ICR 2023 Workshop:

Training on clean cooling and heating solutions

Monday 21st August
11:55-12:55
Room 352A

Chaired by Kristina N. Widell, SINTEF Ocean, Norway

Cooling – responsible for 7% of global GHG emissions

- High income countries – actions
  - F-gas regulation
  - PFAS
  - = more clean cooling solutions with **natural refrigerants**

- Low and medium income countries
  - Absens of regulations and initiatives?
  - How is the adoption of **natural refrigerants?**

UN climate priority: Highly efficient clean cooling technologies

Urgent and should be accelerated!

Projects and centers behind this workshop:

ENOUGH
EUROPEAN FOOD CHAIN SUPPLY
TO REDUCE GHG EMISSIONS BY 2050

India-Norway Collaboration 2021-2024

INDEE

Future Refrigeration India:
INDEE+

CoolFish

ACES
Africa Centre of Excellence for Sustainable Cooling and Cold-Chain

Training and education

Natural refrigerants

Presentations

- Armin Hafner:
  - How to select the right natural refrigerant for a specific application
- Silvia Minetto:
  - How to talk about energy efficiency in refrigeration systems
- Alexander Pachai:
  - How to pass on safety practices in refrigeration systems
- Judith Evans:
  - How to communicate the resilience, sustainability, and equity of cold chains in developing markets.

How to select the right natural refrigerant for a specific application

Prof. Dr.-Ing. Armin Hafner

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How to convince the end-user?

- This is your major challenge!

SUSTAINABLE DEVELOPMENT GOALS

3 GOOD HEALTH AND WELL-BEING

6 CLEAN WATER AND SANITATION

How to convince the end-user?

- **Training** and **knowledge transfer**
  - **Understanding** that clean cooling/heating is not at all possible with non-natural working fluids
- **End-user awareness**: inform what kind of equipment they are ordering and become responsible for:
  - Material Safety Data Sheet [MSDS] of the working fluid
  - Seasonal energy demand and total GWP of the working fluid, including production & end of life
  - PFAS…

PFASs → per- and polyfluoroalkyl substances

ECHA
EUROPEAN CHEMICALS AGENCY

ANNEX XV RESTRICTION REPORT

PROPOSAL FOR A RESTRICTION

SUBSTANCE NAME(S): Per- and polyfluoroalkyl substances (PFASs)

- addresses the **risks to the environment and human health** of the use of per- and polyfluoroalkyl substances (**PFASs**) and provides an assessment of the effectiveness, practicability, monitorability and socio-economic impacts of **two restriction options** (ROs) under REACH as the most suitable risk management option (RMO) to address the identified risks.

How to select the right natural refrigerant for a specific application?

Talk and understand what the end-user is looking for.

	CO_2 / R744	NH_3 / R717	HC	H_2O / R718	Air / R729
Domestic applications	☺		☺		
Commercial refrigeration	☺	☺	☺		
Industrial refrigeration and heat pump systems,	☺	☺	☺	☺	
Water and space heating heat pumps	☺	☺	☺		
Chillers	☺	☺	☺	☺	
Vehicle air conditioning	☺		☺		☺

Where to find the technical descriptions:

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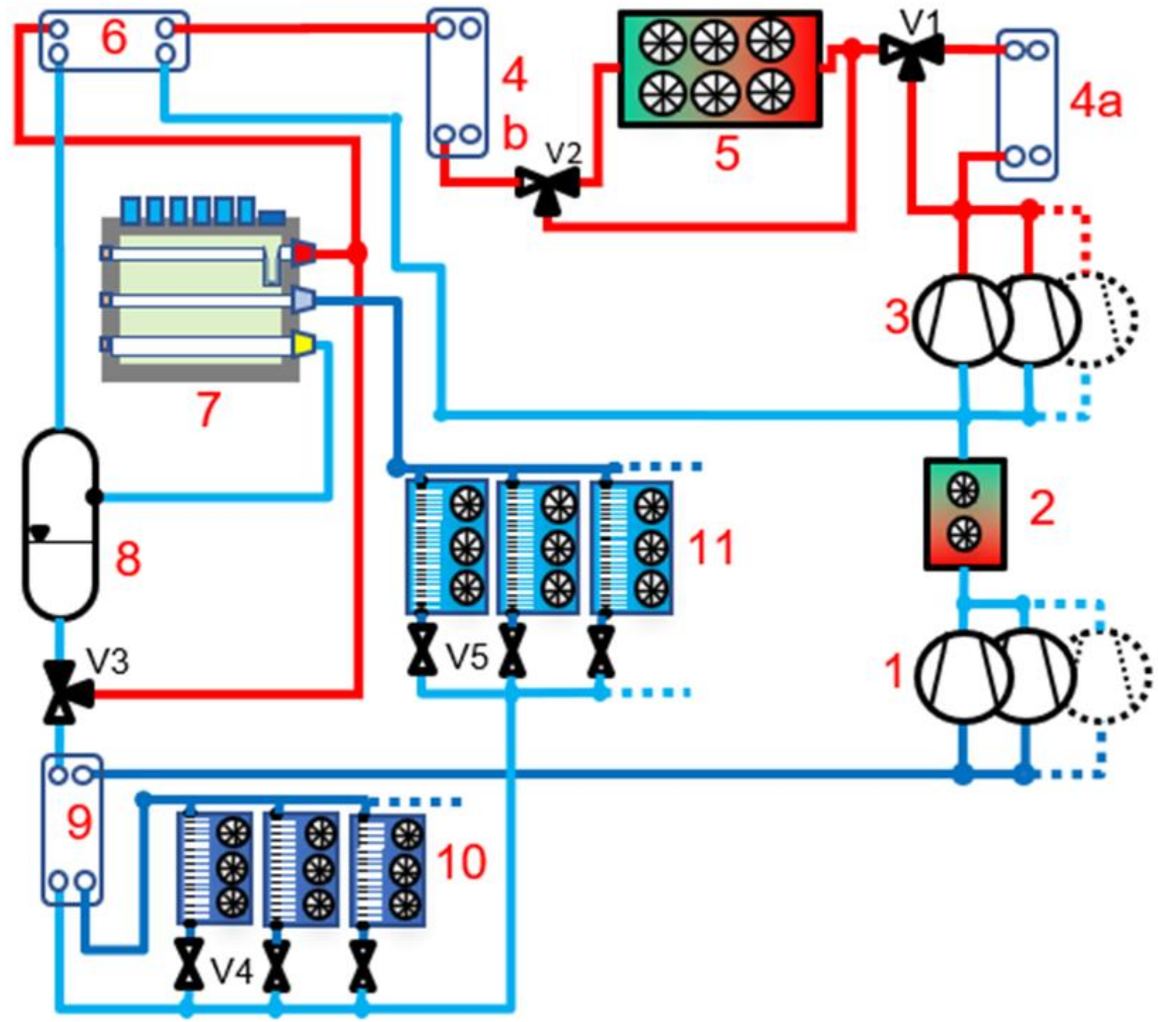
And now some examples:

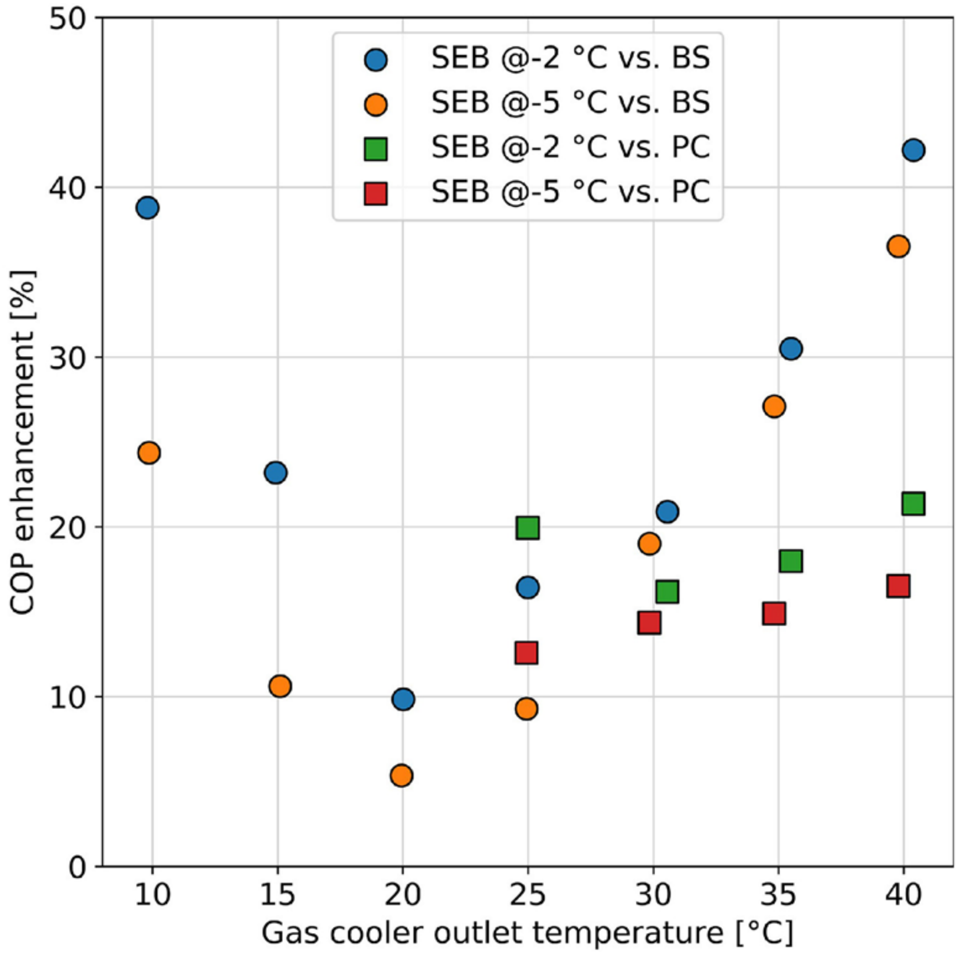
What kind of system* depending on demand?

