ENOUGH

EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

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Opportunities for decarbonisation: how are these applied in the real world?

Silvia Minetto

National Research Council (Italy)

ITC

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ENOUGH DEMONSTRATION CAMPAIGN

Overall Objective: Demonstrate promising **technologies** and improve their performance in **real-life situations**

- ENOUGH project develops and showcases innovating and advanced (TRL5-TRL7) technology demonstrators to achieve neutral carbon food business

21 Demo cases in operation

All demonstrators represent real life chances to decarbonise the food chain and **provide evidence** on how to reduce emissions

PILLARS BEHIND SELECTED TECHNOLOGIES

INTEGRATE AND OPTIMIZE ENERGY FLOWS

INCREASE ENERGY EFFICIENCY

ELIMINATE FOSSIL FUELS AND INCREASE RENEWABLES

IMPROVE PROCESSING AND PRESERVATION CONDITIONS

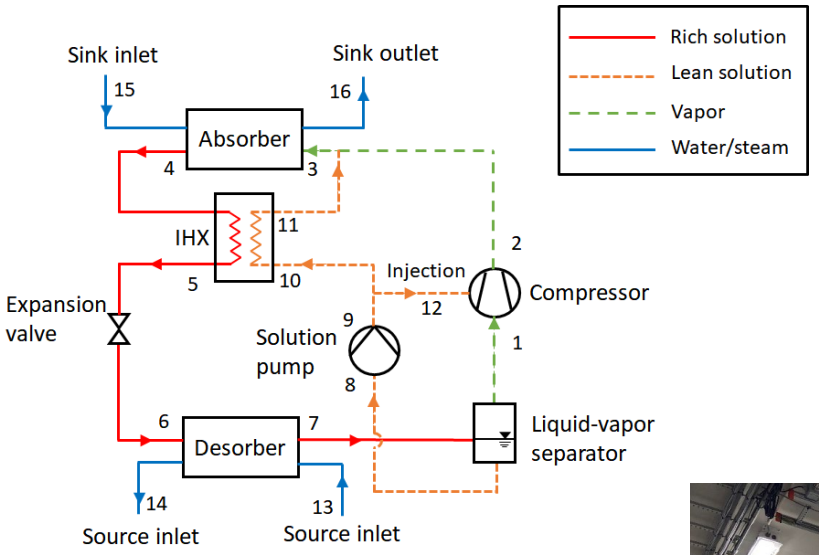
REDUCE FOOD WASTE

USE NATURAL WORKING FLUIDS and MATERIALS

DEMO MATRIX

		Meat	Fish	Dairy	Fruit&Veg	Other
Processing		D14	D15,18,20	D2,3&4		
Transport	D7&8				D6	
Storage&Retail	D9,10,11,16&19				D5	
Domestic	D12&13	D17				
Other					D1,D21	

HIGH TEMPERATURE HEAT PUMPS



Pressurized **water @110°C**
100% natural refrigerant
Reduced CO_2e emissions by up to 87.3% and 46.8% for the Norwegian and European electricity grid scenarios (vs gas boiler)

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ACHP FOR STEAM PRODUCTION

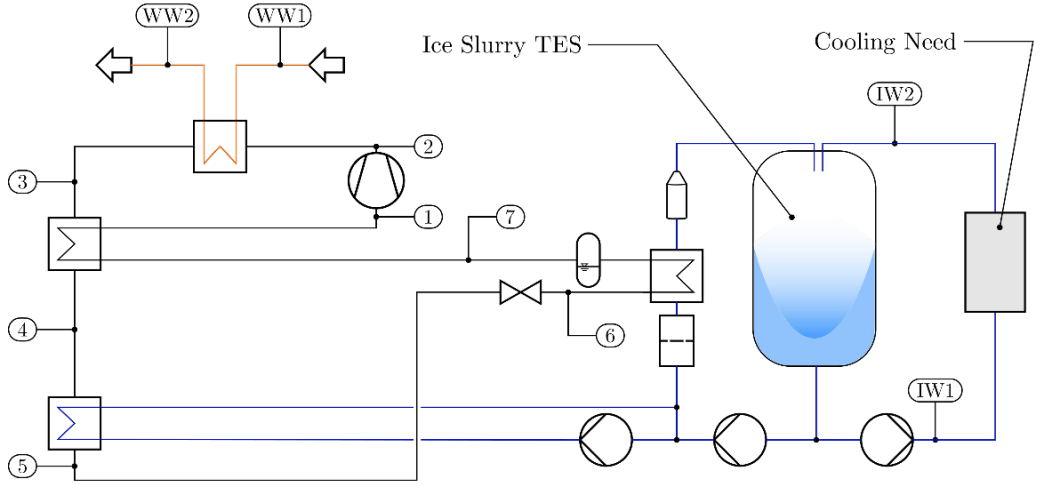
NH_3 and H_2O as the Refrigerant
Waste heat recovery
Oil free compressor

