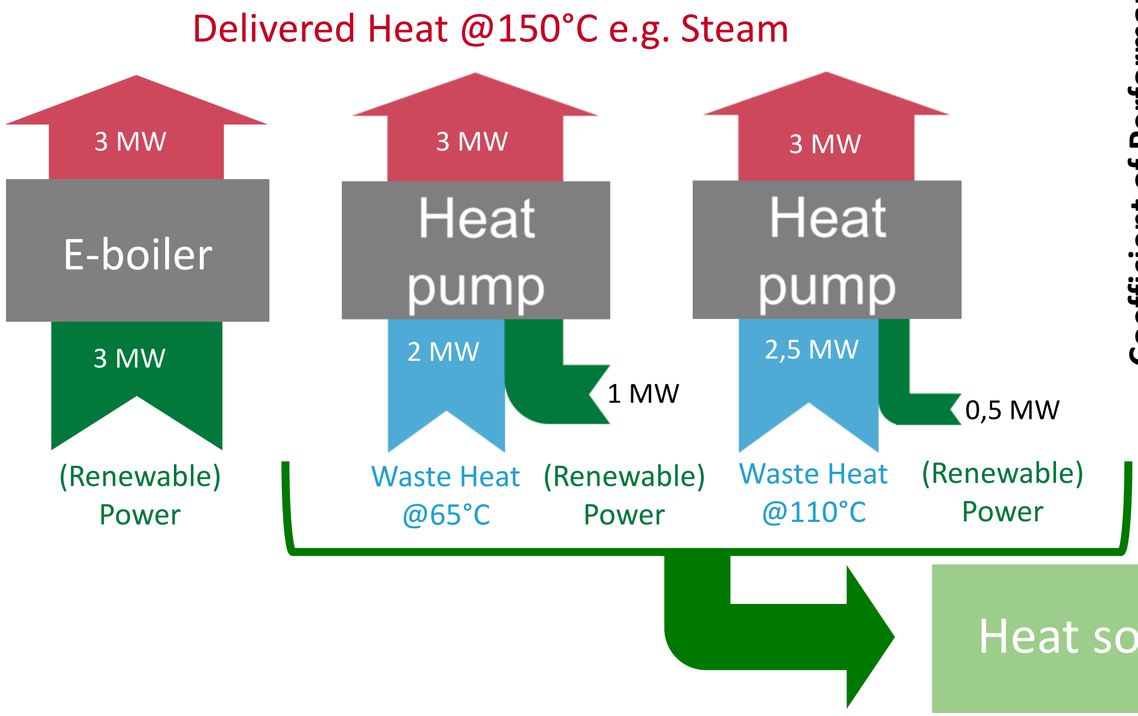
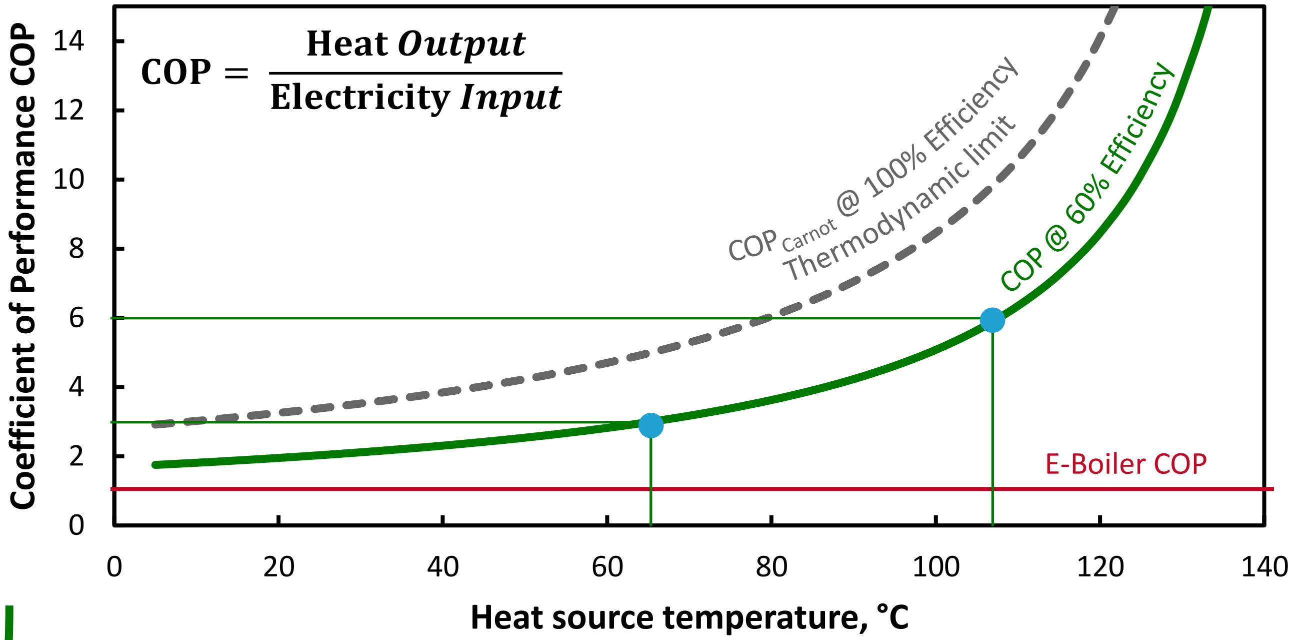
HEAT PUMPS AND THE WASTE HEAT BENEFIT