- Hot water demand (10 -> 75 °C): CO_2 heat pump
- Combined AC (12 -> 7 °C, or DX) and hot water demand:
  CO_2 heat pump chiller
- Industrial freezing av food: CO_2 (-50 °C, DX) NH_3 (-35 °C, DX and indirect)
- Industrial food storage: NH_3 (DX or with CO_2 as a secondary fluid)
- Comfort cooling (AC):
  - Homes: Propane (R290)
  - Trains: CO_2 or Propane (R290)
  - Cars/vehicles: CO_2 or R290
- High temperature heat pumps:
  - District heating: NH_3, CO_2, combined CO_2 and R600 (butane)
  - Industrial units: water (R718), hydrocarbons

* System, with the most energy efficient and sustainable working fluid

Supermarket refrigeration ? (Example R744 / CO_2)

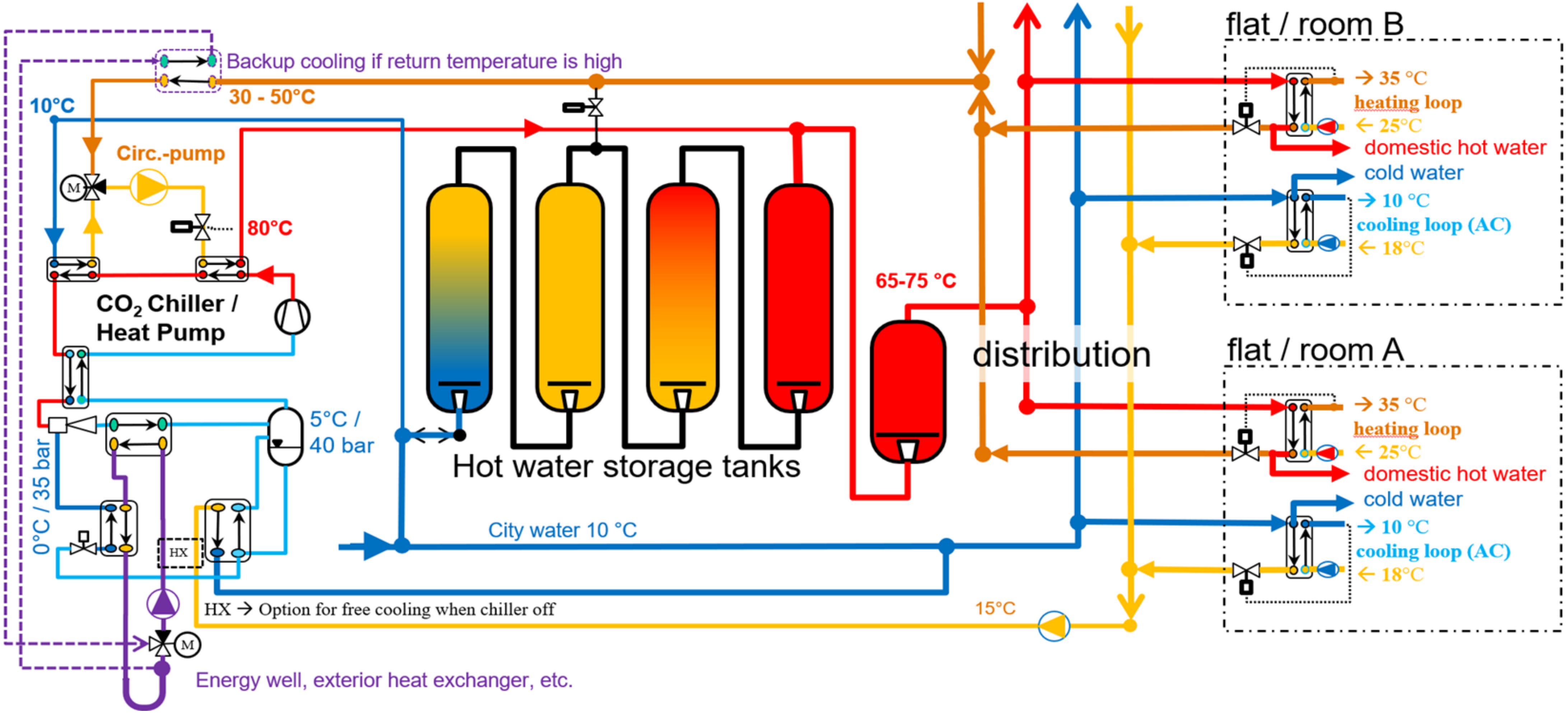




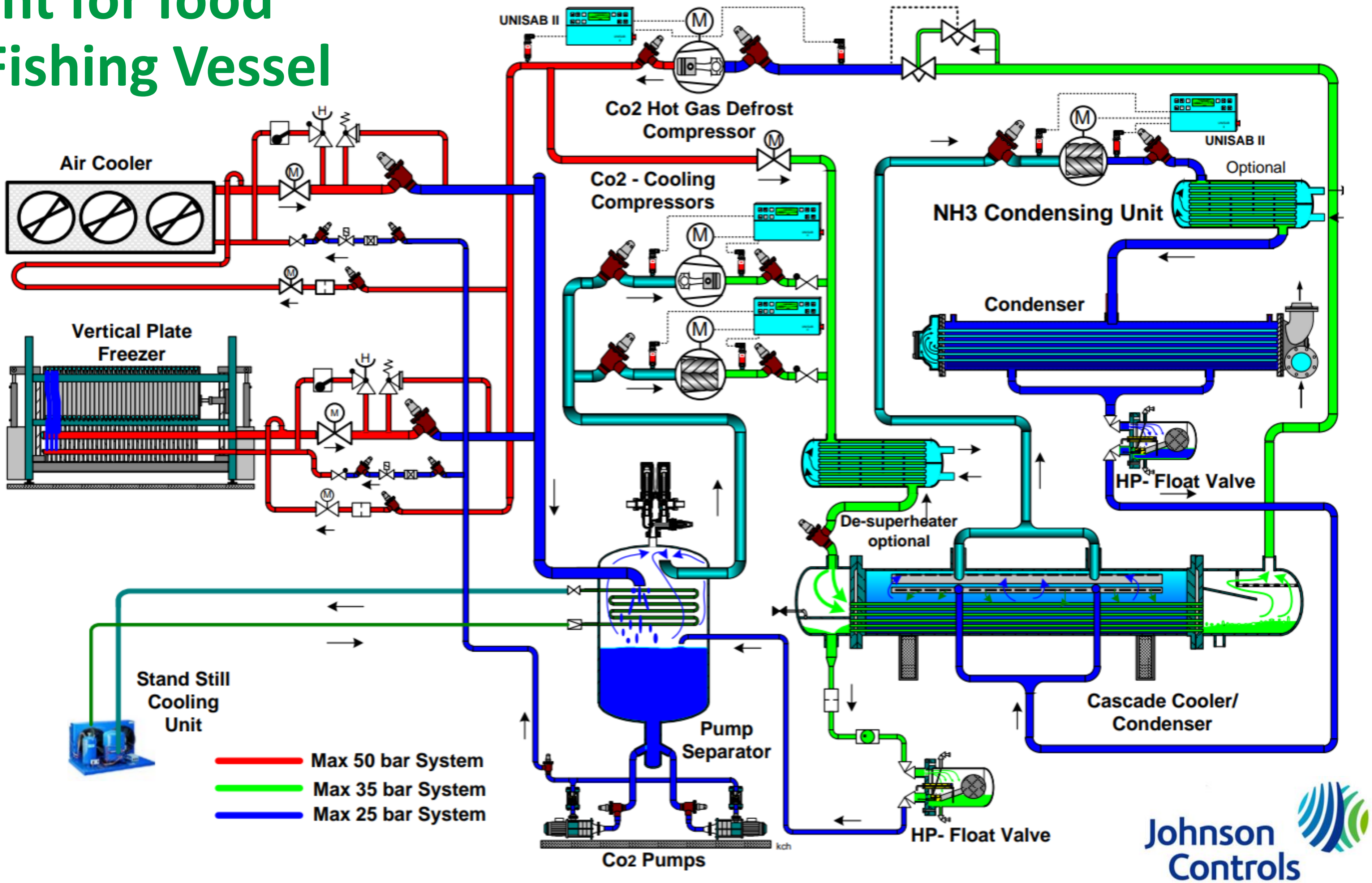
Source: Ángel Á. Pardiñas et al. Next generation of ejector-supported R744 booster systems for commercial refrigeration at all climates, Int. J. Refrig., 2023, https://doi.org/10.1016/j.ijrefrig.2022.10.027