HTHP INTEGRATION IN A DAIRY

NH_3 as the Refrigerant
Waste heat recovery
High Temperature module

100% natural refrigerant
31% of **heat demand** for CIP supplied by HTHP
170 t **CO2e savings** per year

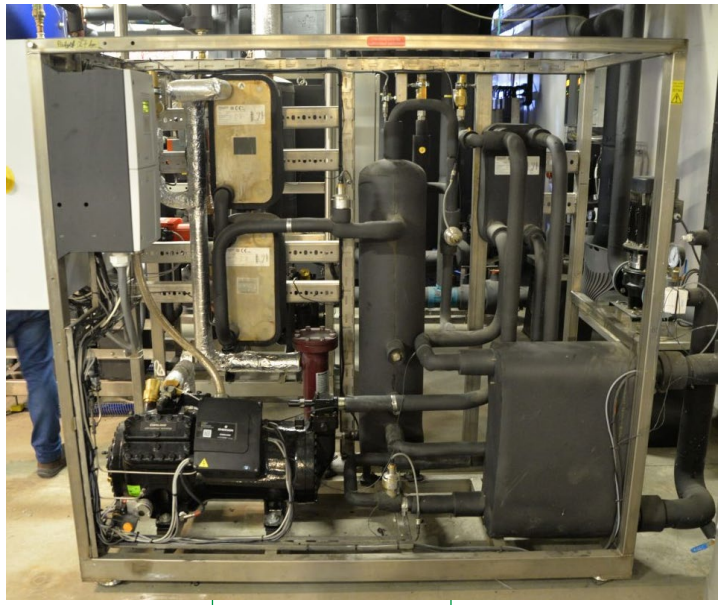
THERMAL ENERGY STORAGE



Energy Smart Dairy

Chiller&Heat Pump function
CO_2 as the Refrigerant
Hot and Cold TES
PV integration

100% natural refrigerant
-10% emissions during ENOUGH project

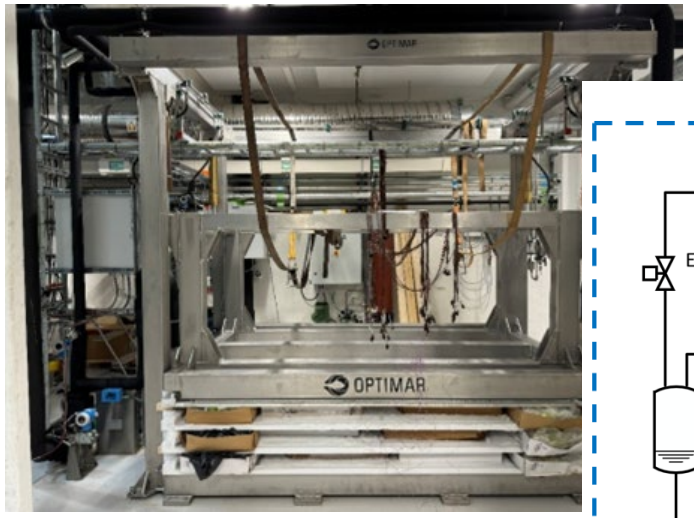


Thermosiphon Thermal Accumulator

CTES integrated into display cabinet

1.4 h power shut off without significant impact on product
Integration with the grid

