From Carbon Accounting to Carbon Management

Case Study on Net-Zero Industry Transformation

WinterSchool on Corporate Climate Management
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KFW DEG IfaS

REC Coach: Institute for applied Material Fow Management

- University of Applied Sciences Trier
- Non-Profit Institute
- Foundation in 2001
- 9 Professors & 80 Employees
- Interdisciplinary Team
  - Ecological Economics
  - Mechanical & Electrical Engineering
  - Policy Science
  - Spatial Planning
  - Agriculture & Forestry Engineering
  - Environmental Law

IfaS Institut für angewandtes Stoffstrommanagement

Coaching for Circular Economy & net-zero transformation

- Support the planning and implementation of (ISO) management and reporting systems, e.g.:
  - GHG accounting, reporting and management
  - Energy-, GHG-, Environment management
- Benchmark analysis of environmental impacts and carbon intensity of peers, sectoral initiatives, NDCs and EU taxonomy
- Definition of (SBTi) decarbonization pathways with KPI´s, interventions points Technical and economical feasibility studies
- (Renewable) Energy (efficiency), water, resource (waste) project development, incl. tender design, supplier research and evaluation
- Education & Capacity development

Global REC experiences in various sectors

Mexico

- Agro-industry: Sugar production

Guatemala

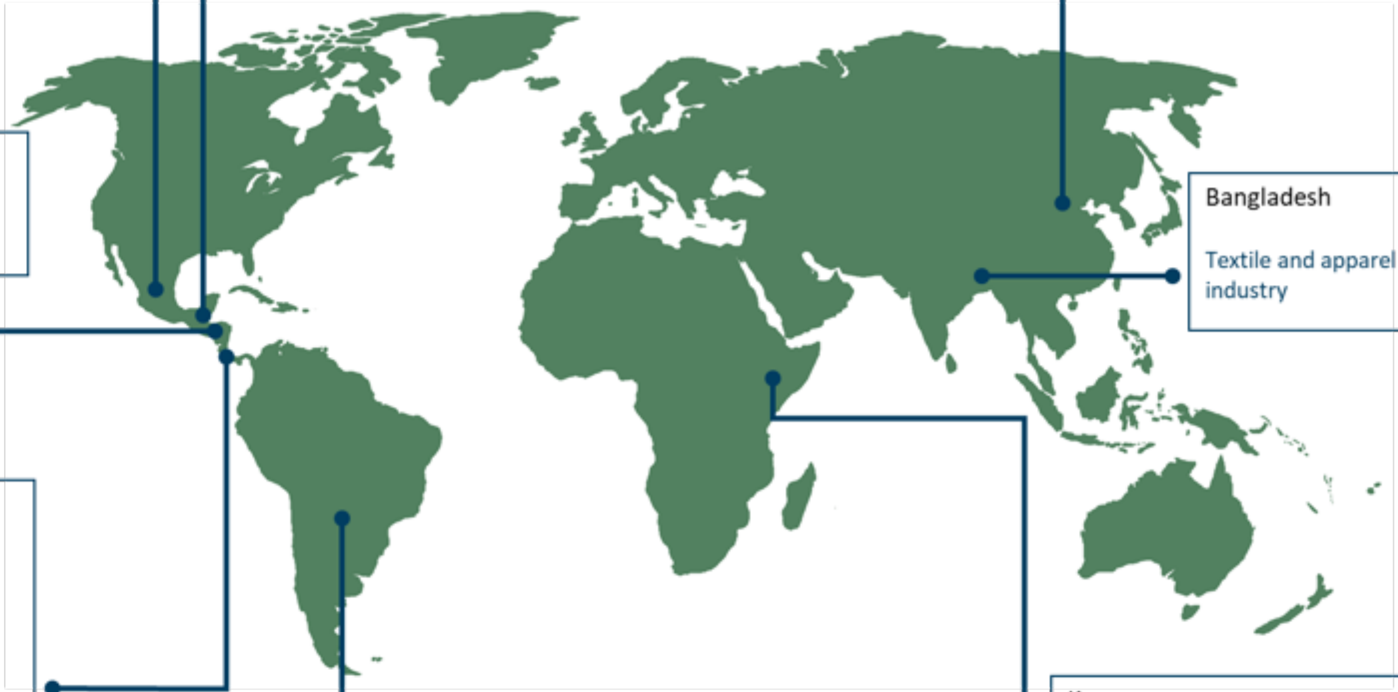
- Agro-industry: Banana and palm oil production
- Agro-industry: Sugar and alcohol production

People's Republic of China

- Hotel and food service industry

Nicaragua

- Agro-industry: Rice production
- Agro-industry: Meat production



Bangladesh

Textile and apparel industry

Costa Rica

- Agro-industry: Rice and pineapple production,
- Service industry
- Agro-industry: Sugar production
- Agro-industry: Sugar and alcohol production
- Agro-industry: Sales & distribution of sugar and liquid sugar
- Milk Cooperative - Dairy

Paraguay

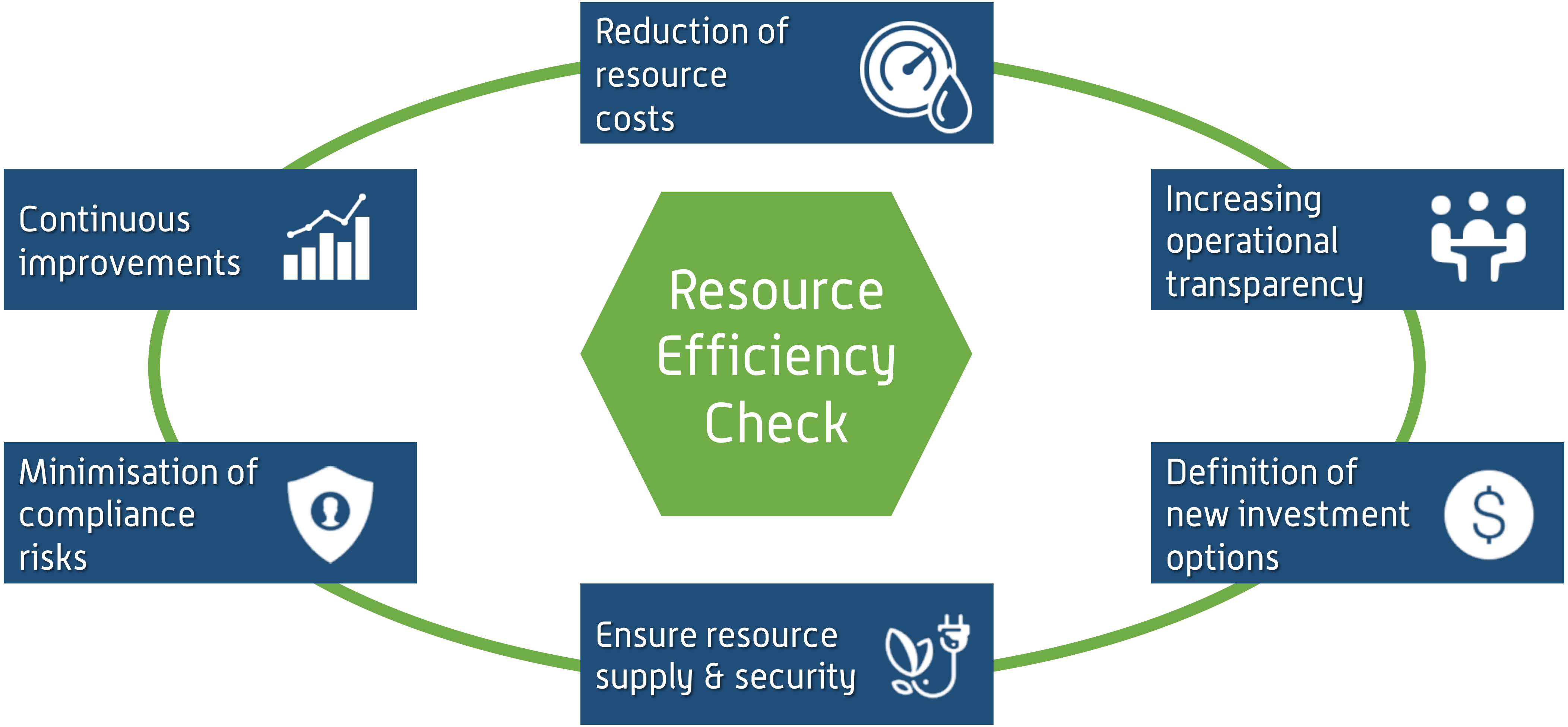
- Paper industry

Kenya

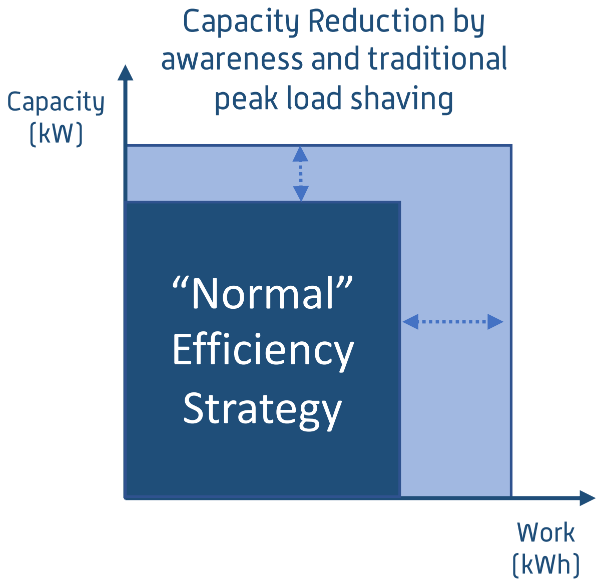
- Food and beverages industry

Objective

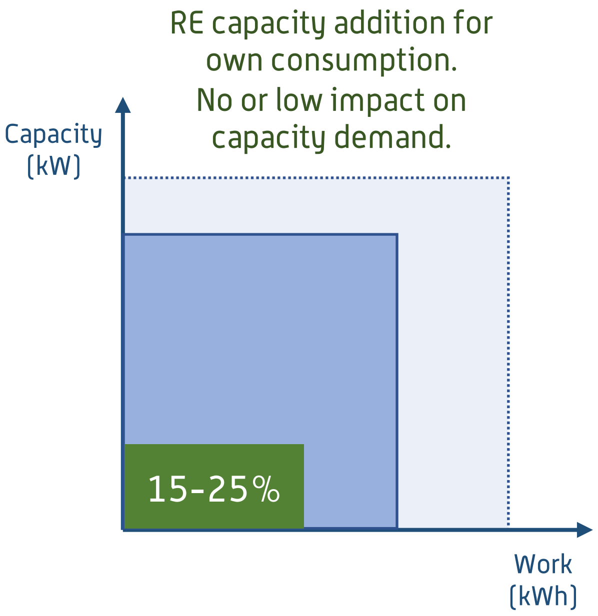
Resource and Efficiency Check (REC)