Heating and Cooling for Hotels and apartment buildings

Example: Heat pump Chiller with CO_2



Freezing plant for food
→ inside a Fishing Vessel

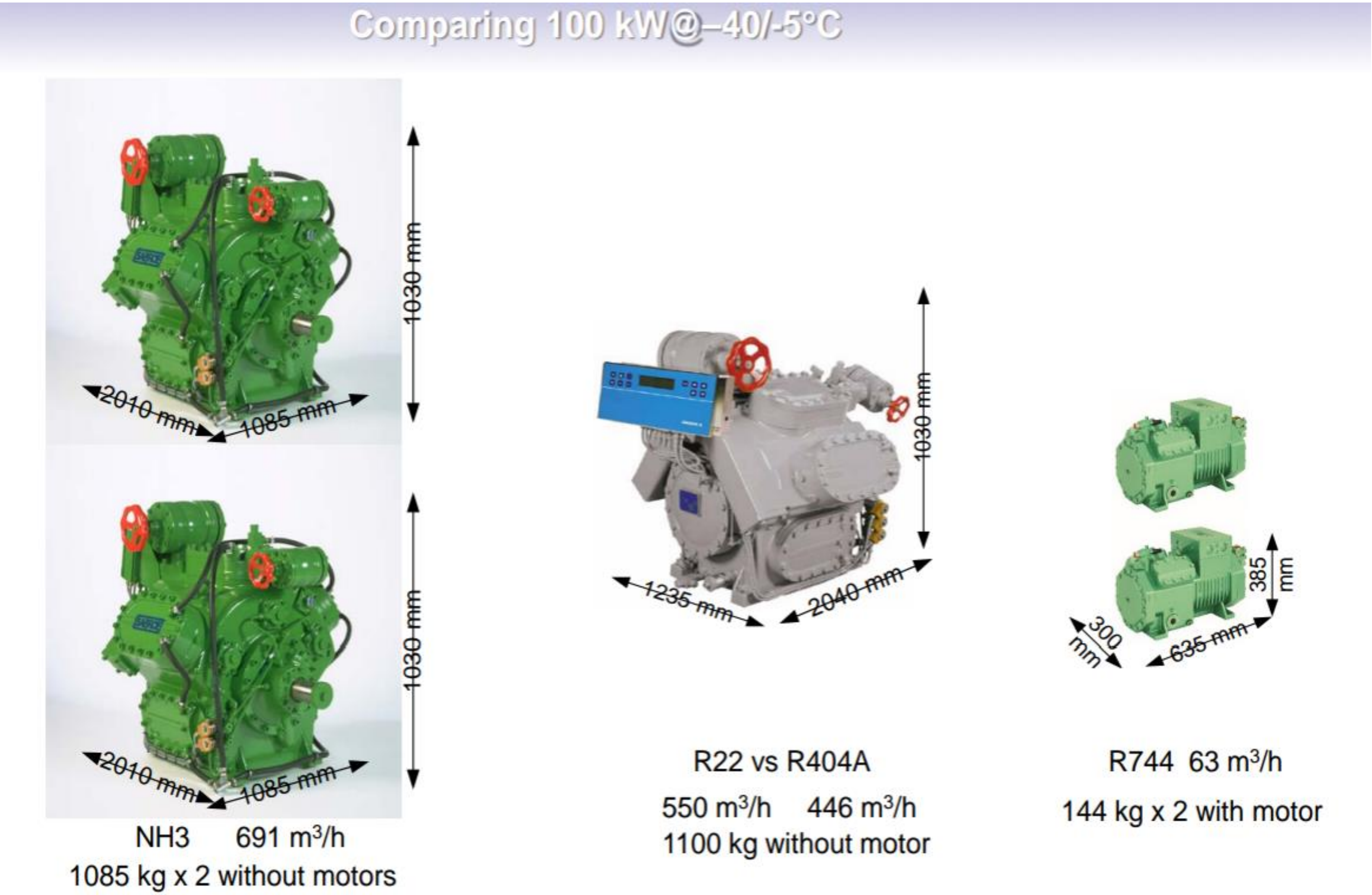


Johnson Controls

Freezing plant for food
→ inside a Fishing Vessel, <u>where size matters</u>

100 kW@–40/-5°C

Data
Suction line [mm]
Discharge [mm]
Liquid line [mm]



Johnson Controls

Freezing plant for food → inside a Fishing Vessel, all CO_2

SuperFreeze

Evaporation temperature: -50 °C

Capacity range: 50 – 500 kW.

KULDE TEKNISK

Split AC unit → R290 is there…

Price / Energy Efficiency Analysis of 52 Offered 3.5 kW Inverter Split-AC Models in German Retail (Online Research, October 2021)

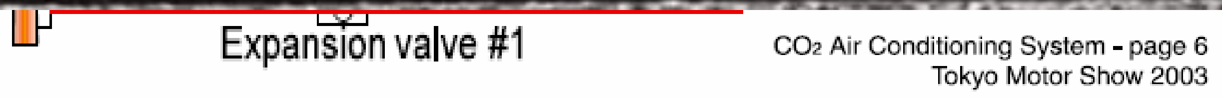
Midea
https://www.midea.com › dam › inverter-ac › S..

Safety Instruction (R32+R290)

Table.1-2 **Min. Room Area (m^2)**

Refrigerant Type	LFL(kg/m^3)	Installation Height H0(m)	Charge Amount in kg Minimum Room Area (m^2)						
R32	0.306		1.224kg	1.836kg	2.448kg	3.672kg	4.896kg	6.12kg	7.956kg
		0.6		29	51	116	206	321	543
		1.0		10	19	42	74	116	196
		1.8		3	6	13	23	36	60
		2.2		2	4	9	15	24	40
R290	0.038		0.152kg	0.228kg	0.304kg	0.456kg	0.608kg	0.76kg	0.988kg
		0.6		82	146	328	584	912	1541
		1.0		30	53	118	210	328	555
		1.8		9	16	36	65	101	171
		2.2		6	11	24	43	68	115

Mobil AC and heat pump system for vehicles



How to accelerate phase-in of clean cooling units applying Natural Working Fluids globally?

World Bank, Multilateral funds, national governments and funding programs should support end-users (investors) to cover additional first costs for cooling units applying natural working fluids with affordable loans following the unit. So, the **end-users (operators) can return the debt during the operational phase.**

Investment in clean cooling/heating is often ‘killed’ by slightly higher capital expenditures (CapEx) for new energy efficient NWF systems.

However, these units give significant operation expense (OPEX) savings for the operator.