FREEZING TECHNOLOGY



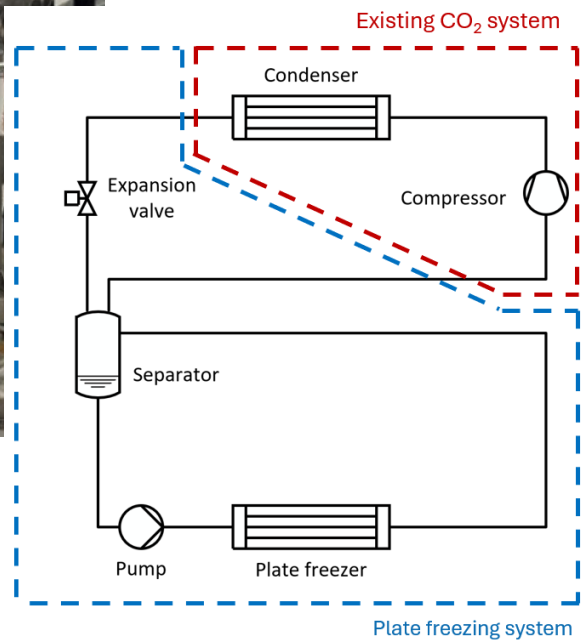


Plate freezing

Plate freezer CO_2 as the refrigerant -50°C evaporation temperature

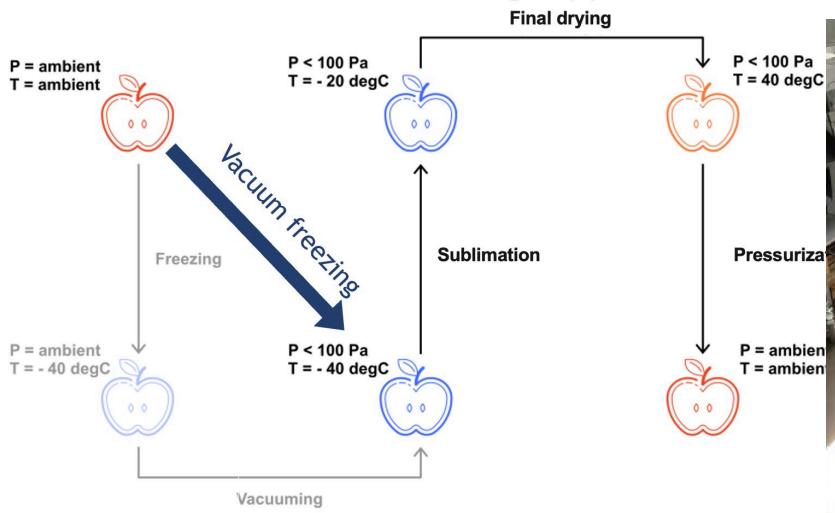
100% natural refrigerant
59% energy reduction vs baseline
43.6% process time reduction with evaporation from -36°C to -50°C

Blast Freezing

CO_2 as the refrigerant
-50°C evaporation temperature

100% natural refrigerant
Reliability assesment
Transient operation below the triple point
Oil return

FREEZING TECHNOLOGY - Quality



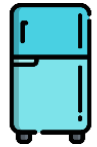
Brine freezing

Single stage or two-stage freezing
Explore savings and practical implications

Partially brine freezing followed by tunnel-freezing allows for **14% energy savings** (vs traditional tunnel)
Brine freezing of single pelagic fish helps in retaining **natural fish shape**