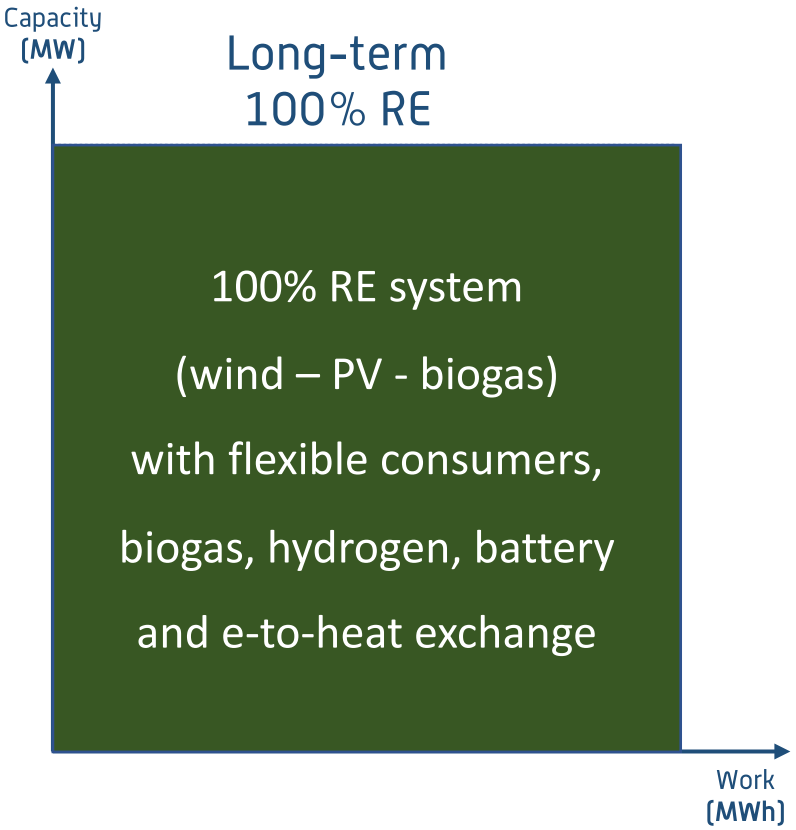
Energy management – Example Electricity



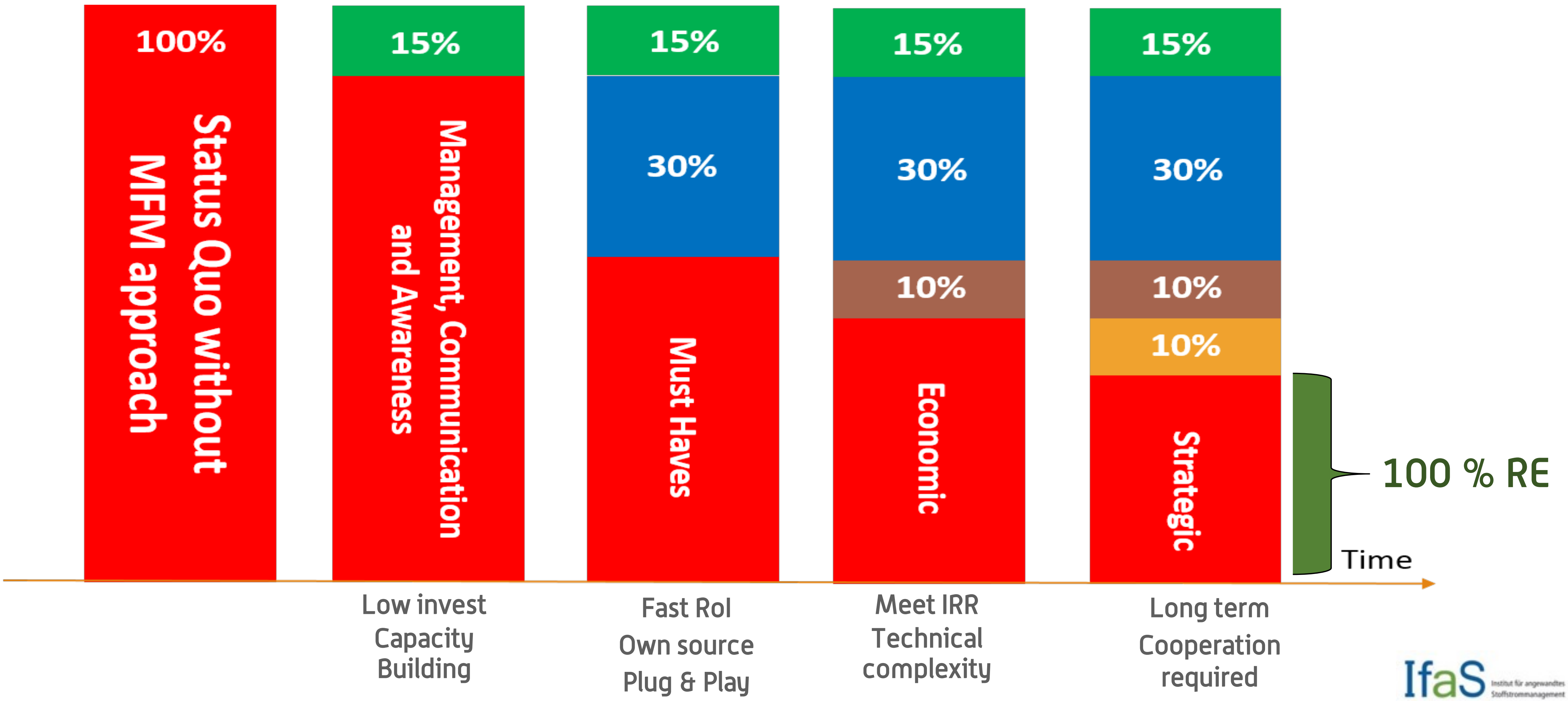
Conventional RE Development



Long-term 100% RE



IfaS Method | Energy and resource management

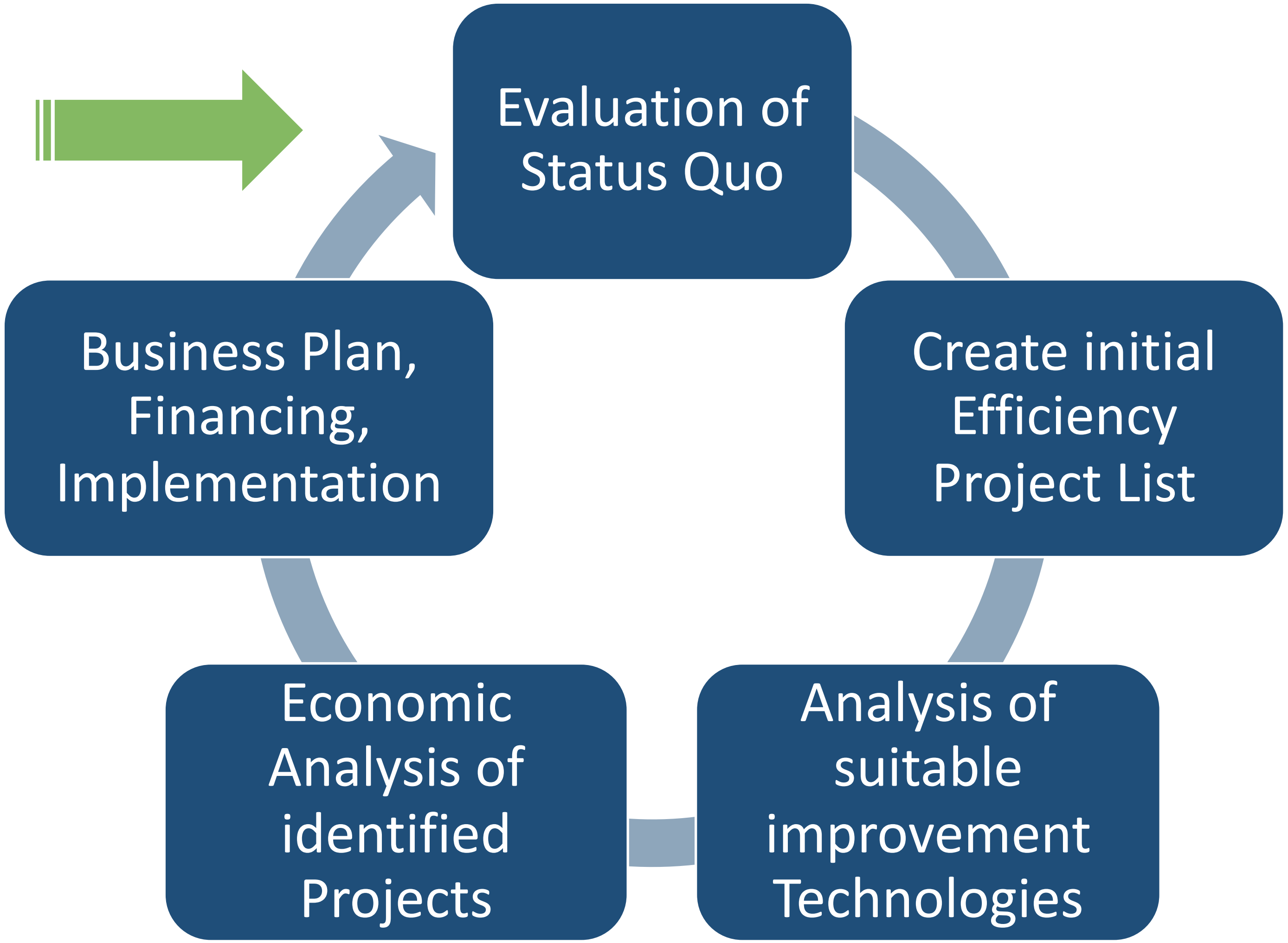


REC Workflow

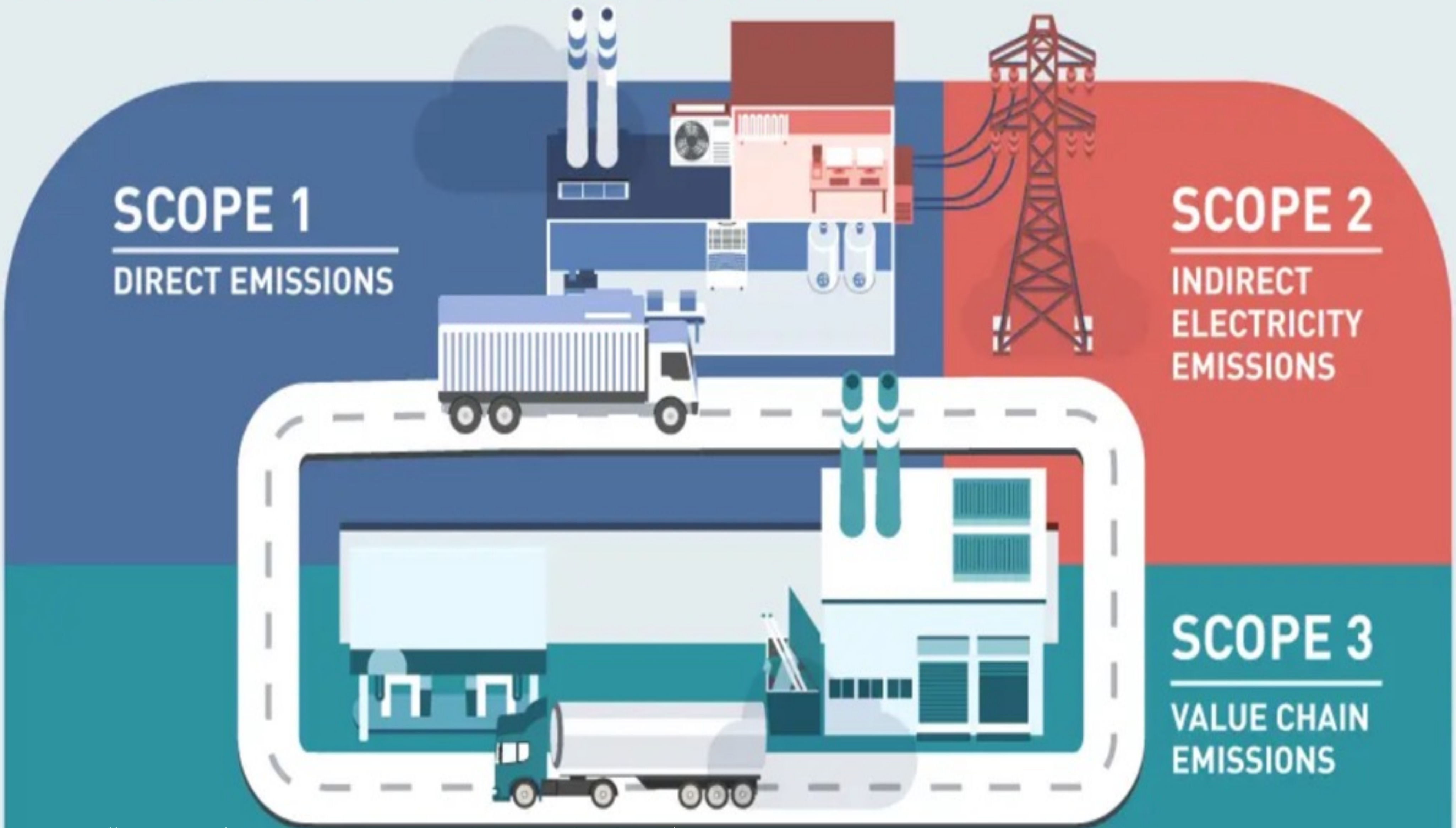
Material Flow Analysis

(Status Quo)

- Inventory of consumer
- Process and consumption analysis
- Load and demand profiles
- Measurements
- Benchmarking
- …..

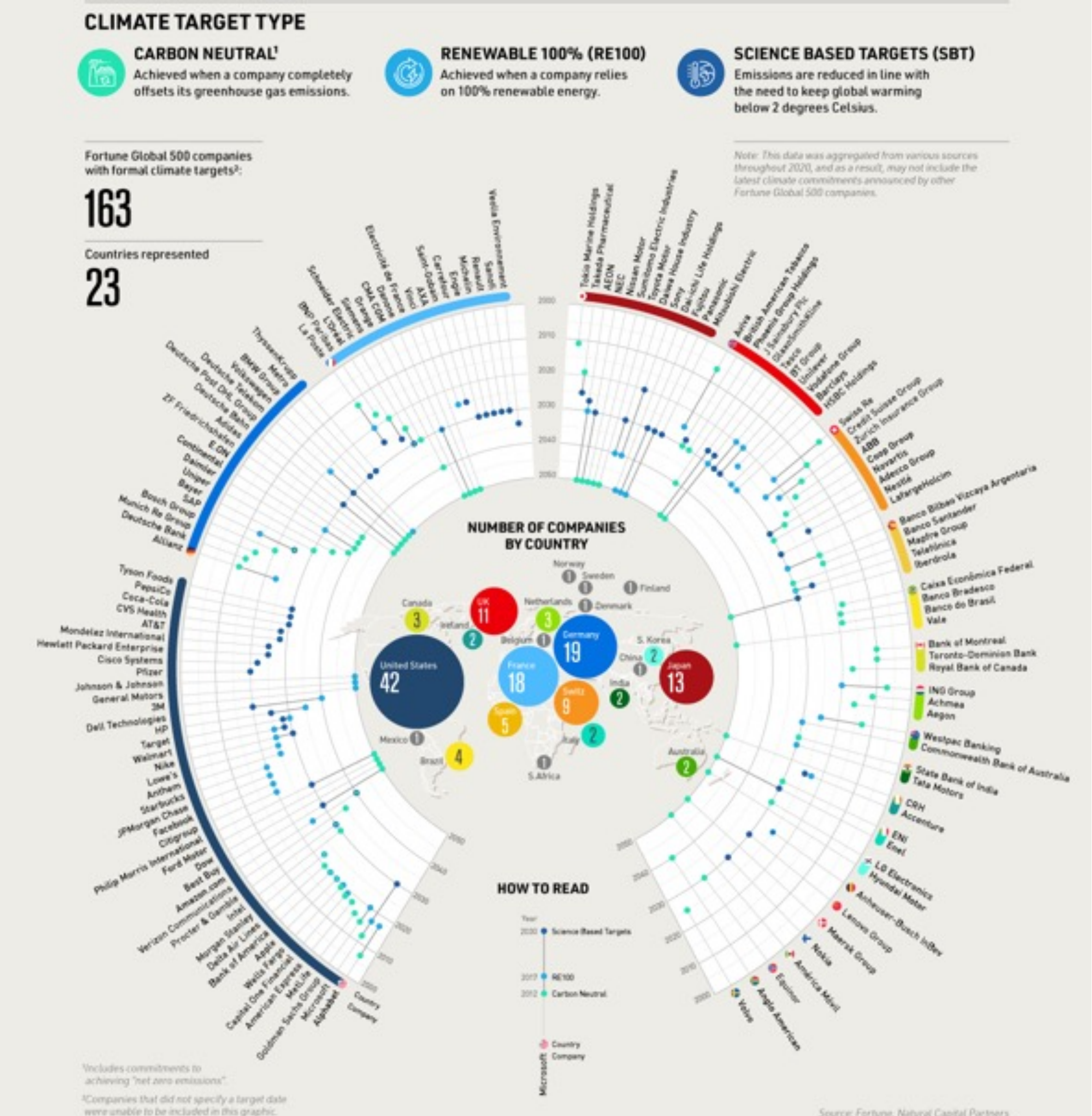


3 Scopes of GHG Protocol – Corporate Standard



Source: https://wpguynews.com/decarbonization-101-what-carbon-emissions-are-part-of-your-footprint/