Summary

- **Food is valuable** and essential for humankind

  → safe and reliable refrigeration equipment is needed to reduce food loss
- **Safety at work** is also important for responsible companies
  - Nobody should become sick due to refrigerants
  - Natural refrigerants are a safe choice
- **Environmental impact** of major importance
  - Only **natural working fluids will survive** towards 2050 (2030?)
  - Great energy efficiency improvements can be achieved
- Let's cooperate and focus on clean cooling

Conclusion

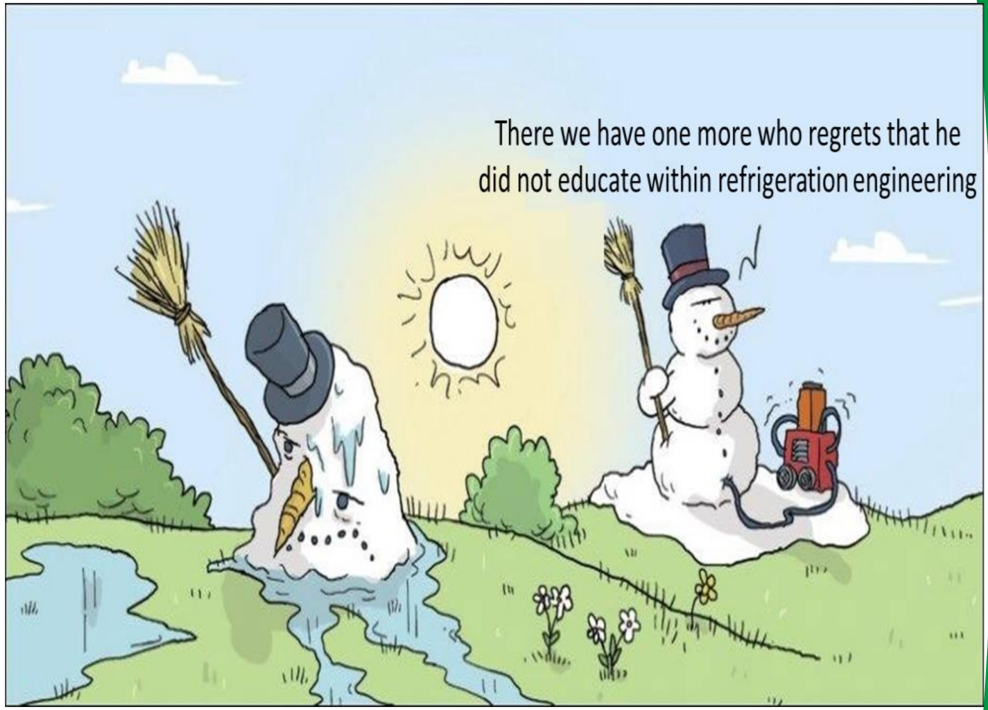
From 2023 on, reminded by the PFAS restriction proposal,

there should be now doubt that **our sector must leave the artificial refrigerant chapter**, the sooner the better.

How dare you to continue jeopardizing the ground water sources, food, and health!

Take home message

- Together – lets cooperate and exchange knowledge
- Let's keep it cool – don't waste food
- Keep it all natural



THANK YOU FOR YOUR ATTENTION
Questions are welcome?

How to talk about energy efficiency in refrigeration systems

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What is energy efficiency?

Energy efficiency relates the desired result with resources used to get it

“**Doing more with less**” (EU, 2005)

“ F**irst fuel** ”, the fuel that you do not need to use

Figures in refrigeration

C.O.P. Coefficient of Performance relates the useful effect to the input

2nd law efficiency is a powerful mean of comparing the actual work needed to provide a certain useful effect to the ideal one; it also allows to identify major losses, but it is not widespread in the sector

What are the benefits of energy efficiency?

Energy savings (reduction in energy consumption: spend less to get the same result)

Lower environmental impact (reduction in greenhouse gases and other pollutants)

Energy security (less dependency on imported energy)

and

Reduced energy costs

Increased economy competitiveness and job creation

What about refrigeration?

Useful effect in refrigeration **not always clearly definable**, as it also involves "quality", like product quality/safety or comfort

Many **EEI**, to take care of **specific services** provided and **boundaries** and to promote **fair** comparison

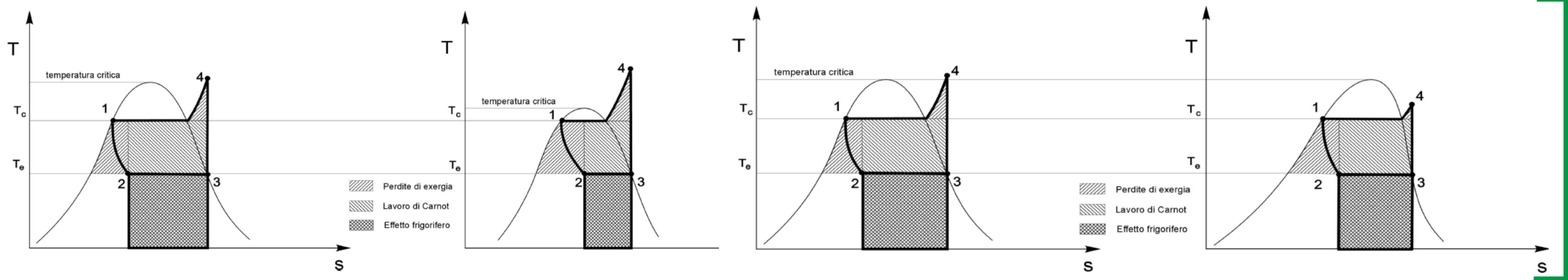
Real demand for selecting the **best option amongst different systems**, especially when new/renewed solutions come to the market to comply with sustainability goals

How to define a « **fair** » comparison in terms of energy efficiency and how to handle it?

Present long term options: natural refrigerants

Present **long-term sustainable options** for VCC refrigeration are **NH_3, CO_2, HC**

Intrinsic losses are in favour of high critical temperature fluids (throttling) and high mass ones (desuperheating)- **Improved cycles** are required to **mitigate**



But many **other refrigerant properties** impact on efficiency

Technological aspects (components size, design, components performance etc),

safety and actual applicability must be considered

Ref: Corradi, 2004, Analisi teorica e sperimentale di sistemi frigoriferi operanti con CO2, PhdThesis, Padova University

Comparison basis

Finding **the right basis** is a key for comparison

- What is the right temperature approches and differences when comparing a subcritical and transcritical cycle? (NH_3 or HC vs CO_2)
- What is the right temperature difference in refrigerant/secondary fluid heat exchangers when comparing DX/direct heat rejection systems (CO_2) to secondary fluid systems (NH_3)
- What is the right temperature difference in evaporator/condenser cascade systems when comparing cascade (NH_3/CO_2 or HC/CO_2) to double stage systems (CO_2 or NH_3)?

Message:

It is very difficult to find homogenoues boundaries for comparison

What happens out in the field may be much different from what is expected. Always cross check assumptions with real data

Unconventional solutions

The need for improving efficiency should stimulate development of **innovative solutions** or borrowal of technologies from other sectors

Example:

Revolution in **DX multiple evaporator system feeding** with transcritical CO_2:

Superheat removal allows for 4-5 K evaporation temperature increase in commercial refrigeration (COP increase up to 15%)

Message: efficiency seek stimulates out of the box solutions

Non-technological barriers (social, behavioural, legislative) to be addresses

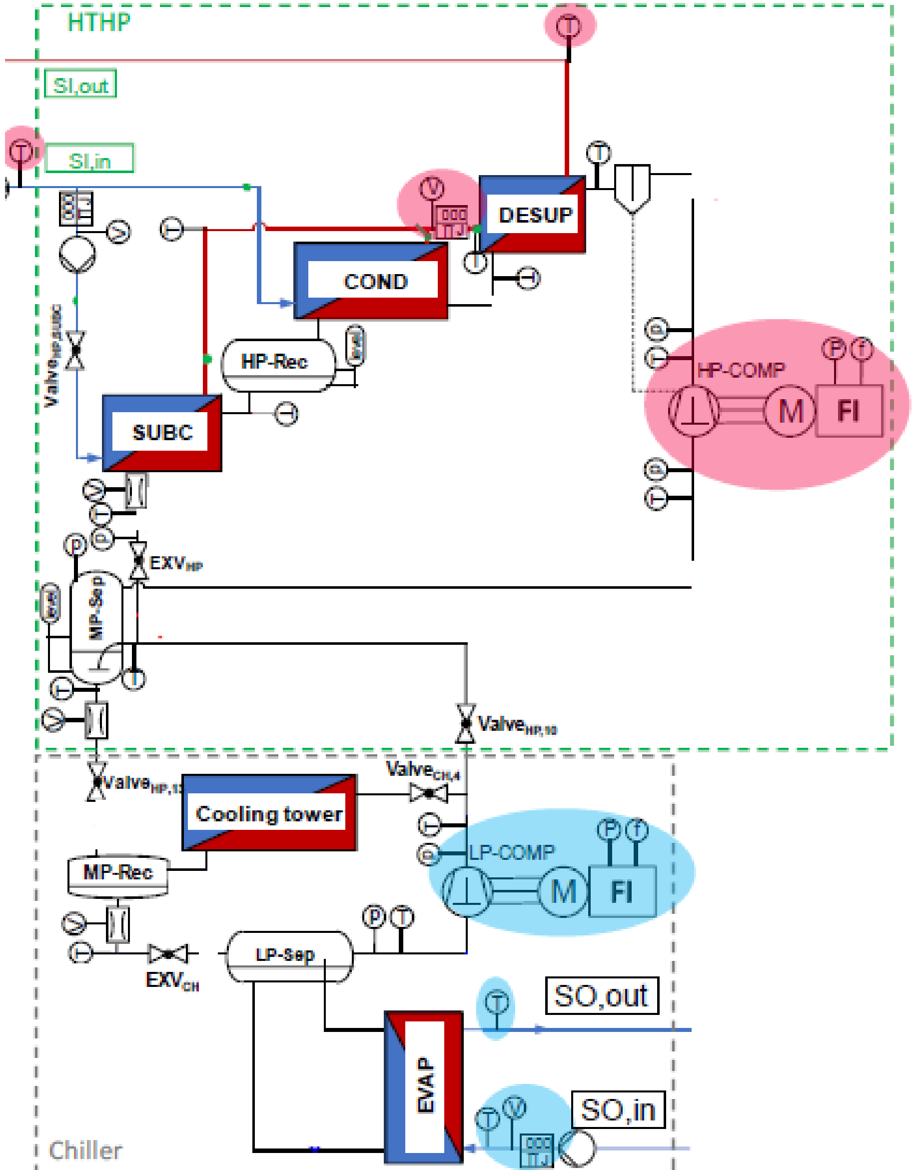
Adequate regulation for innovative solutions