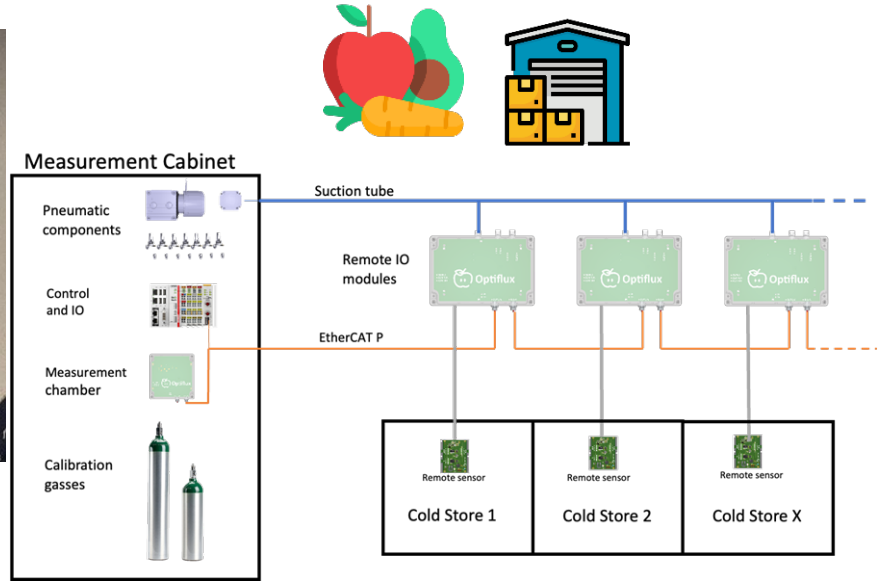
Long term food storage

Apply vacuum freezing for domestic use
R290 unit



38% energy reduction for 3kg load
40% process time reduction for 5kg load
100% natural refrigerant (propane)
Log term zero-energy preservation

IMPROVED PRESERVATION: DCA and SUPERCHILLING



DCA storage of Fruit

Up to **15 % lower energy consumption** compared to conventional ULO storage
100 % organic (no chemical treatments needed during storage)
Eliminating fruit disorders such as superficial scald
Tailored to each specific batch of fruit
Longer shelf life compared to ULO storage

Superchilling Compartment

Compartment at -2.5°C (±0.8°C)

Beef and lamb **shelf life extended** from ~4.5–6 days (chilling) to >16 days (superchilling)
Delay of at least 10 days in reaching critical microbial thresholds

ELECTRIC UNITS FOR TRANSPORT

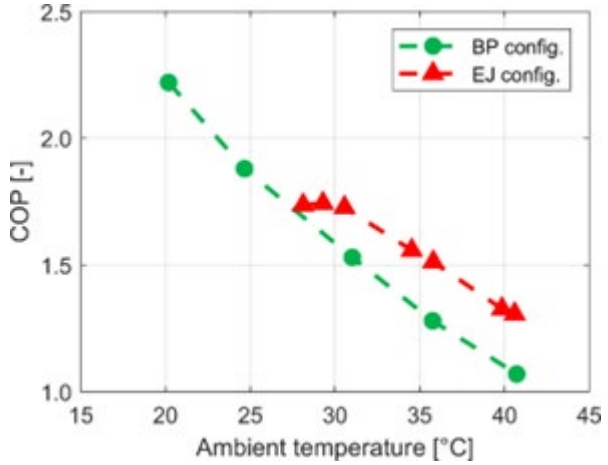
eLCV vehicle (fresh products)

CO_2 as the Refrigerant
Ejector based cycle
PV supported

Insulated box for last mile (frozen products)

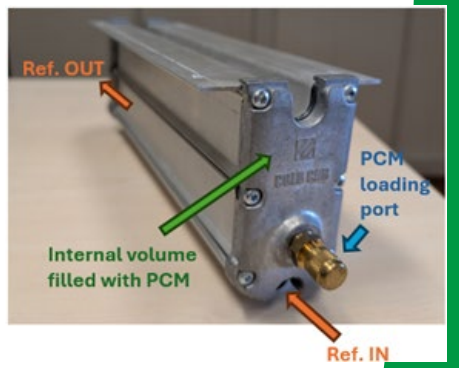
Propane as the Refrigerant
Eutectic pipes

100% natural refrigerant
Total annual reduction in operation emissions between -**30.0% in cold climates** (Helsinki) and **-15.5% in hot climates** (Phoenix) vs R134a