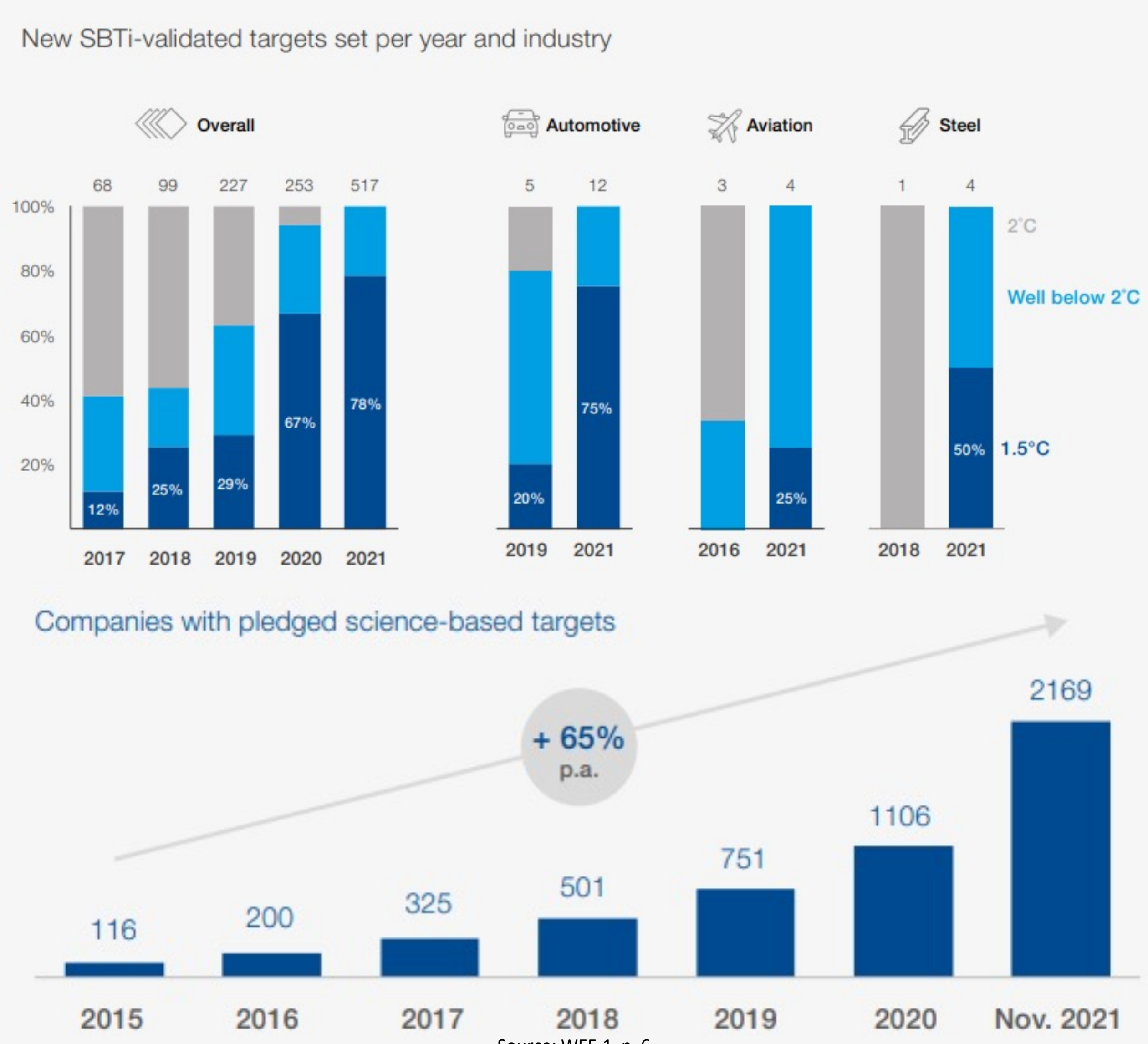
Climate Targets of Fortune 500 – The New Normal



- Improved reputation and costumer relation
- Active risk and compliance management
  - Improved relations with regulators
- Improved innovation, competitiveness and market positioning
- Enhanced operational and OPEX efficiencies (including supply chains)
- (Better) Access to capital (Trend Divestment)
- Building and sustaining shareholder value
- Enhanced ability to address change

Source: https://www.visualcapitalist.com/climate-targets-of-fortune-500-companies/

Science Based (Climate) Targets (SBTi)



Source: WEF-1, p. 6

Fast recognition and application of SBTi by Top-500

- Whether SBTi is manifested as a global standard is subject to be seen
- New SBT for new sectors are constantly added

GHG Protocol Corporate Standard (GHG PCS) is widely recognized and applied as GHG accounting standard

Various reporting/disclosure standards

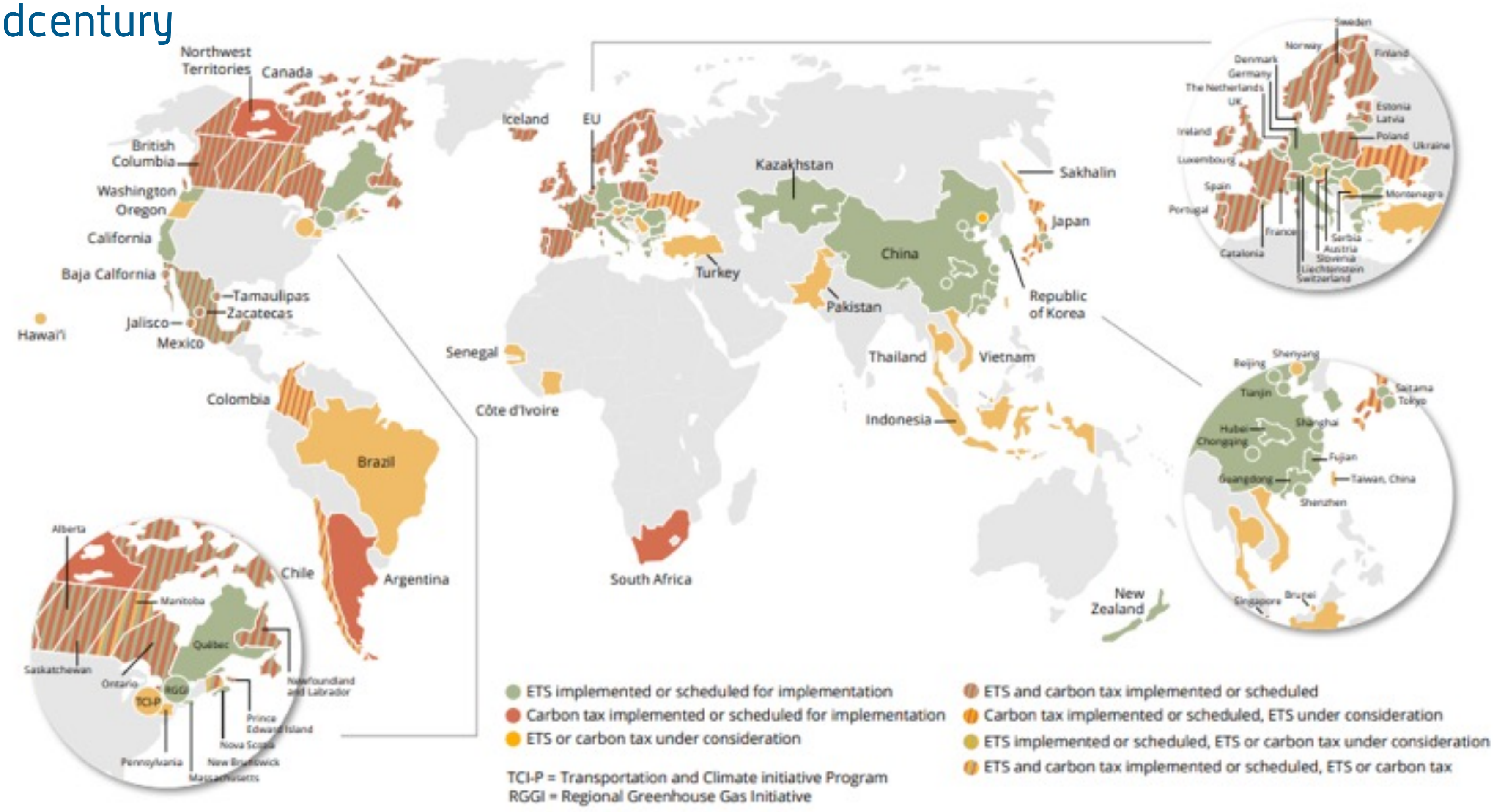
Next step after GHG inventory and target setting are <u>investments</u>!

[1] World Economic Forum (2022): Winning the Race to Net Zero: The CEO Guide to Climate Advantage, p. 6

Carbon Pricing Initiatives: Global rapid developments

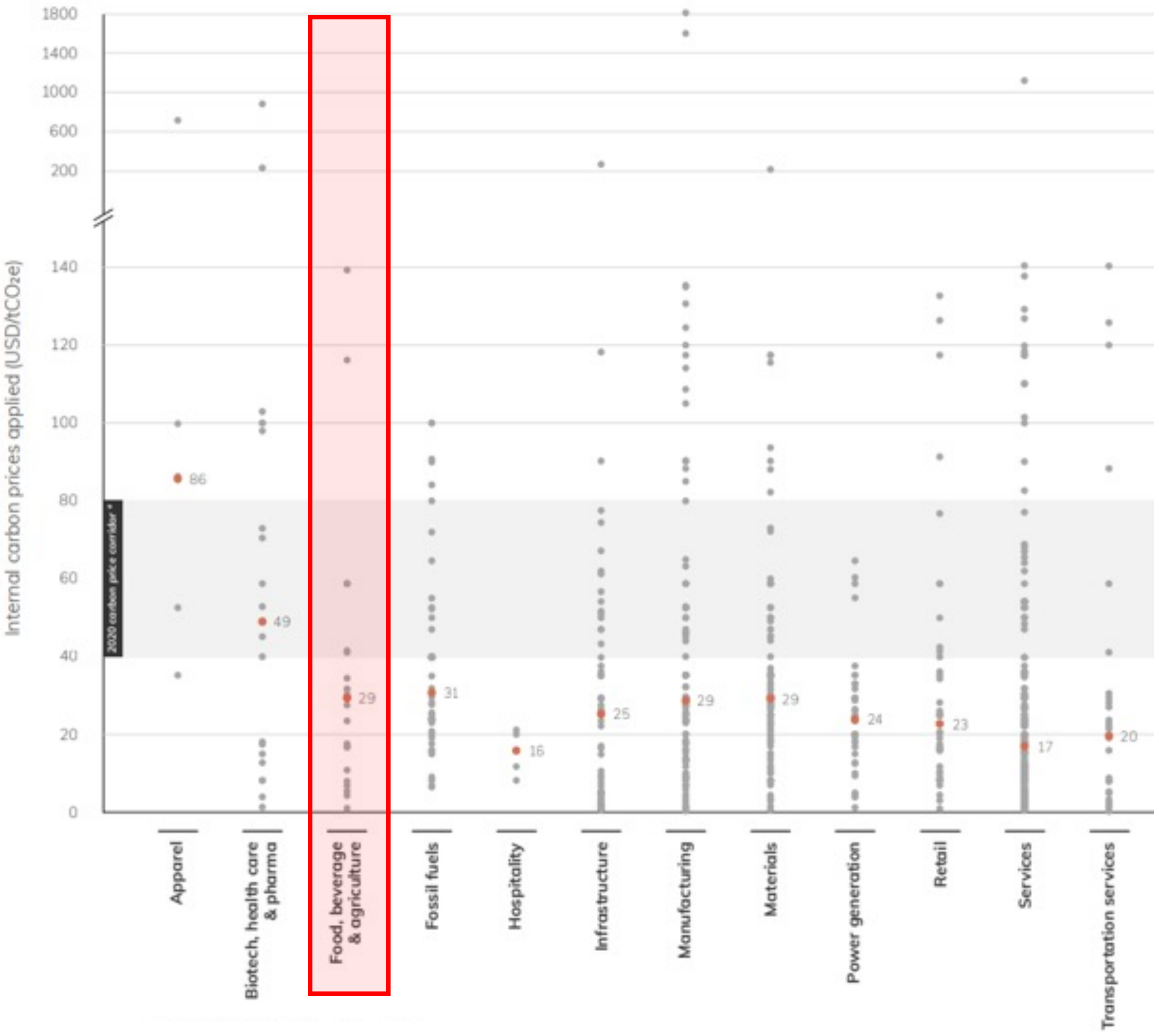
64 carbon pricing instruments (CPIs) in operation covering 21.7% of global GHG emissions

127 countries, 823 cities, 101 regions, and 2,169 companies have committed to decarbonizing their activities by midcentury



World Bank, State and Trends of Carbon Pricing 2021

Sectoral carbon pricing initiatives (trends)



Market trends:

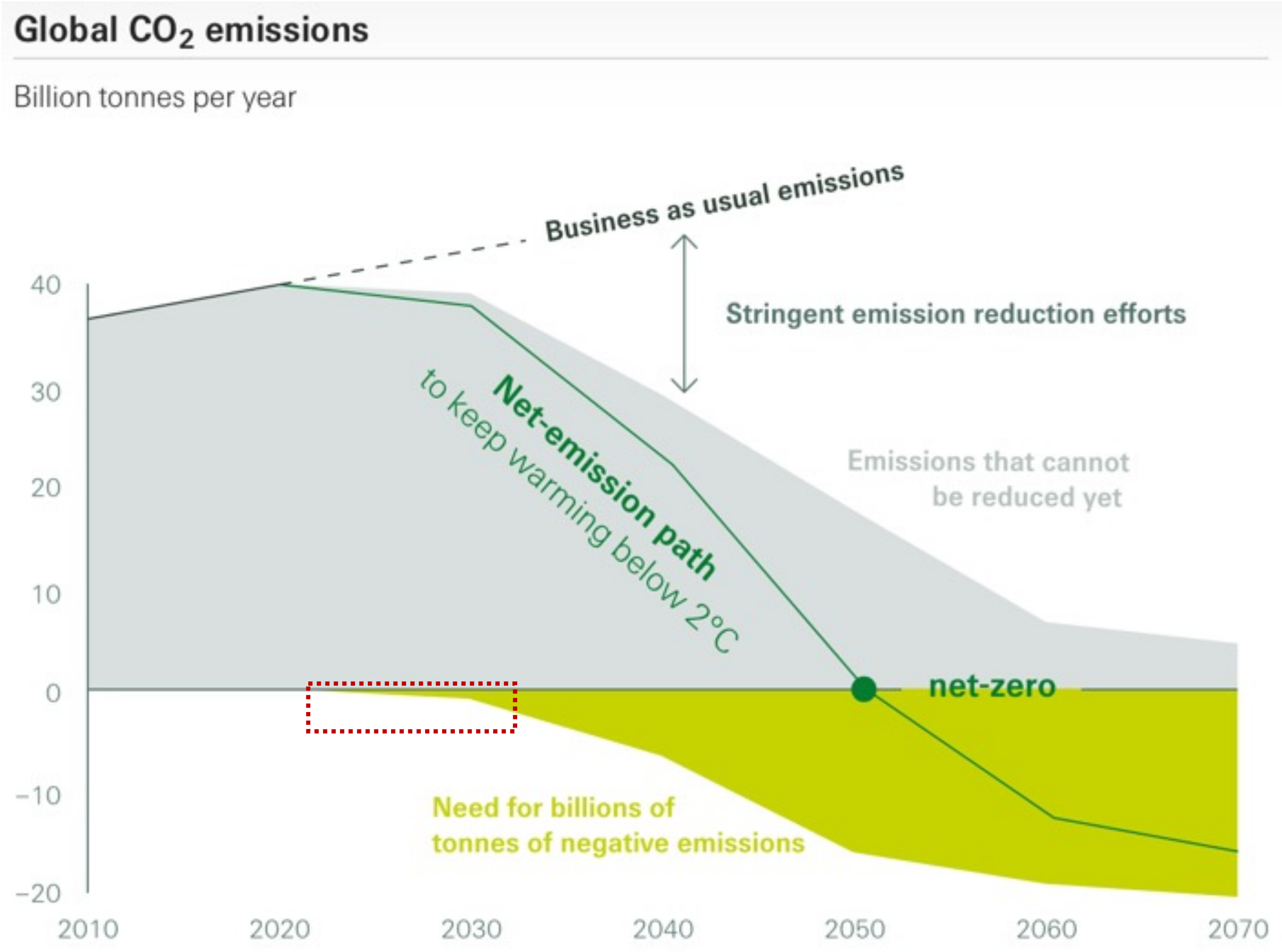
Averaged internal carbon price of 29 USD/tCO_{2e} (with max.140 USD/tCO_{2e}) applied at global food and beverage brands

Motivations:

- Stress test for investments
- Simulation of potential compliance impacts on economic KPIs
- Comparison of internal marginal abatement costs with carbon shadow prices as a new KPI
- Drive low carbon investments

Source: World Bank (2021), State and Trends of Carbon Pricing

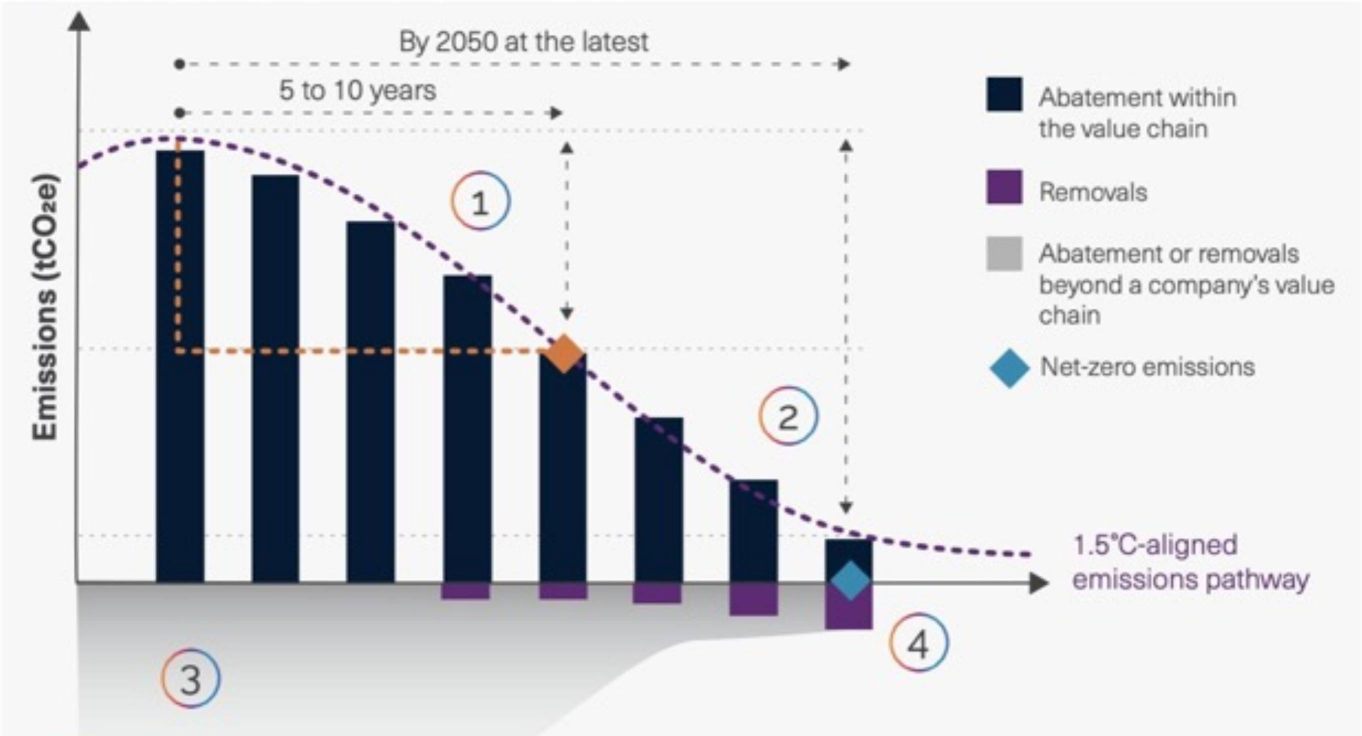
Carbon Pricing Scenario | Development Carbon removal market



- SBTi based decarbonisation pathway demands removal of residual GHG emissions
- Different market price ranges for sustainable removal certificates
- Increasing market demand will result in increasing prices for removals
- **Competitive advantages for early birds**

https://reports.swissre.com/sustainability-report/2019/footprint/net-zero-commitment-in-our-operations-by-2030/focus-our-commitment-in-detail.html

SBTi Target Setting | Management Process Requirements



1. **To set near-term SBTs:** 5–10 year emission reduction targets in line with 1.5°C pathways
2. **To set long-term SBTs:** Target to reduce emissions to a residual level in line with 1.5°C scenarios by no later than 2050
3. **Beyond value chain mitigation:** In the transition to net-zero, companies should take action to mitigate emissions beyond their value chains. For example, purchasing high-quality, jurisdictional REDD+ credits or investing in direct air capture (DAC) and geologic storage
4. **Neutralization of residual emissions:** GHGs released into the atmosphere when the company has achieved their long-term SBT must be counterbalanced through the permanent removal and storage of carbon from the atmosphere.

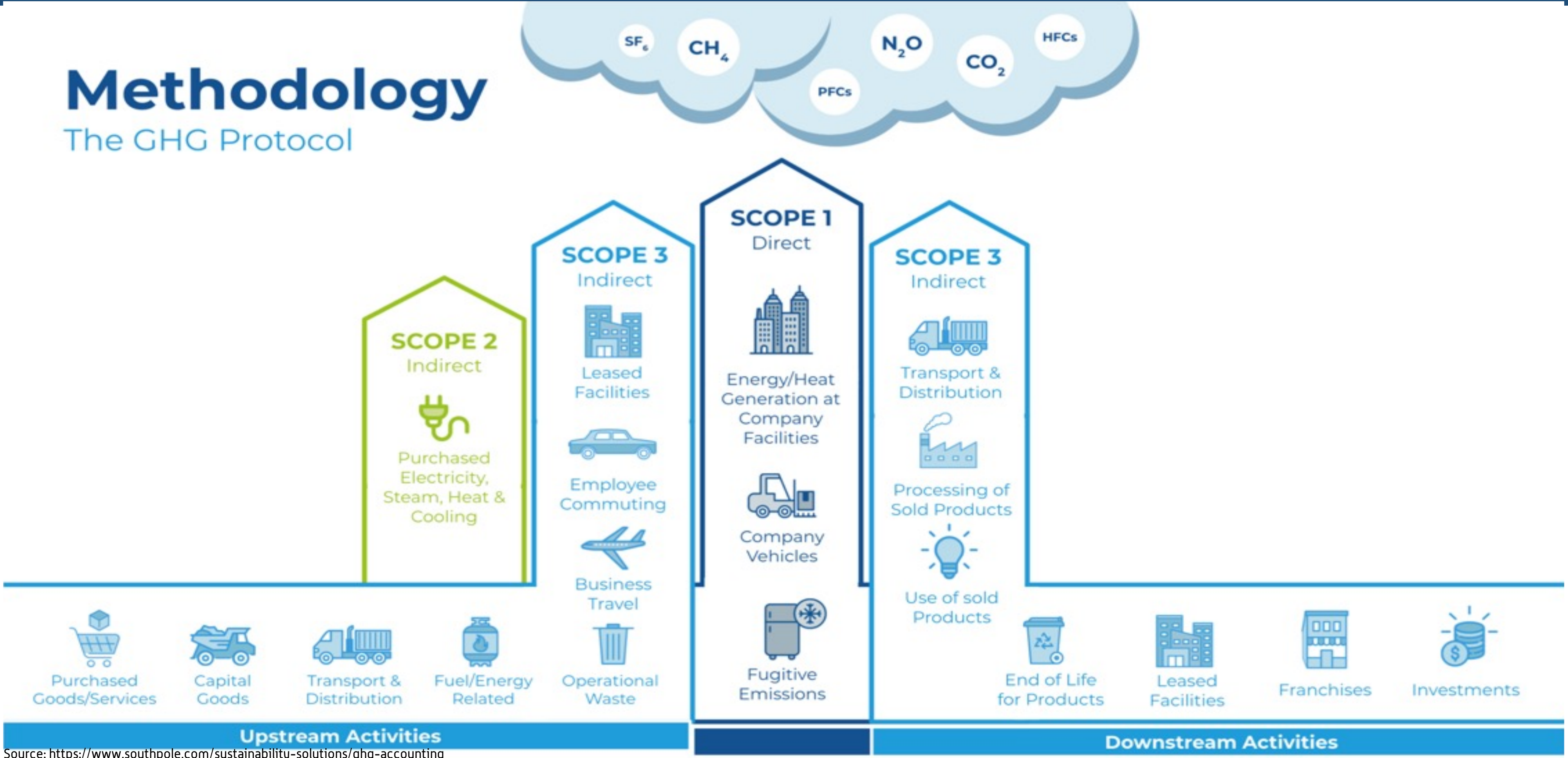
Source: https://sciencebasedtargets.org/resources/files/Net-Zero-Standard.pdf

1. Short term targets and commitments within the company
   - Renewable energy
   - GHG intensity
2. Long term net zero targets for company and value chain
   - Determining WACI and residual emission level
3. Beyond value chain mitigation
   - Scope 3 – double accounting
4. Neutralization of residual emissions

Starting point: Carbon Accounting

Source: https://www.enhelix.com/carbon-accounting-energy-transition-economy/

3 Scopes of GHG Protocol – Corporate Standard



Source: https://www.southpole.com/sustainability-solutions/ghg-accounting

GHG accounting | Calculation Scope 1-2 and partly Scope 3

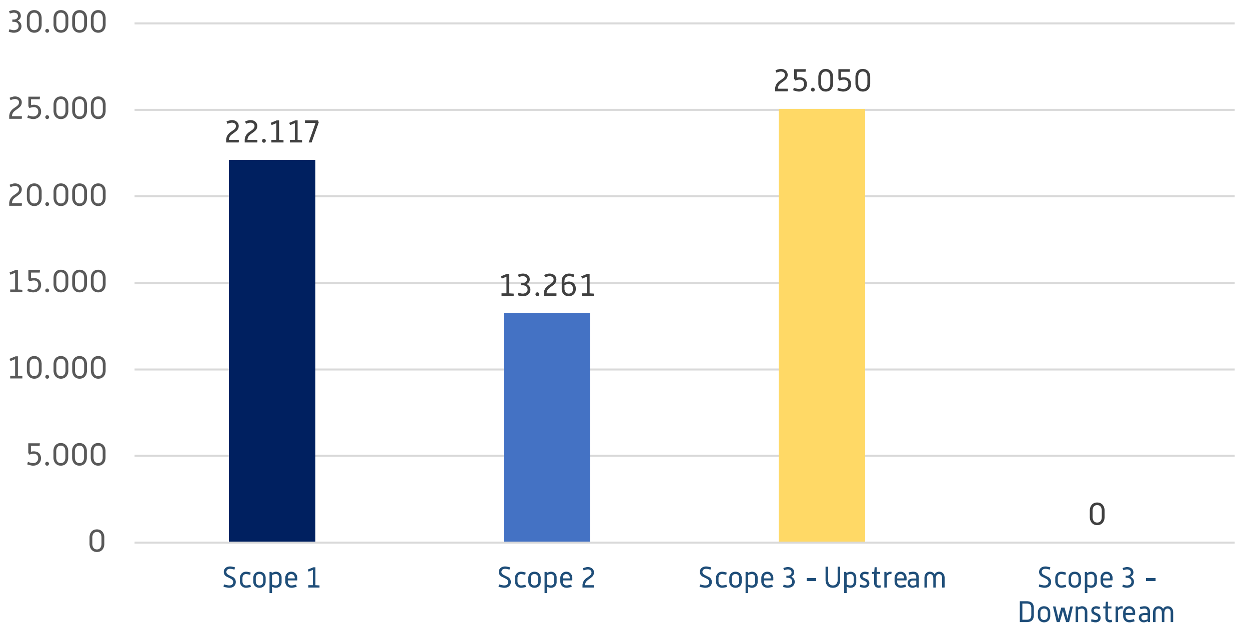
Data based on clients´ KPI 2021 (Energy) and CSR 2020 (GHG; Water)