Select proper domaine for efficiency calculation

Example:

NH_3 Chiller and NH_3 HTHP developed within ENOUGH project. Useful effets: hot and cold water

Measurement of individual and total COP and PF, under steady state and transient operations



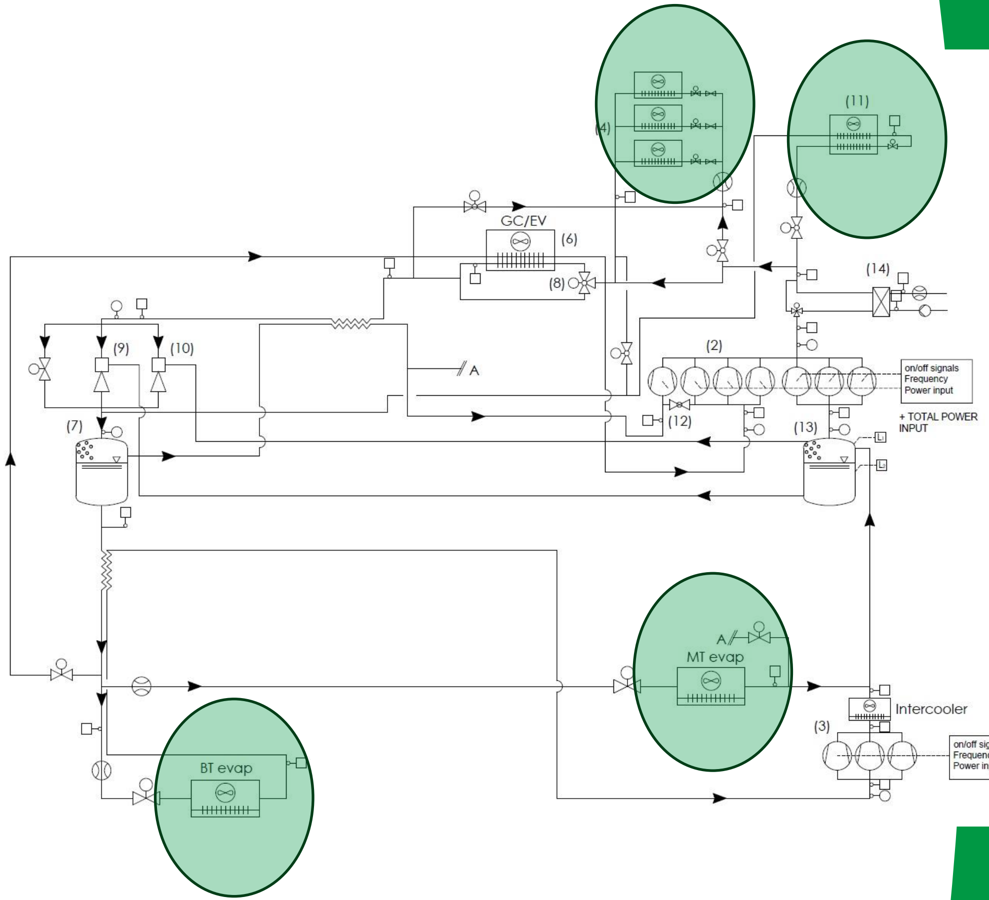
Select proper domaine for efficiency calculation

Example:

Integrated CO_2 supermarket system

Useful effects: MT and LT refrigeration, space heating, space cooling and DHW

Measured annual specific energy consumption 25% lower than average national (Italy) value



Message: exploit fluid properties and adapt lay-outs to **integrate/invent** services.

Identify suitable EEI to benchmark the system

multi PACK

Overcome behavioural habits

Some **constraints** come from previous technologies and less sustainable approaches

Critical **revision of habits and usual approches** to check if more sustainable working conditions are possible

Example:

when using traditional fossil fuel burners, water delivery temperature is tycally 80°C

Do we need this temperature? Is there any chance to decrease the average temperature to promote heta pumps?

> **Message**: use the need for more sustainable technical solutions to **revise traditional approaches** and **explore new possibilities** to provide the same (or better !) service with less

Conclusion

- Within a limited number of options (natural refrigerants), **boundaries** (safety, space, size, weight, components availability, cost, service, etc…) **are relevant** for selecting the right fluid
- Efficiency is not limited to a single « number » but must **account for services** and **direct and indirect** benefits. **Additional services** might be discovered with natural fluids
- **The best** out of each fluid must be taken, **exploiting its peculiarities** and accounting for all benefits in the efficiency calculation

Conclusion

- **Not just try to target the reference «high GWP old technology»** but achieve high efficiency, satisfactory service and overall benefit
- Efficiency determines **operational costs**…to be reminded when investing on a new system

We do not need to set a one-to-one comparison….we need to find the best long-term sustainable efficient solution for our needs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 101036588

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How to pass on Safety Practices in refrigeration systems

- Alexander Cohr Pachai
- ACP Global Consultancy ApS, Denmark
- Alex.Pachai@gmail.com

Accidents or incidents – a few words

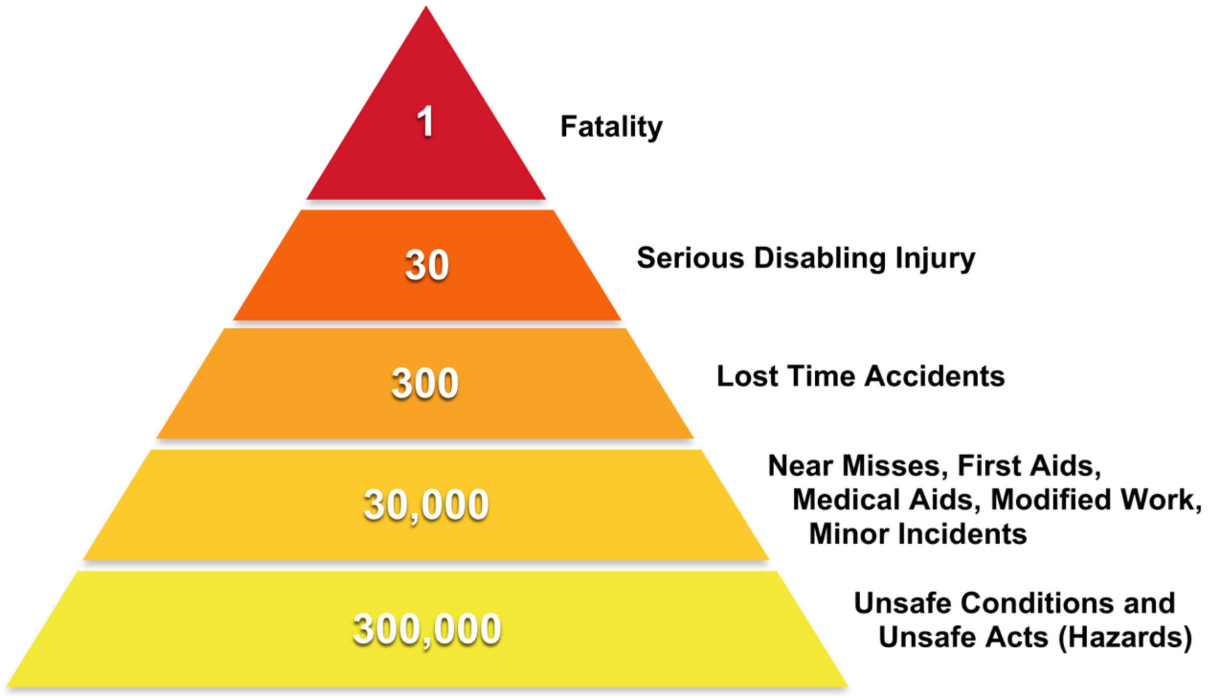
- The incidents are caused due to 3 broad reasons
- a) Technical glitch b) Human Performance c) Missing barrier

- Heinrich´s Theory:
- 1) Behind every accident there is a cause
- 2) Accident don’t happen but they are caused
- 3) 78% of accidents cause due to unsafe act
- 4) 20% of the accidents are due to unsafe condition

Different ways of estimating the risk

SAFETY PYRAMID

It is far better to be reporting and learning from Near Misses, Minor Incidents and Hazards, where there is little or no loss, than to be reporting actual serious losses.