Coefficient of Performance (COP) Heat pump vs. E-boiler

Direct transformation of power to heat means significant exergetic losses

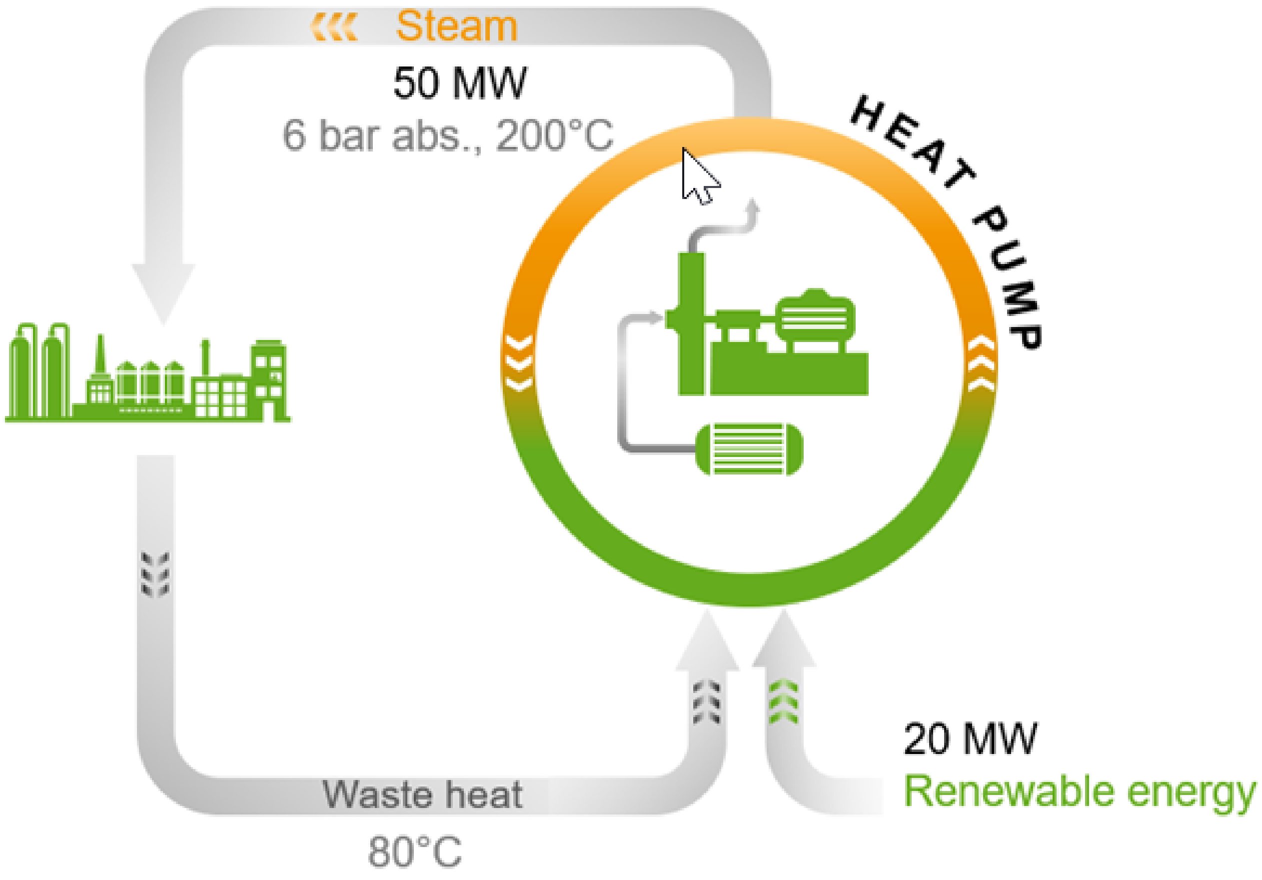


Example: Heat output @ 150°C



Heat source temperature ↑ COP ↑ electricity demand ↓

FIRST HIGH-TEMPERATURE HEAT PUMP TO SUPPLY STEAM TO THE BASF VERBUND IN LUDWIGSHAFEN



- **Integration of a high-temperature heat pump** into the BASF Verbund implemented on commercial Scale
- Use of waste heat and changes to operation of the steam network will **avoid 160,000 tons of CO_2 emissions a year**
- Annual cooling water consumption **reduced by more than 20 million cubic meters**
- **Engineering design** with Siemens Energy is progressing as planned
- Startup targeted for **Q3 2024** if funding gets approved.

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COMPARISON OF DIFFERENT REFRIGERANTS FOR BASF ACETYLEN