Production (Baseline Year 2021)		
Beer production	1.748.244	hl
Drinks production (Water + Soft Drinks)	1.633.480	hl
Total beverage production	3.381.724	hl
Total Water extraction	9.187.466	hl
Total HFO Consumption	2.606.375	l
Total Diesel Consumption	1.736.607	l
Total LPG Consumption	607.250	l
Electricity consumption (Grid)	19.218.542	kWh
Electricity consumption (PV)	2.463.316	kWh
Total Electricity consumption	21.681.858	kWh

Emissions		
Scope 1		
HFO consumption	8.111.038	kg CO_{2e}/a
Diesel consumption	4.555.120	kg CO_{2e}/a
LPG consumption	978.887	kg CO_{2e}/a
Total Energy consumption	**13.645.045**	kg CO_{2e}/a
Wastewater treatment	164.000	kg CO_{2e}/a
Waste	232.000	kg CO_{2e}/a
Transportation	6.724.000	kg CO_{2e}/a
Use of Refrigerant	1.352.000	kg CO_{2e}/a
Total Scope 1	**22.117.045**	kg CO_{2e}/a
Scope 2		
Purchased electricity	**13.260.794**	kg CO_{2e}/a
Scope 3		
Total Upstream Scope 3 Emissions	**25.050.138**	kg CO_{2e}/a
Total Downstream Scope 3 Emissions	**tbc**	kg CO_{2e}/a

GHG Accounting | Scope 1-2 complete – Scope 3 incomplete

Scope	Emissions (t CO_{2e})	%
Scope 1	22.117	36,6%
Scope 2	13.261	21,9%
Scope 3 - Upstream	25.050	41,5%
Scope 3 - Downstream	0	0,0%



Diesel and LPG consumption data is different in two sources.
Emission balance is based on the initial data received by the client

General GHG inventory remarks:

1. Attempt to create a GHG start balance in accordance to SBTi and GHG PCS
2. Scope 3 needs to be reported if, significant: Criteria > 40% of total GHG emissions
3. Literature and peer review indicate that Scope 3 in “Beer & Beverage Sector” ranges between 60 – 85%
4. SBTi requests for individual Scope 3 targets but no removal (yet)

| Parts of Scope 3 - upstream inventory

Total upstream emission - Scope 3				
Main Material(s)	Consumption		Material Emission factor	Emissions
	Value	Unit	kg CO2e/Unit	kg CO2e
Glass	6.711.360	kg	1,25	8.410.742
Barley				
Malt	21.098.000	kg	0,11	2.236.388
Sorghum	694.948	kg	0,25	173.737
Rice	6.746.580	kg	0,60	4.047.948
Cans (Aluminum)	1.176.350	kg	8,53	10.034.266
PET	903.570	kg	0,06	57.015
HDPE	160.790	kg	0,56	90.042
Paper				0,00
Cardboard				0,00
Plastik beer boxes				0,00
				0,00
Total Upstream Emissions (SC-3)	25.050.138	kg CO2e		
	25.050	t CO2e		

- Start with scope 3 accounting (only upstream emissions) to determine significance (>40% of total GHG)
- Based on (available) clients procurement data and LCA benchmark values of peers and eco-invent database
- Exemplary Scope 3 – upstream emissions exceed >40% threshold already

| (Significant) Variations in product EF/WACI

Beer - KPIs (per hl $_{beer}$)				
	Unit	Calculated	Client	Client target
Water consumption (72.4% from total water)	hl/hl	3,80	3,46	3,67
HFO consumption	l/hl	1,49	1,48	1,55
Electricity consumption (88.6% from total elec.)	kWh/hl	10,99	10,06	10,20
Electricity consumption (88.6% from Grid supply)	kWh/hl	9,74		

Soft drinks - KPIs (per hl $_{softdrinks}$)				
	Unit	Calculated	Client	Client target
Water consumption (27.6% from total water)	hl/hl	1,55	1,41	1,38
Electricity consumption (11.4% from total elec.)	kWh/hl	1,51	1,39	1,6
Electricity consumption (11.4% from Grid supply)	kWh/hl	1,34		

Beer emission factor	kg CO_{2e} / hl	11,36	(Grid electricity and HFO only)
Soft drink emission factor	kg CO_{2e} / hl	0,93	(Grid electricity only)

- Client CSR: one aggregated EF for total production (beer and soft drinks)
  - **9,12 KgCO2e/hl**
  - **excluding Scope 3**
- Significantly different product EFs revealed by source-attribution of energy related GHGs

GHG Accounting | Linear Forecast – a small difference matters

BAU		
Total Production in baseline year	3.381.724	hl
Production growth	3,93%	/a

Beverage emission factor (Total production) - kg CO_2/hl)		
Client value	9,12	kg CO_{2e}/hl
Calculated (Total Scope 1 and 2)	10,46	kg CO_{2e}/hl

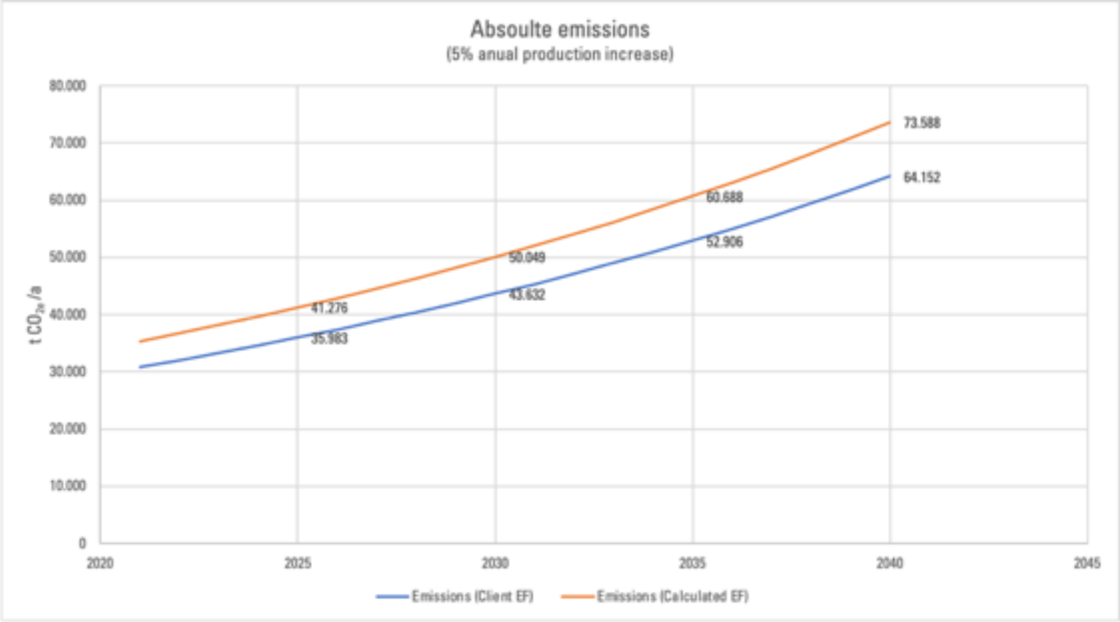
Year	Emissions (Client EF)	Emissions (Calculated EF)
2021	30.841	35.378
2022	32.053	36.768
2023	33.313	38.213
2024	34.622	39.715
2025	35.983	41.276
2026	37.397	42.898
2027	38.867	44.584
2028	40.394	46.336
2029	41.982	48.157
2030	43.632	50.049
2031	45.346	52.016
2032	47.128	54.061
2033	48.981	56.185
2034	50.906	58.393
2035	52.906	60.688
2036	54.985	63.073
2037	57.146	65.552
2038	59.392	68.128
2039	61.726	70.806
2040	64.152	73.588

KPI: Doubling the production until 2040

Compound annual growth rate (CAGR) of 3,93 %/y

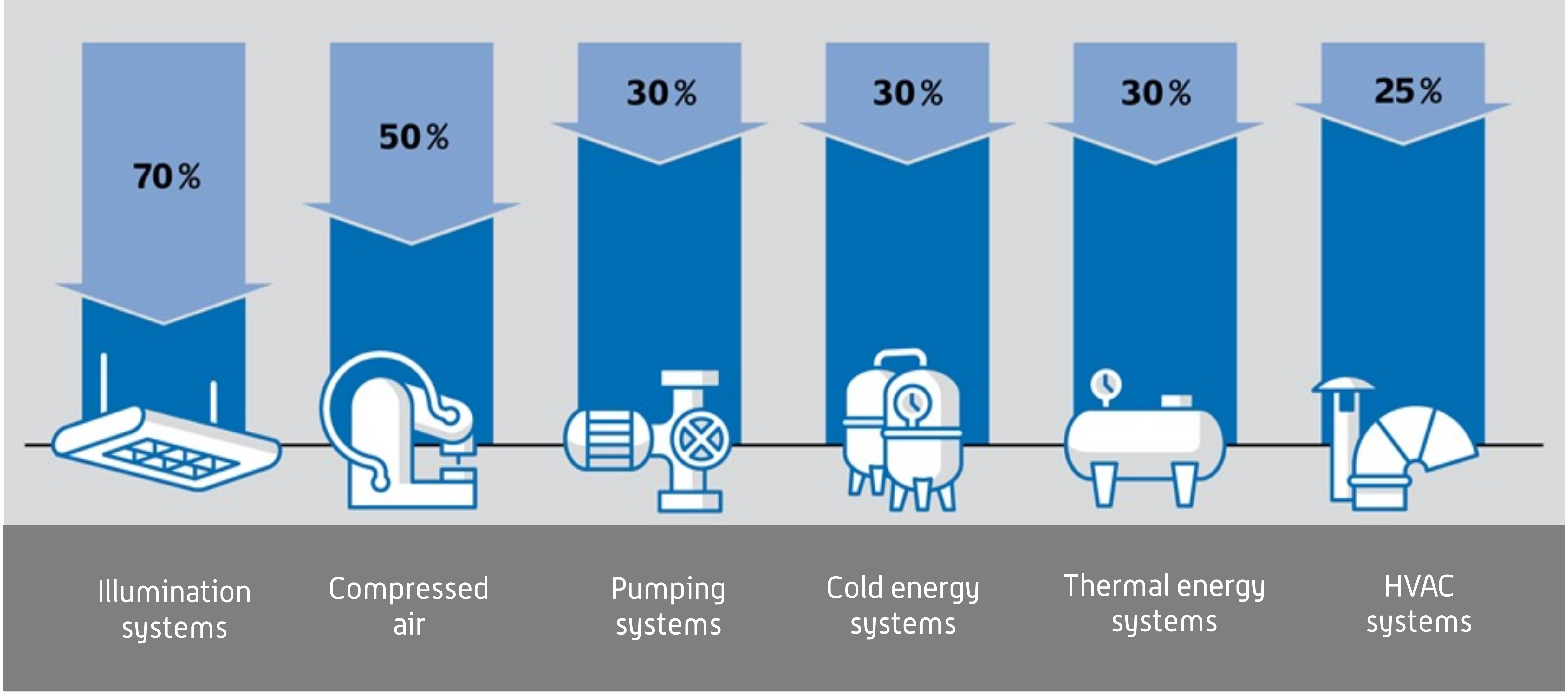
Clients EF: GHG increase from 30.841 tCO_{2e}/y to 64.152 tCO_{2e}/y in 2040

Consultants EF: GHG increase from 35.378 tCO_{2e}/y to 73.588 tCO_{2e}/y in 2040

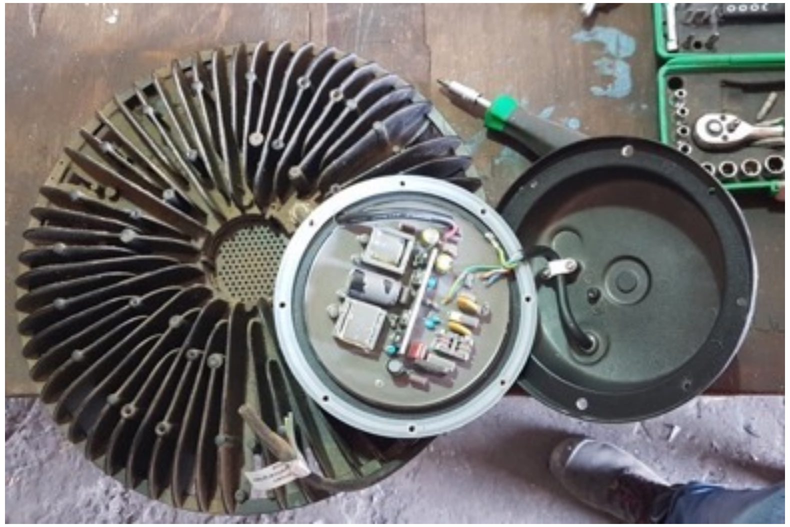


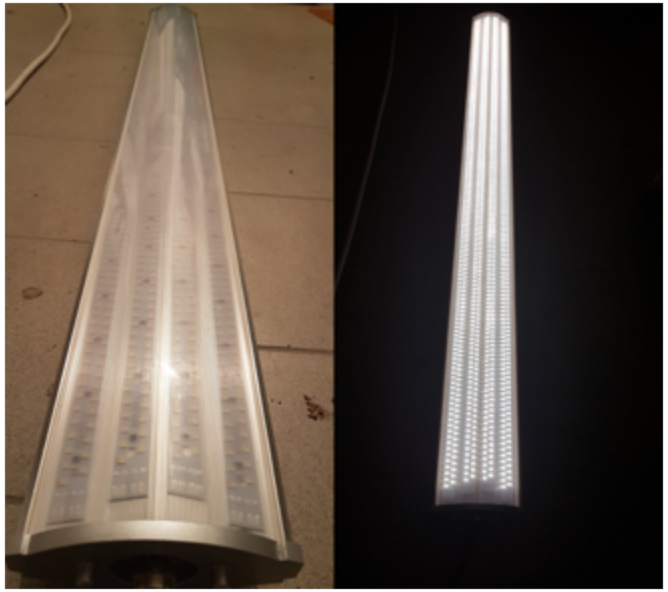
REC Method

Identify systemic efficiency potentials



Comparison Disk versus Longfield LED





Longfield LED is a product of Lanz Manufaktur

High-bay Lights VS Longfield			
Parameter	**[Unit]**	**Disc**	**Lanz**
Power Rating	W	240	120
Ballast Losses	%	8%	
Number of units	x	250	250
Total installed capacity	kW	64,8	30,0
Annual operating time	h/a	4.380	4.380
Annual elec. consumption	kWh/a	283.824	131.400
Energy savings	kWh/a		152.424
Electricity Price	USD/kWh	0,15	0,15
Annual electricity costs	USD/a	42.574	19.710
Cost savings **OPEX**	USD/a		22.864
Price per LED unit	USD/x	400	650
Total Invest	USD	100.000	162.500
OPEX Payback Period	**a**		**2,7**
Life Span	h	21.900	48.000
Investment at equal life span	USD	219.178	162.500
Cost savings **CAPEX**	USD		56.678