Heinrich´s triangle

Accidents and safety

The most common accident

Avoid distraction

Safety of the system – a short conclusion

- Following standards, guidelines and codes of good practice has reduced the number of accidents
- Some accidents happen when technicians are not properly trained and informed
- Updates from suppliers must be made available also to staff in the field
- Lessons learned by others should also be discussed at meetings in the company
- Finally: A more open culture about risks and near miss situations if we want to pass on safety culture to the coming generations

Thank you for your attention

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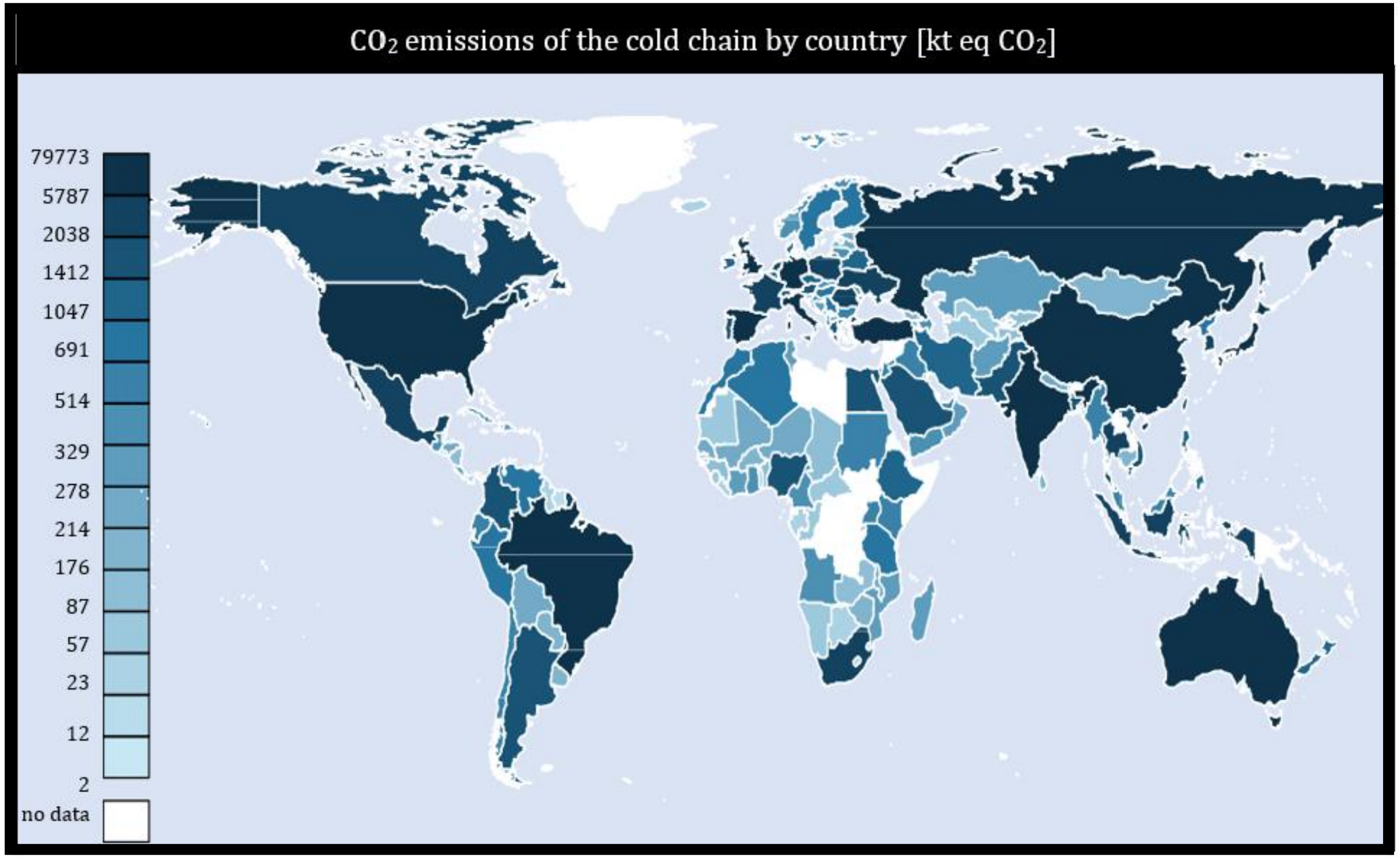
How to communicate the resilience, sustainability, and equity of cold chains in developing markets

Prof. Judith Evans, LSBU

EST 1892 LSBU

Emissions

- ✓ 26-35% of global greenhouse gas emissions are a result of food and agriculture[1]
- ✓ ~18-29% of these emissions are related to the food supply chain (the remaining proportion is related to land use, crop and animal production)[2]
- ✓ 9–14% from crop and livestock activities within farm gate
- ✓ 5–14% land use and land-use change including deforestation and peatland degradation
- ✓ 5–10% from supply chain activities (includes GHG emissions from food loss and waste)[3]
- ✓ Total carbon emissions from the global cold chain ~1,265 Mt CO_2eq[4]



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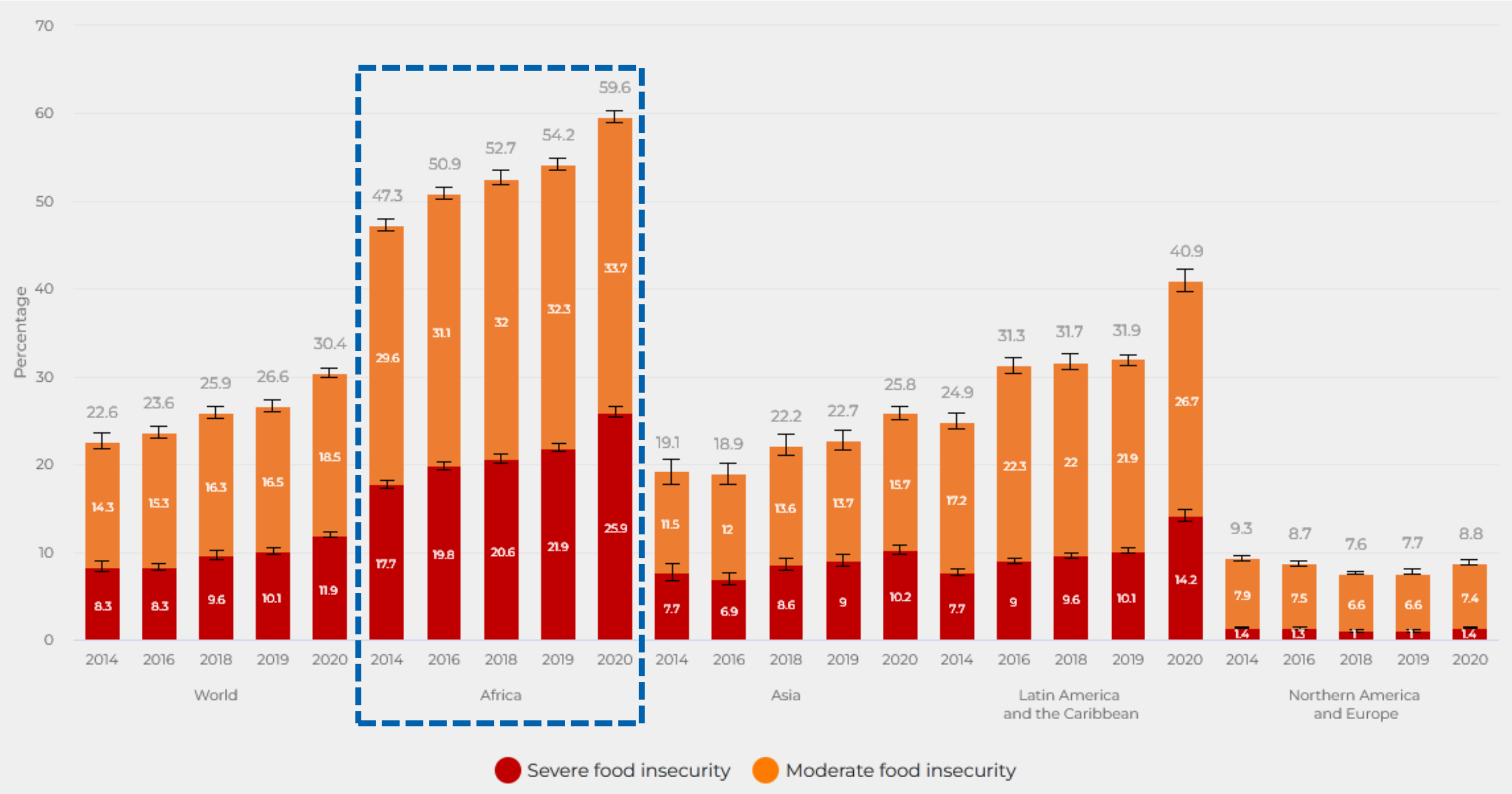
1. Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. Science, 360(6392), 987-992.
2. Crippa, M., Solazzo, E., Guizzardi, D. et al. Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food (2021).
3. IPCC special report on climate change and land, 2019.
4. IIR. The carbon footprint of the cold chain, 7th Informatory Note on Refrigeration and Food.