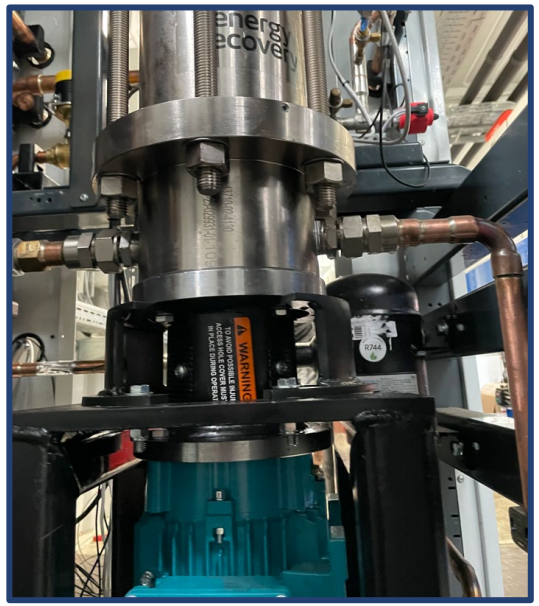


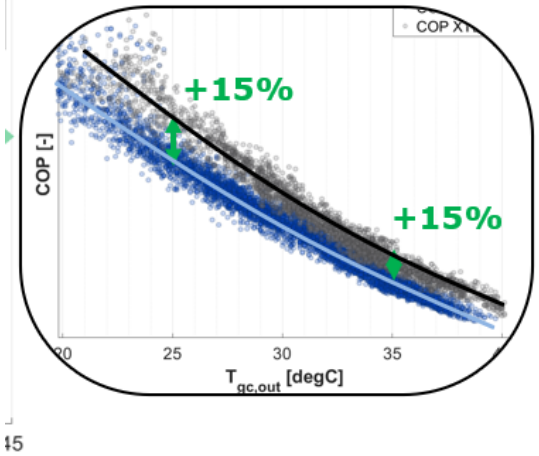
100% natural refrigerant

-8% freezing energy input (ATP test conditions) vs R452A



SOTA COMPONENTS AND DIGITAL TOOLS



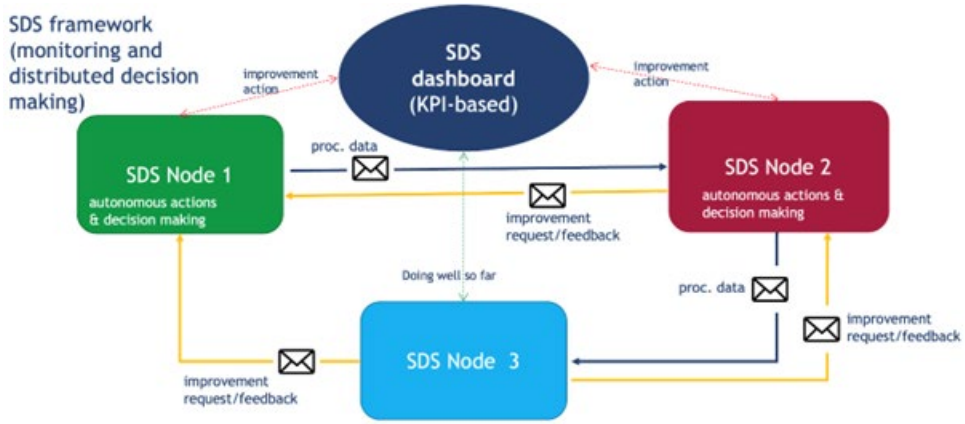


+15% @ $T_{gc,out}$ = 20°C
+15% @ $T_{gc,out}$ = 30°C
+15% @ $T_{gc,out}$ = 40°C

Pressure Exchanger for Retail

CO_2 as the Refrigerant
Booster System for supermarket

100% natural refrigerant
+15% average COP
Reliable operation up to 43°C ambient



Holistic Supply Chain Management and Control

Smart Data Systems platform committing supply chain actors in a continuous decision-making and feedback loop
Address complexities of supply chains in real-world contexts towards emission reduction

Application to Dairy, Storage and Retail

WP6 KEY MESSAGES

- Future food chain can rely on **100% natural refrigerants-based** technologies (D2,3,4,5,7,8,10,11,12,14,15,17,18,19,20)
- **Flow Integration, Energy Storage, Heat Recovery, use of Waste Heat** are key towards decarbonization (D2,3,8,9,11,14,16,18)
- **Electrification** is possible for industrial **processing heating** and **transport** (D2,3,7,8, 14)
- Adopt **innovative storage methods** (D4,5,12,17) and processing (D15) to reduce food waste at professional and domestic level
- **Advanced control** guarantees emission reduction and trustability of the chain (D1,D21)

CONCLUSIONS

- **Technologies for food chain decarbonisations do exist**
- ENOUGH has **adapted, implemented, improved and documented 21 technologies**, spanning from large industrial appliances, to small domestic ones, components and digital tools
- **Cooperation of research organisation and industrial partners and stakeholders** throughout the project and further lay-out of business plans has been the key towards success
- **Results are openly available** for different stakeholders, conveying key recommendations to academia, industry, market, policy and society

Final public reports for all demos soon available on ENOUGH website

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THANK YOU !

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