SOURCE (80→64 °C), SINK (STEAM @ 6.5BARA), 39 MW$_{th}$

Criteria	R717 (Ammonia)	R744 (CO2)	R600a (isobutane)	R600 (Butane)	R601 (Pentane)	Cyclo-pentane	R1233zd	R1336mzz
Flammable[1]	yes	no	yes	yes	yes	yes	no	no
Toxic[1]	yes	no	no	no	no	no	no	no
Safety class[1]	B2L	A1	A3	A3	A3	A3	A1	A1
ODP[2]	0	0	0	0	0	0	0.0003*	0
GWP[3]	0	1	3	4	5	5	4.5	1
Critical point [°C / bara]	132.3 / 113.3	30.98 / 73.8	134.7 / 36.3	152.0 / 37.9	196.6 / 33.7	238.6 / 45.7	166.4 / 36.2	171.3 / 29.0
$p_{lower\ level}$ [bara]	25.1	47.7	8.3	6.0	2.0	1.3	3.7	2.3
$p_{higher\ level}$ [bara]	99.4	170.0	32.8	25.7	10.7	7.7	17.8	12.5
COP [-]	2.34[a]	1.59	2.17[a,b]	2.33[a,b]	2.46[b,c]	2.60[b]	2.54	2.47[c]
Compressor suction volume [m³/h] per unit	1’800	3’800	6’270	8’030	22‘700	28‘000	11‘530	19‘270

best option

1: ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) 2: Ozone depletion potential, high values are forbidden by Montreal protocol 3: Global warming potential 100 years