Food security

- ✓ Food security
  - ✓ United Nations' Committee on World Food Security definition: 'All people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life'
- ✓ Food loss
  - ✓ 13 % of the food produced in the world lost because of a lack of refrigeration (estimated >475 million tons)
  - ✓ In sub-Saharan Africa, ~37% of ALL food is lost
  - ✓ Lack of pre-cooling estimated to account for nearly 50% of these losses
- ✓ Food safety
  - ✓ According to WHO, almost 1 in 10 people contract foodborne diseases every year
  - ✓ 420,000 deaths, including 125,000 children <5 years, African and SE Asia highest burden

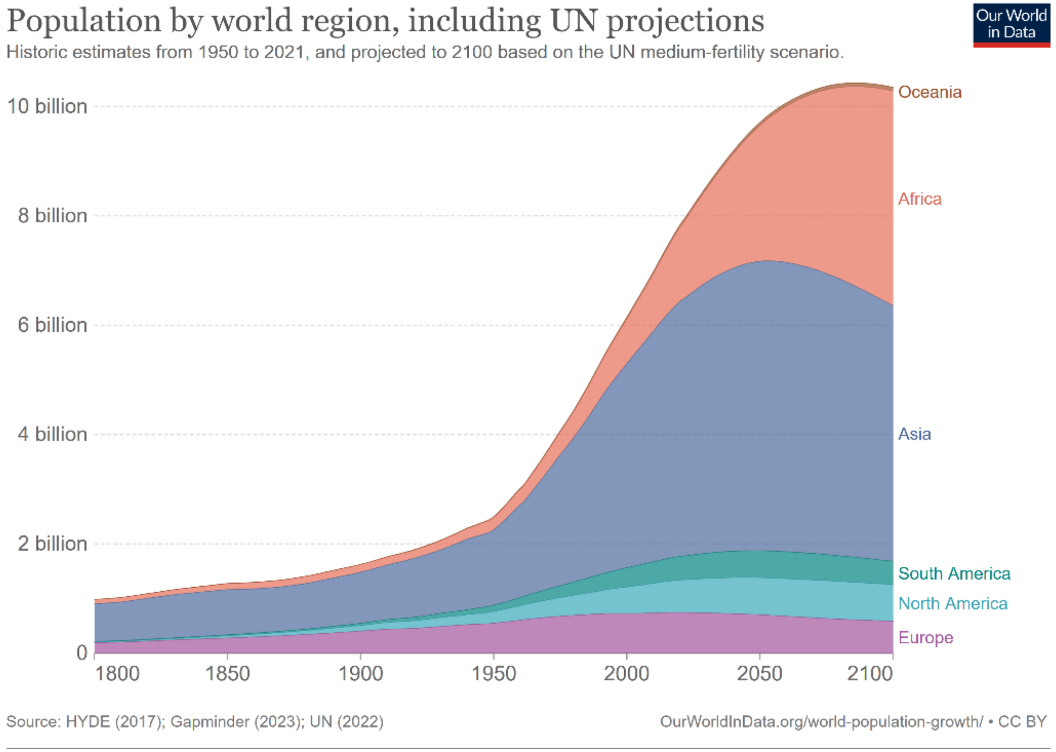


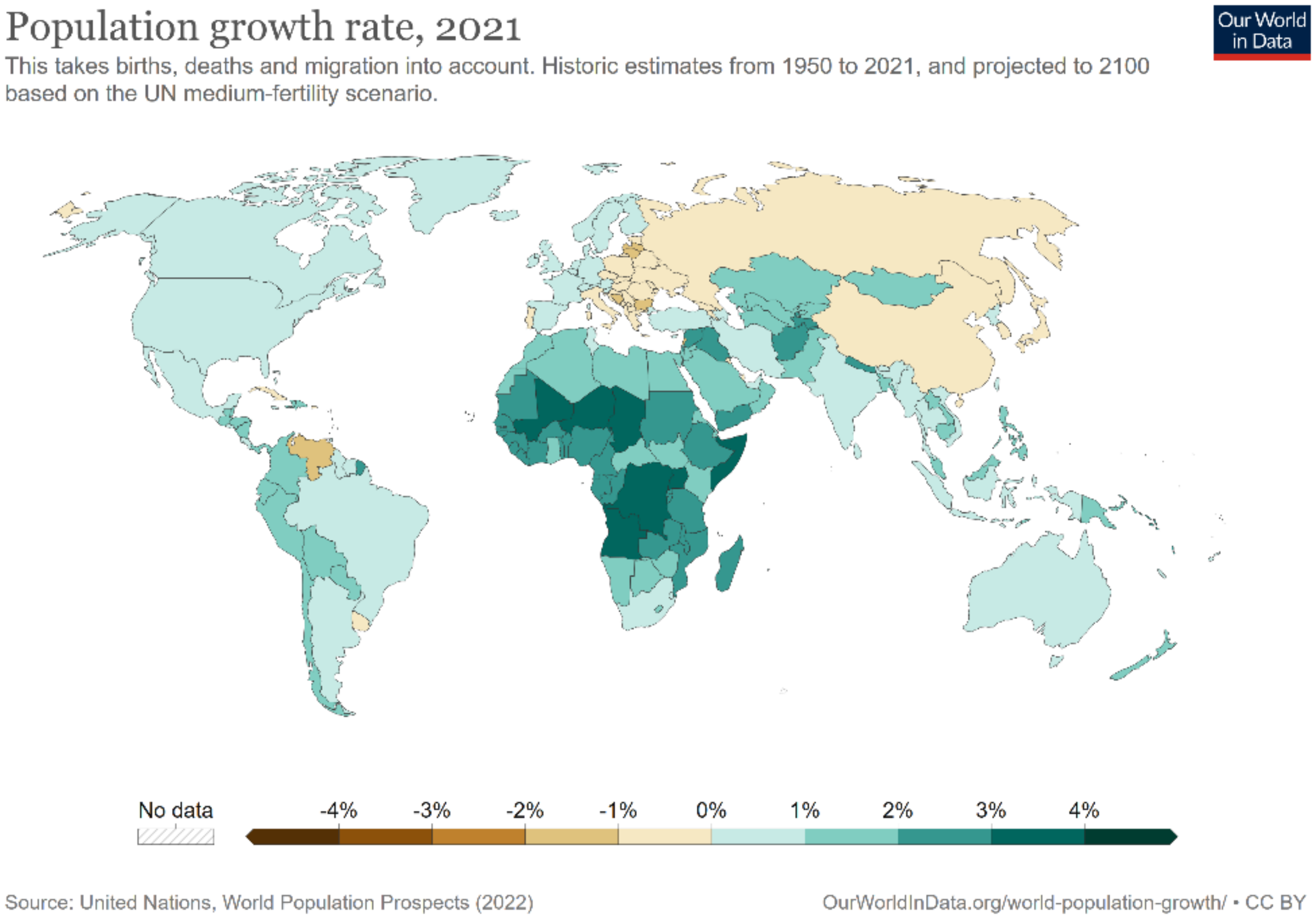
IIR. The Role of Refrigeration in Worldwide nutrition (2020), 6th Informatory Note on Refrigeration and Food.

https://www.fao.org/state-of-food-security-nutrition/2021/en/

Population growth

- ✓ 8 billion in 2022
- ✓ Predicted to increase to 10.4 billion by 2100
- ✓ Differences between regions