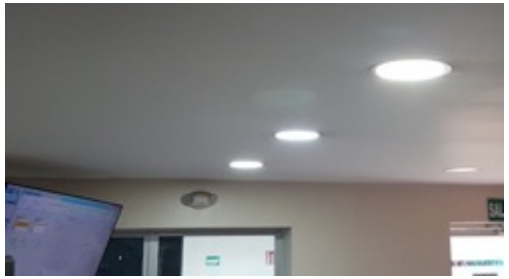
IfaS

Comparison ARGO T8 and Lanz T8

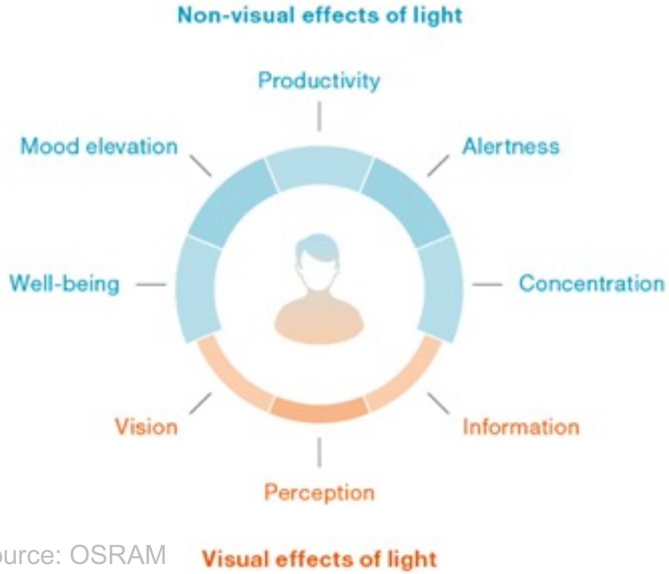
T8-LED is a product of Lanz Manufaktur with a guaranteed life expectancy of 75.000 operating hours

T8 Tubes			
Parameter	**[Unit]**	**CrediCorp**	**Lanz**
Power Rating	W	18	16
Ballast Losses	%	10%	
Number of units	x	1.000	1.000
Total installed capacity	kW	19,8	16,0
Annual operating time	h/a	4.380	4.380
Annual electricity consumption	kWh/a	86.724	70.080
Energy savings	kWh/a		16.644
Electricity Price	USD/kWh	0,15	0,15
Annual electricity costs	USD/a	13.009	10.512
Cost savings **OPEX**	USD/a		2.497
Price per LED unit	USD/x	18	24
Total Invest	USD	18.000	24.000
OPEX Payback Period	**a**		**2,4**
Life Span	h	12.000	64.000
Investment at equal life span	USD	96.000	24.000
Cost savings **CAPEX**	USD		72.000

Lighting for Occupational Health & Safety



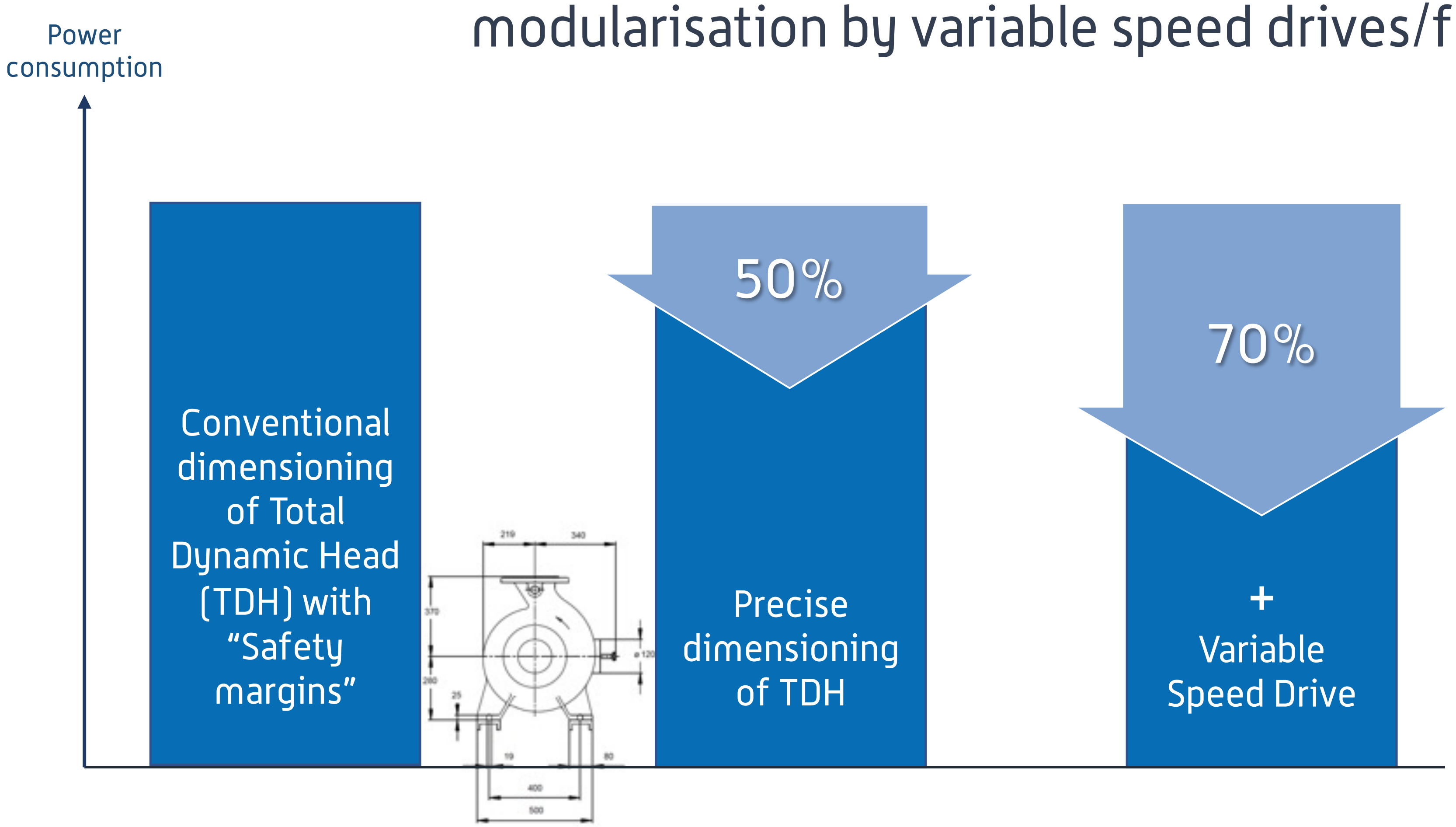
- DIN EN 12462-1: Light and lighting - Lighting of work places - Part 1: Indoor work
  - Storage areas: maintained illuminance 150 lx, CRI 60
  - Operation areas: maintained illuminance 200 lx, CRI 80
- Recommendation: **avoid CCT higher than 5000 K**
  - Reduce exposition to blue light for long periods
  - Minimization of negative health risks (e.g. irritated sight, fatigue and headaches)
  - Protection of good eye health – **healthy retina**
- Dynamic natural light has a direct effect on the human circadian rhythm (sleep-wake rhythm)
  - ↑ Illuminance and blue light components increase until midday
  - ↓ Then they slowly decrease again until evening

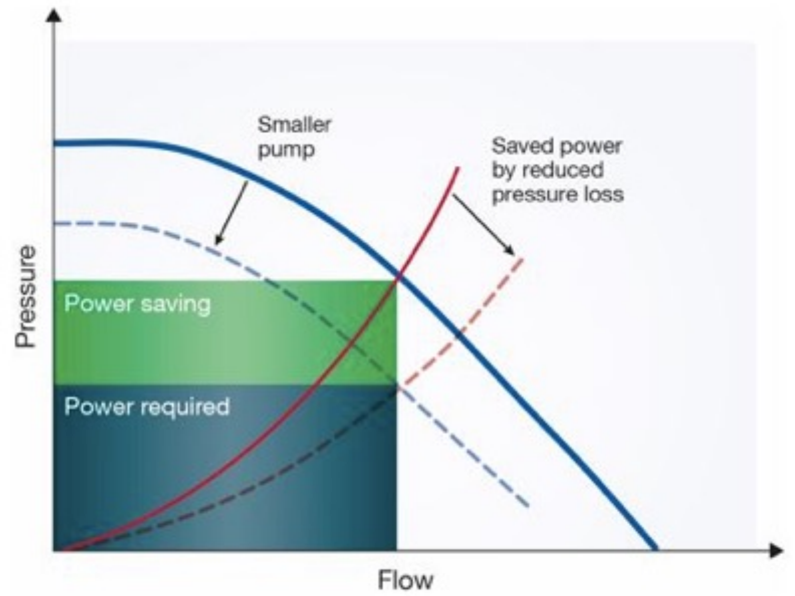


Source: OSRAM

Efficiency potential modeling

Efficiency potentials in precise dimensioning, automatization and modularisation by variable speed drives/frequency inverter





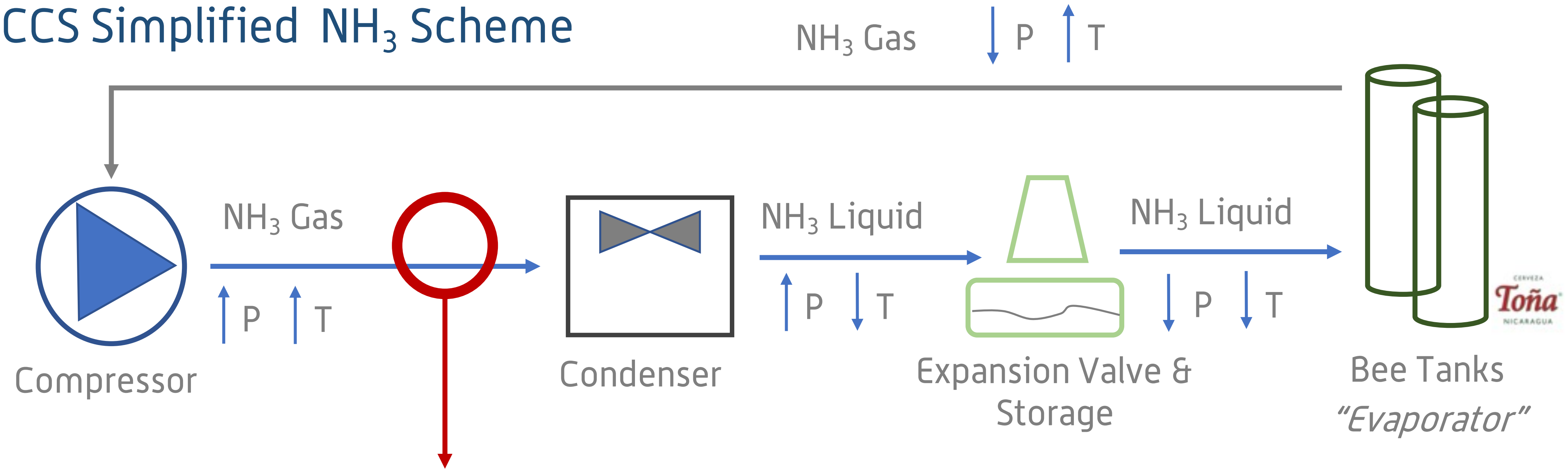
Pump-set replacement in context of inventory

Position	Industrial	Bottling	Brewhouse	Unit
Capacity (based on interims inventory with data gaps)	617	212	1.290	kW
Total electricity demand of pump motors	2.100			kW
Current efficiency (η) level	55% - 90% (new pump-set)			%
Average pump efficiency improvement (η)	19%			%
Potential reduction of electricity demand	396			kW
Theoretical electrical work saving potential (Assumption: 6,400 operating hours/a and 400 kW)	2.560			MWh/a
Theoretical monetary saving potential (Assumption: 0,15 USD / kWh)	384.000			USD/a
GHG mitigation potential (Assumption: 0,631 t CO_{2e} / MWh)	1.615			t CO_{2e}

Cold Energy

| Ammonia (NH_3) heat recovery

CCS Simplified NH_3 Scheme



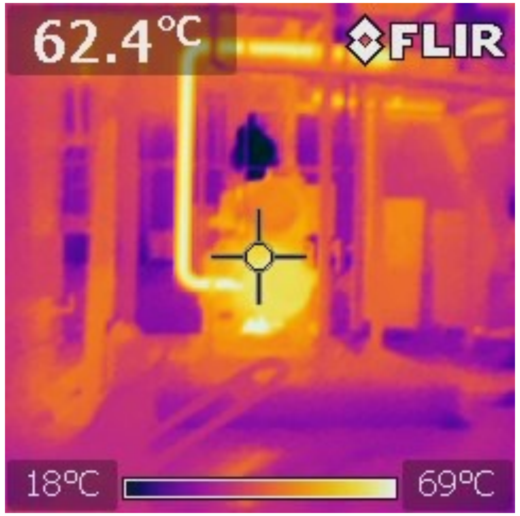


Plate-and-shell heat exchanger (PSHE)