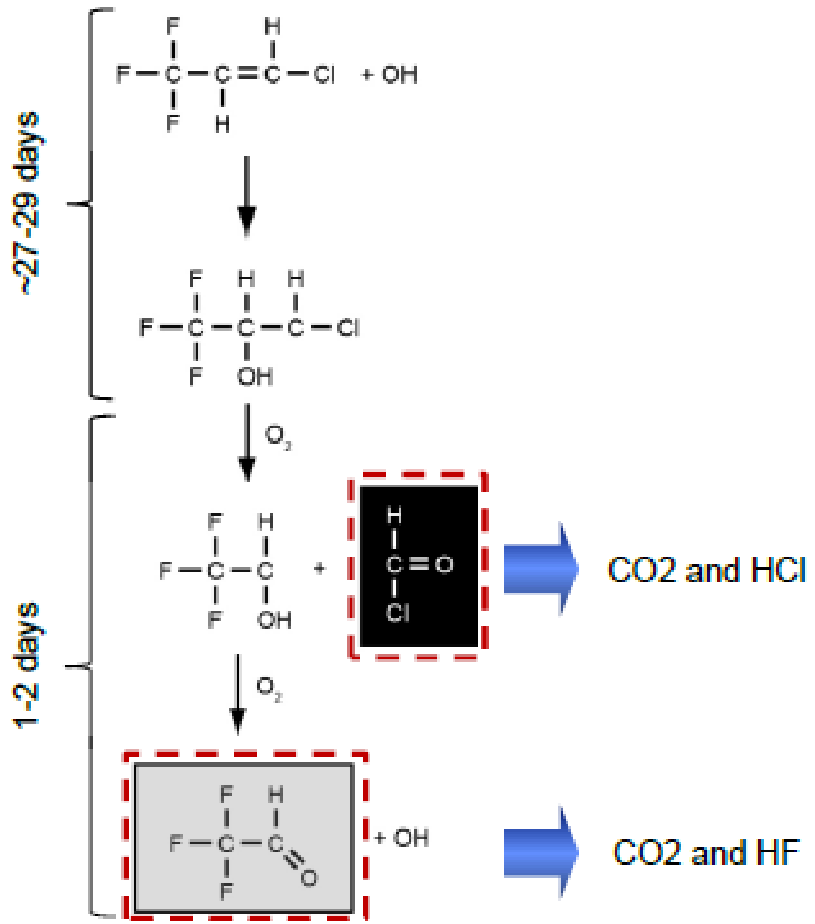
* Considered to be insignificant in EU and US legislation. Fluids with very low values are allowed for usage without any restriction. R1233zd is not listed in the F-Gas regulation appendix 1 and is by legal authorities recommended substitute for ozone depleting and global warming substances

a: screw compressor; b: double-walled heat exchanger; c: internal recuperation required due to a minimum distance to the saturated vapor line

HFO DEGRADATION & ENVIRONMENT

M. P. Sulbaek Andersen et. al., *Phys. Chem. Chem. Phys.* **2012**, *14*, 1735-1748

Reaction Pathway*



Phys. Chem. Chem. Phys., 2012, 14, 1735–1748, M. P. Sulbaek Andersen, O. J. Nielsen, M. D. Hurley and T. J. Wallington

- **Atmospheric decomposition of Solstice LBA**
  - OH (and other radicals) in the atmosphere breakdown 1233zd over ~30 days
  - Final breakdown products are not new or long lived
  - Final byproducts are same as 245fa and 141b at levels much lower than naturally present
  - No new or long lived decomposition products found

MEASURES TO REDUCE RISK OF ENVIRONMENTAL RELEASE

- BASF is **aware of potential risk** in case of release of refrigerant
  - ODP of 0.0003
  - GWP of 4.5
  - Formation of TFA
  - Suffocating atmosphere in the direct vicinity of the plant

- The plant is **designed as technically tight** e.g.
  - Special seals at compressors
  - Minimization of flanges by use of welded pipes
  - Blow-out proof seals at flanges

  - By definition of ChemKlimaschutzV, 1%/a leakage of refrigerant is defined
    - Based on GWP, this would lead to app. 1,3 t/a of CO_2 equivalent emissons
    - Formation of 6 kg/a of TFA in the environment

The use of R1233zd can be seen as an enabler for the roll out of heat pumps. Different heat pump technologies will be a key technology in the energy transformation