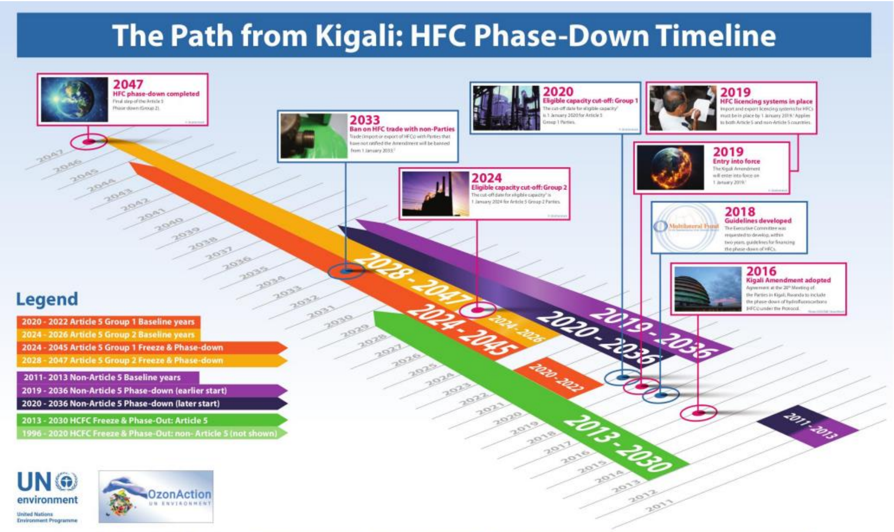




Growth is in areas where there is least cold chain development and greatest food loss

Challenges

- ✓ Some technical:
  - ✓ Design of equipment
  - ✓ Use of pre-cooling
  - ✓ Refrigerants
- ✓ Fragmented nature of agricultural land-holdings
- ✓ Resources (land, water, energy, human capital/skills)
- ✓ Business models - models used in more industrialised countries may not always be successful in LMIC
- ✓ Funding - lack of access to finance
- ✓ Knowledge in post-harvest biology and technology, leading to food loss and waste, technical skills to operate and maintain facilities
- ✓ Lack of appropriate training
- ✓ Global warming



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What are we doing: ACES

- ✓ **Develop, test, demonstrate and deploy fit-for-market pathways to net zero cold-chain and cooling at scale in Africa**
- ✓ Economically empower farmers and fisheries, increase export revenues, enhance job creation in rural areas
- ✓ Improve nutrition, healthcare and quality of life
- ✓ Mitigate climate and environment impacts and foster low-carbon development
- ✓ Exchange lessons learned via a hub-and-spoke model
- ✓ Also working in India (Haryana and Telangana)

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Facilities

- ✓ 4.8 hectare Kigali: Rubirizi Campus - ACES HQ
- ✓ Demonstration hall
  - ✓ Chilling (air, vacuum)
  - ✓ Freezing
  - ✓ Storage rooms
  - ✓ CA rooms
  - ✓ Environmental room
  - ✓ Vehicle testing space assigned
- ✓ Solar powered cold room
- ✓ Refrigeration training facility
- ✓ Telemetrics lab
- ✓ Conference facilities
- ✓ Supporters area
- ✓ Offices
- ✓ Incubation facilities
- ✓ 200 hectares next to Rubirizi for ACES model smart farm – fully integrated farm-fork

Rubirizi campus

Model farm

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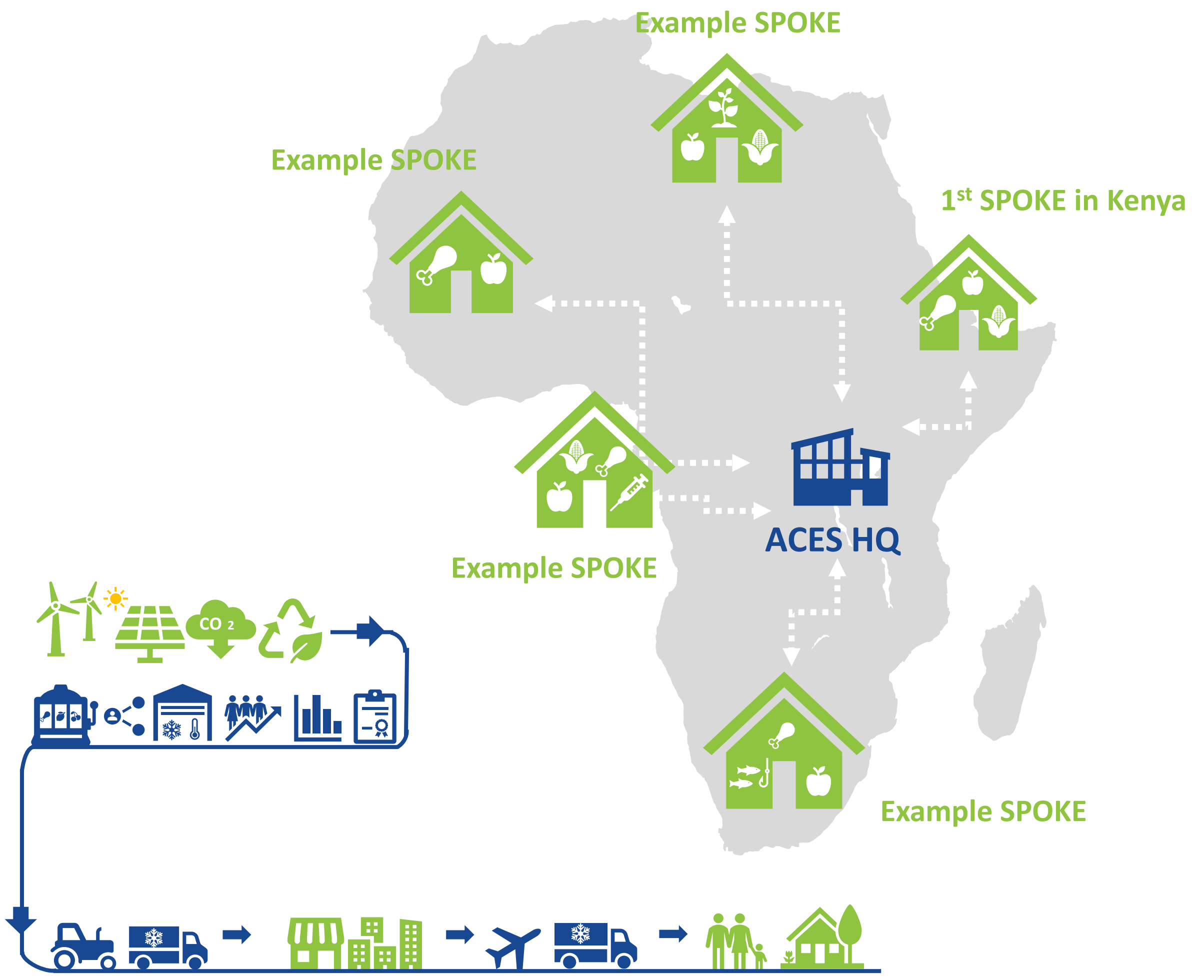
ACES “Hub and SPOKE” approach

- ✓ Specialized Outreach and Knowledge Establishments (SPOKES) deployed in strategic locations as real-world applications
- ✓ Specializing in particular needs and opportunities for local markets
- ✓ Fixed and mobile assets – holistic and integrated system approach
- ✓ Provide technical assistance, demonstrations and knowledge transfer
- ✓ SPOKEs in Kenya, Rwanda, proposed Senegal, Lesotho, Nigeria
- ✓ Try before you buy



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Training

- ✓ Absolutely critical to develop cold chain
- ✓ Flagship programme support development of business models and access to finance
- ✓ Covers:
  - ✓ Needs assessment
  - ✓ Specification, design and commissioning of facilities
  - ✓ Operation
  - ✓ PHM
  - ✓ Finances
  - ✓ Developing a business plan

FIVE PILLARS				
I	II	III	IV	V
Comprehensive flagship programme for farmer co-operatives	Business accelerator	Individual Modules and academic short courses building out to MSc	Refrigeration engineers	Train the trainer
Industry body accredited professional courses and certifications				

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Whole-system approach is essential

Enable farmers and companies to deploy sustainable cold chain solutions at scale with fit-for-market technologies and business models

Research Centre

R&D on comprehensive food and vaccine cold-chain solutions

- Future-proof, localised solutions for food loss and supply chain resilience
- Specifications and best practices for refrigeration, pack houses, logistics, etc.
- Integration of renewable energy, e-logistics and other advanced solutions
- Assess market gaps, leverage data acquisition and modelling capabilities
- Collaborative research

Technology Hub

Develop, test and demonstrate best available technologies

- Demo hall, SPOKES, TBYB

Business Incubator

Deploy solutions and increase market connectivity and uptake

- Implement sustainable business models
- Foster linkages between entrepreneurs, investors, agri-businesses
- Encourage use of standards and certifications

Knowledge Hub

Enhance capacity and raise awareness of rural communities

- Capacity building in the field for farmers and technicians
- Training and skills (inc. installation and maintenance)
- Skills development and innovation support for students and start-ups
- Disseminate key findings, exchange learning, orchestrate communications campaigns on benefits of sustainable cold chain

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Contact

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[ACES Webpage]

Find out more:
Industry flyer
General flyer

Closure & how to get more information?

- enough-emissions.eu
- www.sintef.no/en/projects/2019/coolfish
- https://www.ntnu.edu/indee
- https://coolingafrica.org/
- https://www.sustainablecooling.org/

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THANK YOU !

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