- Load reduction for condenser
- Heat utilisation for make-up water and CIP

Cooling | Ammonia (NH_3) heat recovery

Parameter	Unit	VSM 701	VRS 700	VCM-450XL	VSS-601	VSM-701	VML-6A	VML-6A	SUM	
Nominal Displacement	m^3/h	1.191	1.189	506	1.021	1.191	516	516		
% Capacity	%	99,4%	99,4%	99,4%	99,4%	99,4%	99,4%	99,4%		
Operating displacement	m^3/h	1.184	1.182	503	1.015	1.184	513	513		
Density NH_3 (@11,5bar / 60°C)	kg/m^3	7,71	7,71	7,71	7,71	7,71	7,71	7,71		
NH_3 Mass rate	kg/h	9.130	9.117	3.881	7.828	9.130	3.956	3.956		
Specific heat capacity	kJ/kg*K	2,75	2,75	2,75	2,75	2,75	2,75	2,75		
Average NH_3 Temperature	°C	60	60	60	60	60	60	60		
Ambient temperature	°C	30	30	30	30	30	30	30		
Delta T	K	30	30	30	30	30	30	30		
Waste heat flow	kJ/h	751.852	750.779	319.613	644.599	751.846	325.737	325.737		
Potential thermal output	**kW_{th}**	**209**	**209**	**89**	**179**	**209**	**90**	**90**	**1.075**	
Full Load Hours (90% utilisation)	h/a	6.400	1.400	3.800	5.000	4.200	4.400	4.400		
Heat Exchanger Eff.	%	72%	72%	72%	72%	72%	72%	72%		
Energy Potential	MWh_{th}/a	962	210	243	645	632	287	287	**3.265**	
Energy Price	USD/kWh_{th}	0,08	0,08	0,08	0,08	0,08	0,08	0,08		
Monetary Saving Potential	USD/a	76.990	16.817	19.432	51.568	50.524	22.932	22.932	**261.195**	
Water heat-up equ. (30-60°C)	m^3/a	27.562	6.021	6.957	18.461	18.087	8.209	8.209	**93.507**	14%
Bunker equ. (42,8 kWh/gal, 82%eff.)	gal/a	22.501	4.915	5.679	15.071	14.766	6.702	6.702	**76.336**	11%

In-built PSHE by Vahterus

- Analysis of the real load curve required to determine best available heat recovery potential
- Estimated investment for PSHE: 80.000 USD and annual **OPEX saving of 260.000 USD**
- **Energy Saving potential of 3.265 MWh/a or an equivalent of 289.000 l/a HFO (11% of total HFO)**
- **CO_{2e} mitigation potential of 1.011 t CO_{2e}**

Source: *https://accelerate24.news/regions/europe/vahterus-launches-interactive-3d-heat-exchanger-model/2021/*

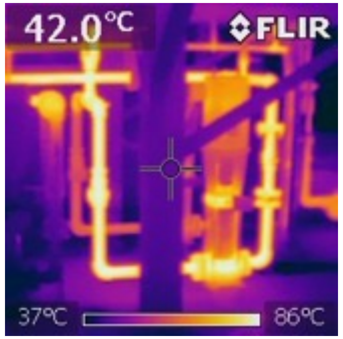
Thermal Energy

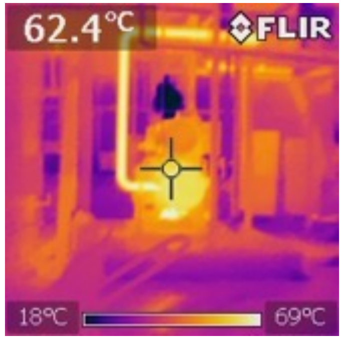
| Insulation of tubes

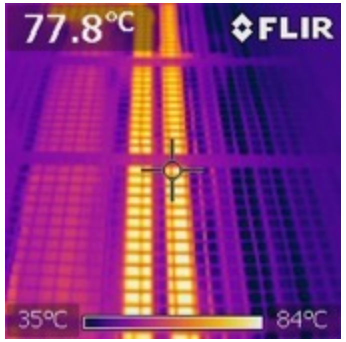
	[Unit]	Status Quo	1.5"	2.0"	2.5"	3.0"
Total heat loss	kWh_{th}/a	**70.648**	10.583	9.180	8.236	7.553
Energy consumption	kWh/a	86.156	12.906	11.195	10.044	9.211
Energy savings	**kWh/a**		**73.251**	**74.962**	**76.112**	**76.945**
Energy costs	USD/a	6.893	1.032	896	804	737
Cost savings	**USD/a**		**5.860**	**5.997**	**6.089**	**6.156**
Total CO_{2e} Emissions	t CO_2/a	25	4	3	3	3
Insulation + Installation	**USD**		**6.300**	**6.800**	**8.200**	**9.700**
Simple PBP	**a**		**1,08**	**1,13**	**1,35**	**1,58**

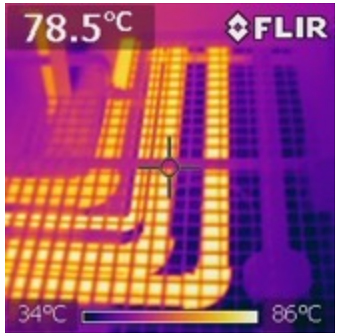
Example: Mineral rock with aluminum coating

Calculation assumptions: Ambient temperature of 35°C; Feed water temperature of 85°C; pipe material 2" STD Stainless Steel (304 L); length of pipes: 100 m; 82% Boiler Efficiency; heat price of 0.08 USD/kWh_{th}

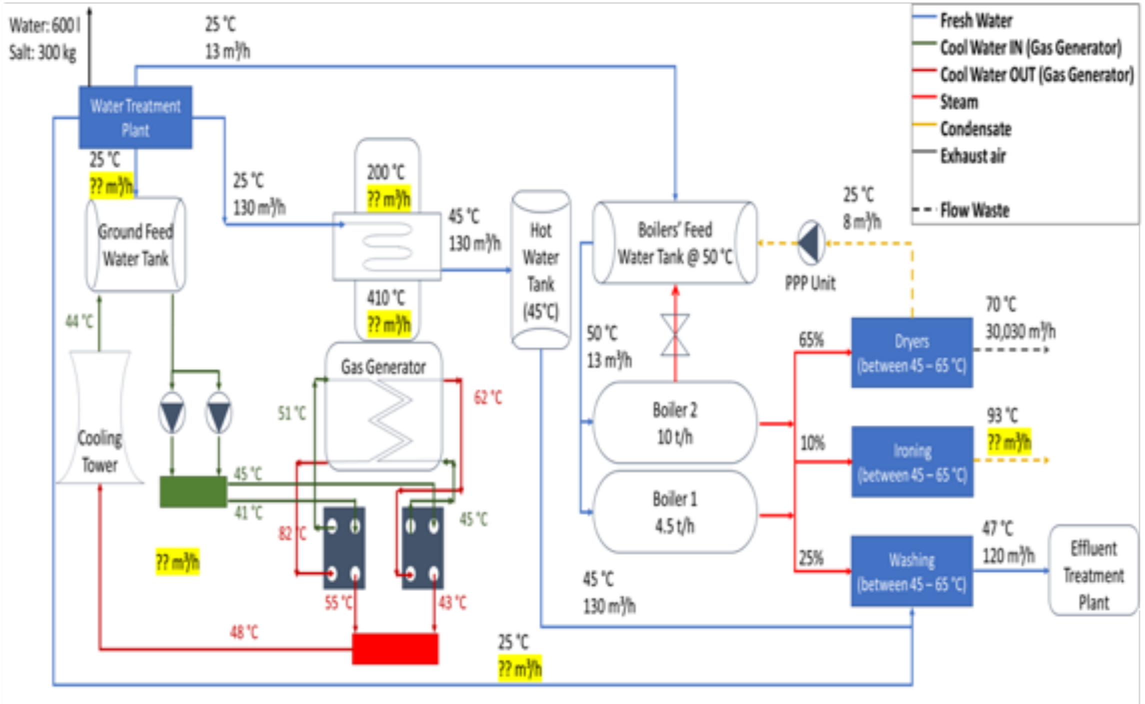






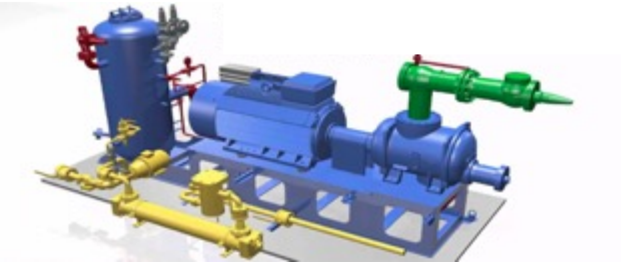


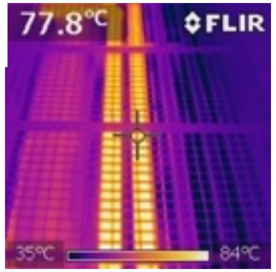
Thermal Energy | Mapping heat optimisation potentials

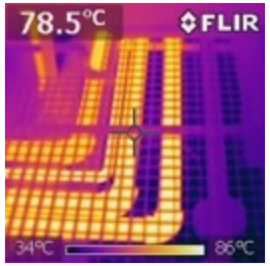


Recommendation:

1. Mapping all thermal (exhaust) processes, e.g.
   - Exhaust of Boilers
   - Heat Exchangers
   - Waste Water
   - Compressors
   - NH_3 Cooling
2. Determine heat re-utilization (sinks) options at different temperature levels







Mid-term
DeCarb.-Projects

| Utilization of e-forklifts

High Performance

Energy Efficiency & GHG avoidance

Safety

- Maintenance-free and wear-free motors in 3-phase technology
- OHAS: significant reduction on noise, dissipative heat and LPG handling
- Service (and experience) in host country available
- Economically interesting if LCOE Renewables is below LCOE of LPG
- GHG abatement if PV-powered

Drive motor, power	4 kW
Lift motor	6 kW
Battery capacity	24/500 V/Ah
Energy consumption	2.6 kWh/h
Approx. cost	Reg. CAPEX + 20K USD as of 2020

| Utilization of e-forklifts

Comparison of LPG vs Electric forklifts

Parameter	Unit	LPG forklift	Electric forklift	
			Grid electricity	Photovoltaic
Energy consumption	kWh/h	21,34	3,61	3,61
Fuel consumption	l/h	3,92		
Energy price*	USD/kWh	0,10	0,15	0,09
Annual operating hours	h/a	1.800	1.800	1.800
Annual energy consumption	kWh/a	38.407	6.500	6.500
Annual energy savings	kWh/a		31.907	31.907
Annual energy costs	USD/a	3.839	969	585
Annual cost savings	USD/a		2.870	3.254
Additional CAPEX e-forklifter	USD		20.000	20.000
GHG emissions	t CO_{2e}/a	8,7	4,9	
Annual GHG savings	t CO_{2e}/a		3,9	8,7
Simple payback additional CAPEX	a		7,0	6,1

*Client Data: Weighted average energy price for LPG (based on consumption) and LCoE-PV

Source – JUNGHEINRICH, https://www.jungheinrich.de/produkte/neufahrzeuge/gabelstapler/elektrostapler/efg-110-115-102524

| e-forklifts – Scenario 2025

Comparison of LPG vs Electric forklifts

Parameter	Unit	LPG forklift	Electric forklift	
			Grid electricity	Photovoltaic
Energy consumption	kWh/h	21,34	3,61	3,61
Fuel consumption	l/h	3,92		
Energy price (LPG + 5 %/y / PV declined)	USD/kWh	0,12	0,15	0,06
Annual operating hours	h/a	1.800	1.800	1.800
Annual energy consumption	kWh/a	38.407	6.500	6.500
Annual energy savings	kWh/a		31.907	31.907
Annual energy costs	USD/a	4.666	969	390
Annual cost savings	USD/a		3.697	4.276
CAPEX e-forklifter - 50%	USD		10.000	10.000
GHG emissions	t CO_{2e}/a	8,7	4,9	
Annual GHG savings	t CO_{2e}/a		3,9	8,7
Simple payback additional CAPEX	a		2,7	2,3

*Client Data: Weighted average energy price for LPG (based on consumption) and LCoE-PV

Source – JUNGHEINRICH, https://www.jungheinrich.de/produkte/neufahrzeuge/gabelstapler/elektrostapler/efg-110-115-102524

Mid-Term
DeCarb-Project

| (Electrical) Rapid Steam Generator

Electro steam generator, model E 72 M, with a steam output of 97 kg/h

Fully stainless steel version of an electro steam generator, model E 56 M

- Instant steam generation according to demand (from 3 up to 11 bar)
- Quick reaction for fluctuating steam requirements (8 kg/h up to 160 kg/h) – option for steam cascading
- More efficient than LPG or Natural Gas boilers at lower or no steam consumption (modulation from 40% up to 100%)

Technical details			
Parameter	**Unit**	**E 6 M - E 72 M**	**E 100 M - E 120 M**
Steam output	kg/h	8 - 97	
Heat output	kW	Jun 72	
Electrical connection value	kW	6.8 - 73.8	
Height / Width / Depth	mm	1,850/880/680	1,925/1.005/800
Max. operating pressure	bar	3.5 - 11	5 - 10
Max. perm. overpressure	bar	6 / 10 / 12	6 / 10 / 12
Average equipment price	USD	12,000 - 100,000	

Source – https://www.certuss.com/en/steam-generators/electric-steam-generators

| (Electrical) Rapid Steam Generator

Electro steam generator, model E 72 M, with a steam output of 97 kg/h

Fully stainless steel version of an electro steam generator, model E 56 M

- Instant steam generation according to demand (from 3 up to 11 bar)

Levelized cost of steam - Economic comparison HFO vs Electricity				
Parameter	Unit	HFO	Electricity	
			National Grid	Photovoltaic
Energy content (NCV)	kWh/l	11,2		
Density	kg/m^3	840		
Emission factor (Primary Energy)	$kg\ CO_{2e}/kWh$	0,28	0,712	
Net fuel price	USD/l	0,52		
Net fuel price	USD/kWh	0,046	0,149	0,09
spec. Total Enthalpy of steam (@7 barG)	kJ/kg_{steam}	2.375		
spec. Total Enthalpy of steam (@7 barG)	kWh/t_{steam}	660		
Boiler Efficiency	η	82%	98%	98%
Steam distribution efficiency	%	92%	99%	99%
End energy demand for steam generation	kWh/t_{steam}	874,87	680,27	680,27
Levelised costs of steam (excl. CAPEX)	USD/t_{steam}	40,55	101,36	61,22
GHG emission level	$kg\ CO_{2e}/t_{steam}$	244,96	484,35	0*