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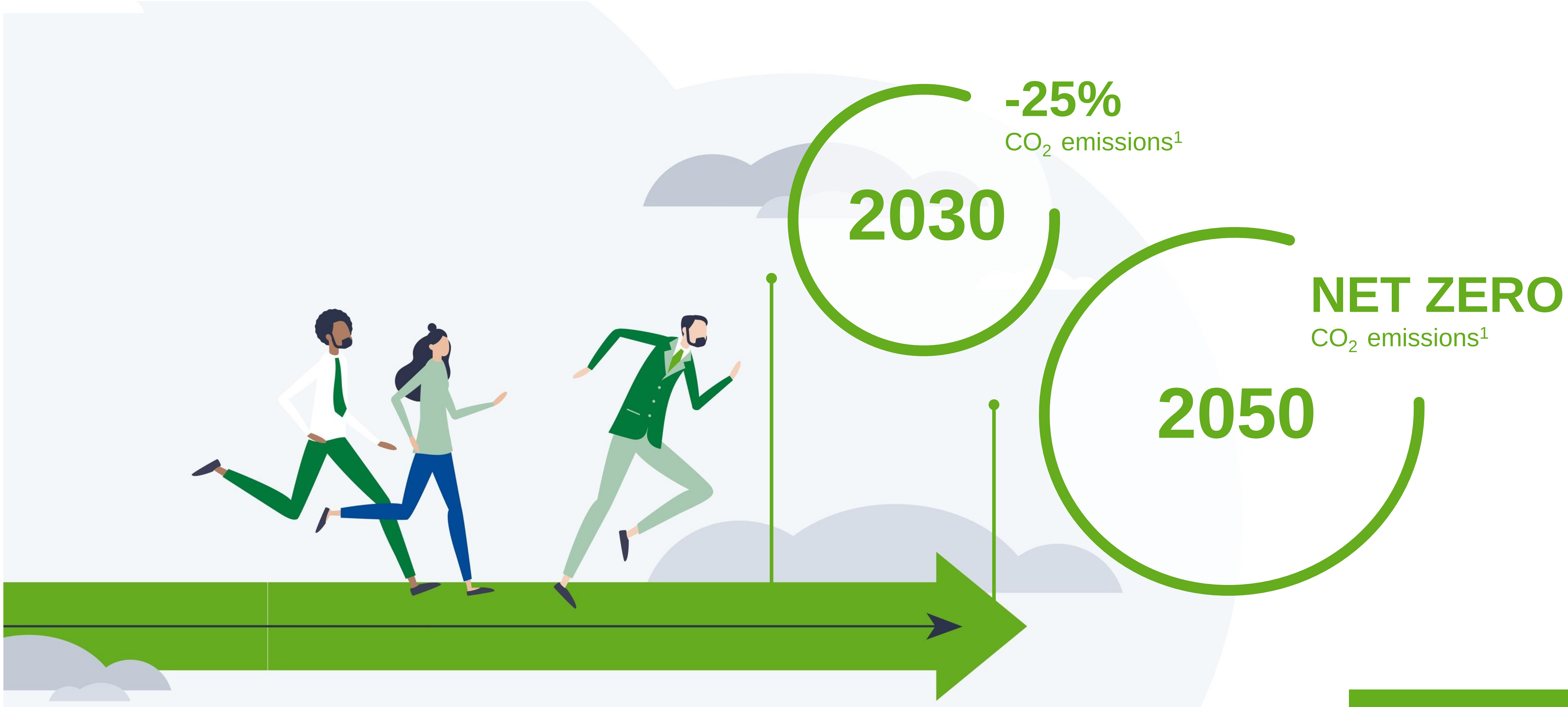
PROCEEDINGS WITH OTHER PROJECTS

- The choice of the appropriate refrigerant must be made case by case
- Several factors have to be evaluated e.g.:
  - Safety aspects
  - Temperature lift
  - Available space -> size of the plant

- For further project studies BASF also considers natural refrigerants like ammonia or butane as alternative to HFOs

OUR TRANSFORMATION HAS STARTED
SPEED IS KEY FOR SUCCESS!



[1] Scope 1 and

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