Source – https://www.certuss.com/en/steam-generators/electric-steam-generators

Mid-Term
DeCarb-Project

| (Electrical) Rapid Steam Generator – 2025

- Price increase HFO + 5%/y versus declining LCoE-PV

Levelized cost of steam - Economic comparison HFO vs Electricity - 2025				
Parameter	**Unit**	**HFO**	**Electricity**	
			National Grid	**Photovoltaic**
Energy content (NCV)	kWh/l	11,2		
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Emission factor (Primary Energy)	$kg\ CO_{2e}/kWh$	0,28	0,712	
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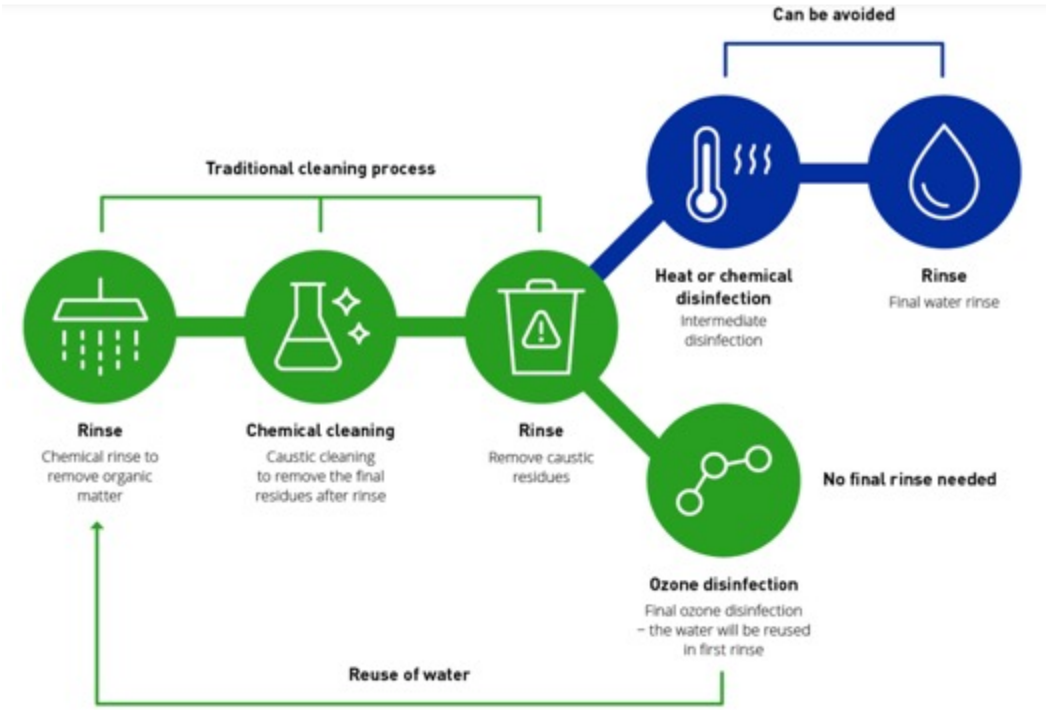
End energy demand for steam generation	kWh/t_{steam}	874,87	680,27	680,27
Levelised costs of steam (excl. CAPEX)	USD/t_{steam}	49,28	101,36	40,82
GHG emission level	$kg\ CO_{2e}/t_{steam}$	244,96	484,35	0*

Source – https://www.certuss.com/en/steam-generators/electric-steam-generators

| Ozone CIP compact system (120x80x270 cm)

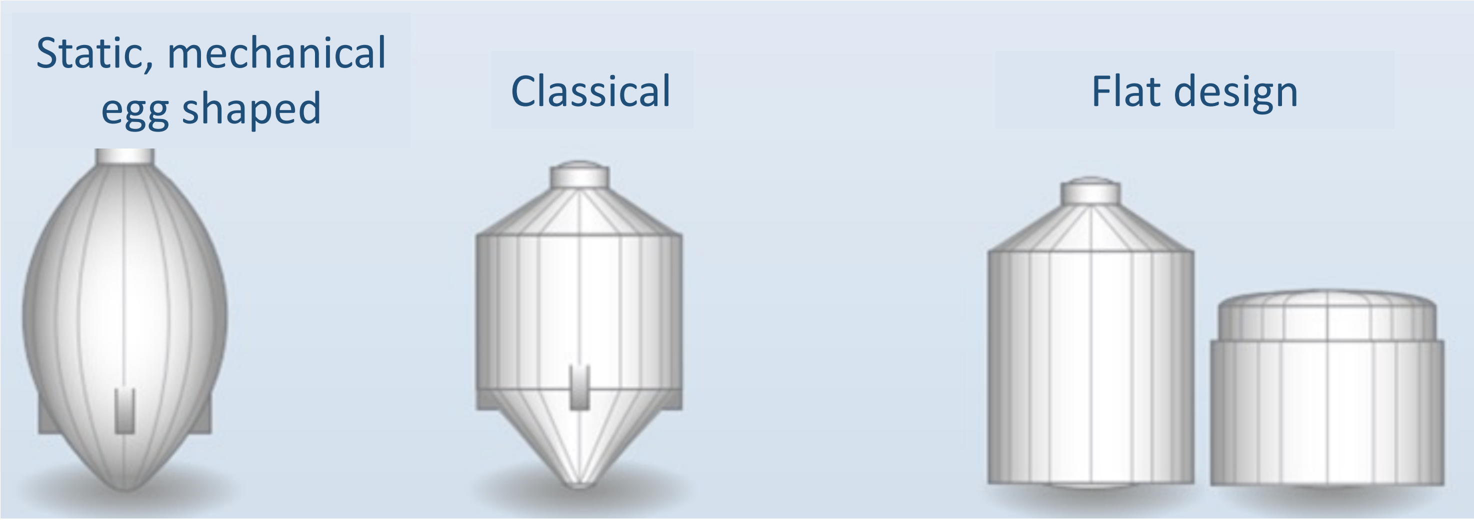
- Cut CIP cycle time by 20-30 minutes due to shorter sanitation and rinse-free operation
- Eliminate all disinfection agents used for treatment or sanitation
- Reduce (HFO-steam based) energy requirements by replacing hot water with cold ozone sanitation
- No handling of chemicals, transport and costs
- Chemical-free feed and process water quality assurance



https://www.ozonetech.com/

Left: RENA Vivo B-series front. Right: RENA Vivo B-series back.

Anaerobic treatment of activated sludge – Example Germany



Different construction design results in different

- CAPEX (800 bis 2.000 EUR/m^3)
- OPEX
- Maintenance

Quelle: Neubewertung von Abwasserreinigungsanlagen mit anaerober Schlammbehandlung vor dem Hintergrund der energetischen Rahmenbedingungen und der abwassertechnischen Situation in Rheinland-Pfalz - NAwaS Modul 2: Weitergehende Untersuchungen

Quelle: Fraunhofer IGB (2012): Abschlussbericht – Voruntersuchungen zur anaeroben Vergärung von Primär- und Sekundarschlamm der GKA Weilerbach

Wastewater treatment

| Increasing biogas production sludge digestion

DM-content	DM-%	Amount [m³/d]	DM [m³/d]	
Primary sludge	5%	118,4	5,9	m³/d
Secondary sludge	5%	341,4	17,1	m³/d
Total	**5,00%**	**459,8**	**23,0**	**m³/d**

oDM-content	oDM-%		oDM	
Primary sludge	67%		4	m³/d
Secondary sludge	70%		12	m³/d

Methane content (based on oI	l_N/kg oDM	Biogas production		Methan-rate %	Methan production	
Primary sludge (54%)	400	1.586	m³/d	60%	952	m³/d
Secondary sludge (59%)	400	4.780	m³/d	60%	2.868	m³/d
Total per day		**6.366**	**m³/d**	60%	**3.820**	**m³/d**
Total per year		**2.100.789**	**m³/a**		**1.260.473**	**m³/a**

Volume of the digester		
Hydraulic retention time	20	d
DM sludge	5,00%	
Volume Sludge	460	m³/d
Volume digester	**9.196**	**m³**

Objective:

Complement UASB reactor with second fermenter for anaerobic stabilization of the activated (primary and secondary) sludge

- 635% biogas production increase from 1.191 Nm³ to 7,557 Nm³ per day
- Follow-up potential

Fossil
Fuel Switch

| Long-Term: net-zero steam production

www.rjt.ac.lk

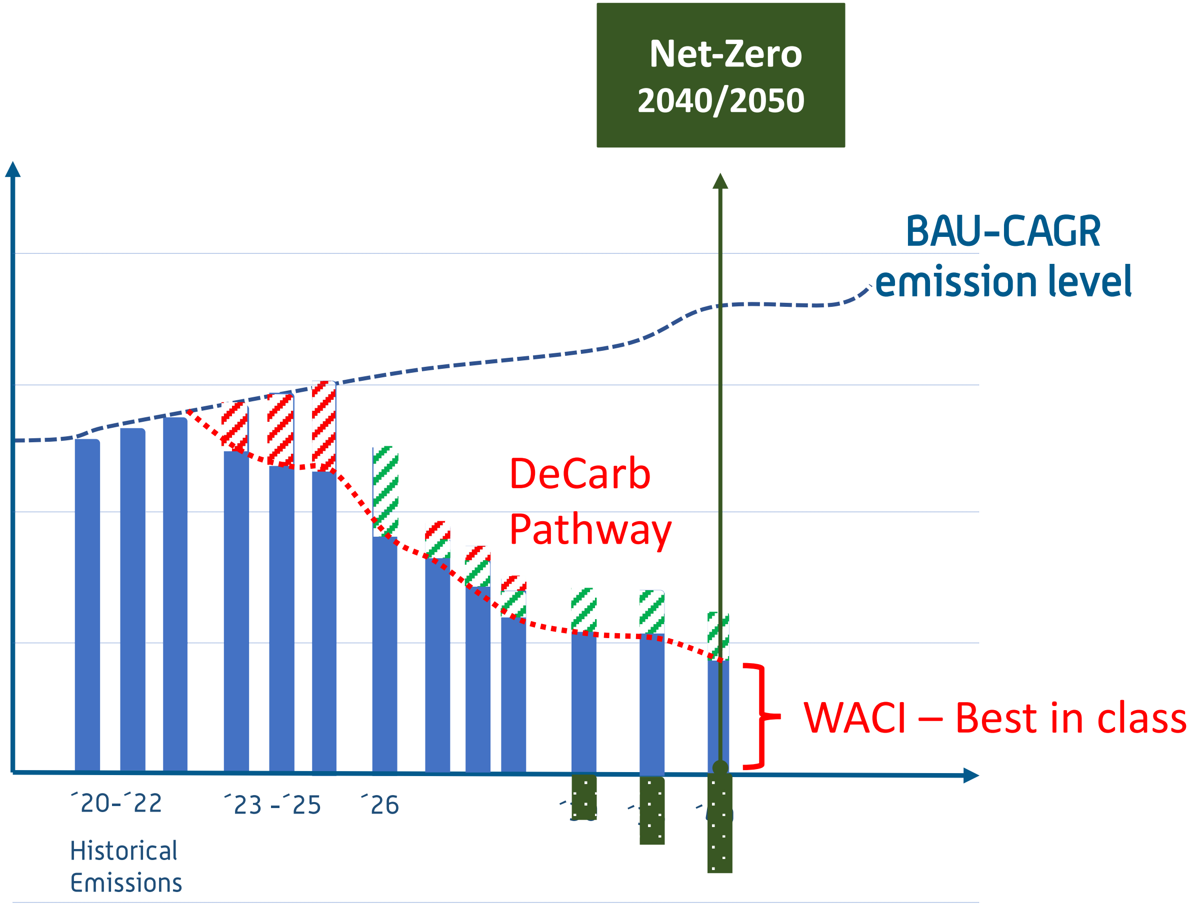
Strategic approach of fossil fuel switch (steam generation):

- Reduction of steam demand (and thermal energy losses)
- Utilising excess heat by auxiliary technologies (Compressed air and ammonia cooling compressors)
- Increasing biogas production and utilisation in bi-fuel boiler
- Acquire new biogenic fuels for existing boilers
- Introduce point of demand e-steam

Final Results

Transformation Pathway 2050

GHG Management | Exemplified net-zero trajectory



2023-25: Production increase & constant WACI

"Must have" efficiency projects reducing WACI and continuous efficiency improvement

Strategic projects:
Expansion of RE (biogas & PV);
Stepwise HFO-steam replacement powered by RE;
Expansion of e-mobility based distribution
Securing carbon removal certificates
Battery based peak load shaving
Green Hydrogen and Wind energy

Start (partly) neutralising GHG (sourcing until 2024) (MAC internal > cost of removal)

Net-zero Transformation

| DeCarbonisation Pathway – MODEL Result

Year	Total production	Total Emissions (Transformation) (Scope 1 and 2)	Weighted average Carbon intensity
	hl	t CO_{2e}/a	kg/CO2e/hl
2021	3,381,724	35,378	10.46
2022	3,514,626	35,543	10.11
2023	3,652,751	34,260	9.38
2024	3,796,304	33,123	8.73
2025	3,945,498	28,024	7.10
2026	4,100,556	28,474	6.94
2027	4,261,708	28,767	6.75
2028	4,429,193	28,690	6.48
2029	4,603,261	28,615	6.22
2035	5,801,111	20,761	3.58
2038	6,512,293	12,564	1.93
2040	7,034,217	12,039	1.71

KPI development of Paris-aligned net-zero pathway:

- CAGR of 3,93% = Double the production until 2040
- Emission base year (2022): 35.543 tCO_{2e}
- **Emission net-zero (2040): 12.039 tCO_{2e}**
- Absolute GHG reduction: 66%
- **Relative GHG reduction: 84%**

  (based on 73.588 tCO_{2e} in CAGR scenario)
- WACI Reduction: 84%
- Annual GHG removal cost saving: 6.921.071 USD

(based on 73.588 tCO_{2e} in CAGR scenario and 581 USD/tCO_{2e} in EIB scenario)

Contribution to SDGs (impact assessment)

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