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A Cool World

1st International Congress on Clean Cooling

18th - 19th April, University of Birmingham

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DAY TWO WELCOME

#CoolWorldCongress

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Global LEAP
Lighting and Energy Access Partnership

Product Nominations: deadline: 25.05.2918

http://globalleap.org/

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HOT, COLD AND FLEXIBLE

Professor Eddie Owens, Heriot-Watt University

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Renewables are not enough!

Professor Edward Owens

Director of Heriot Watt Energy Academy

School of Energy, Geoscience, Infrastructure and Society

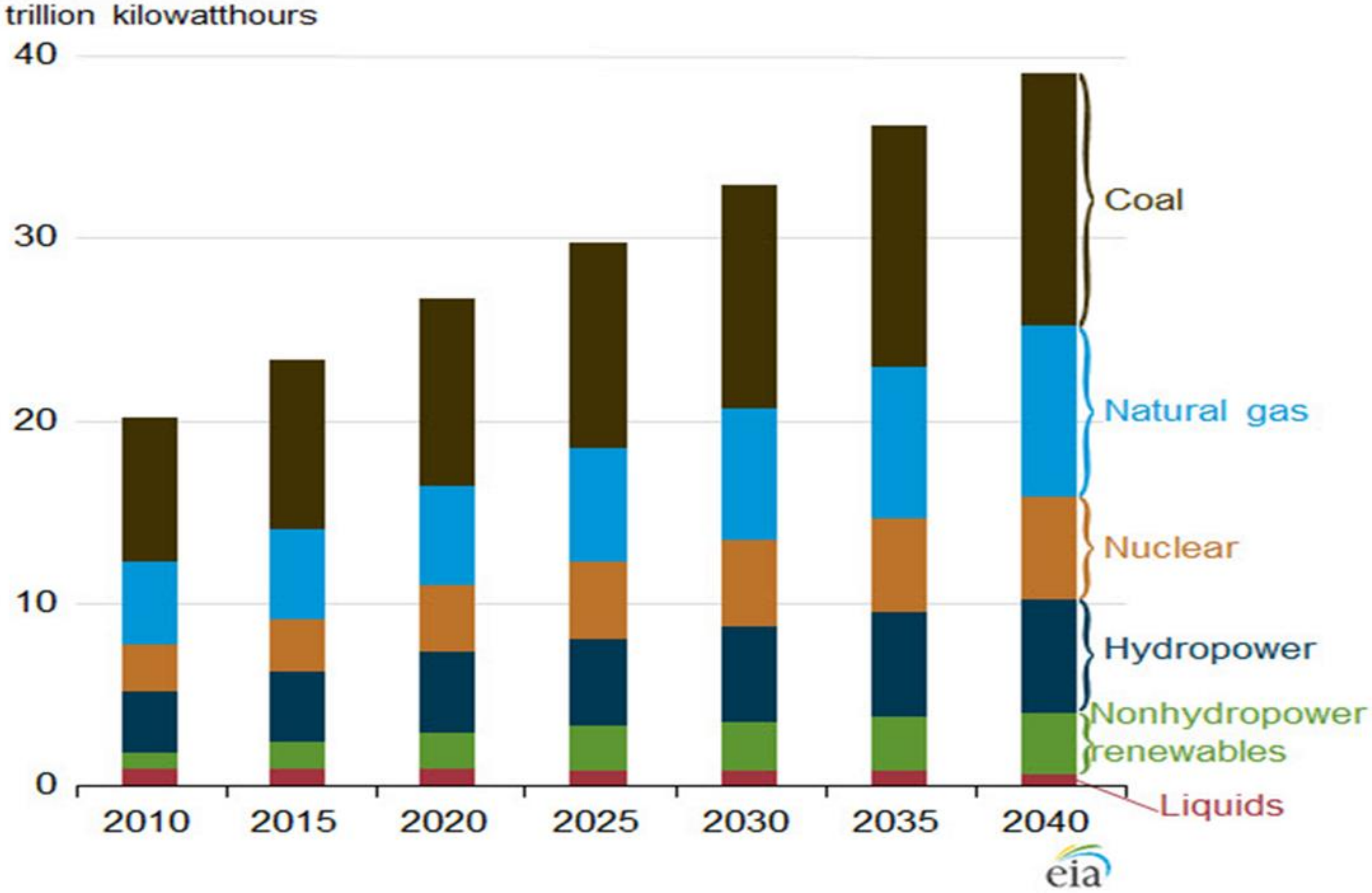
Current Energy Issues include

Resource depletion and concerns over climate change

Fast growing demand for energy

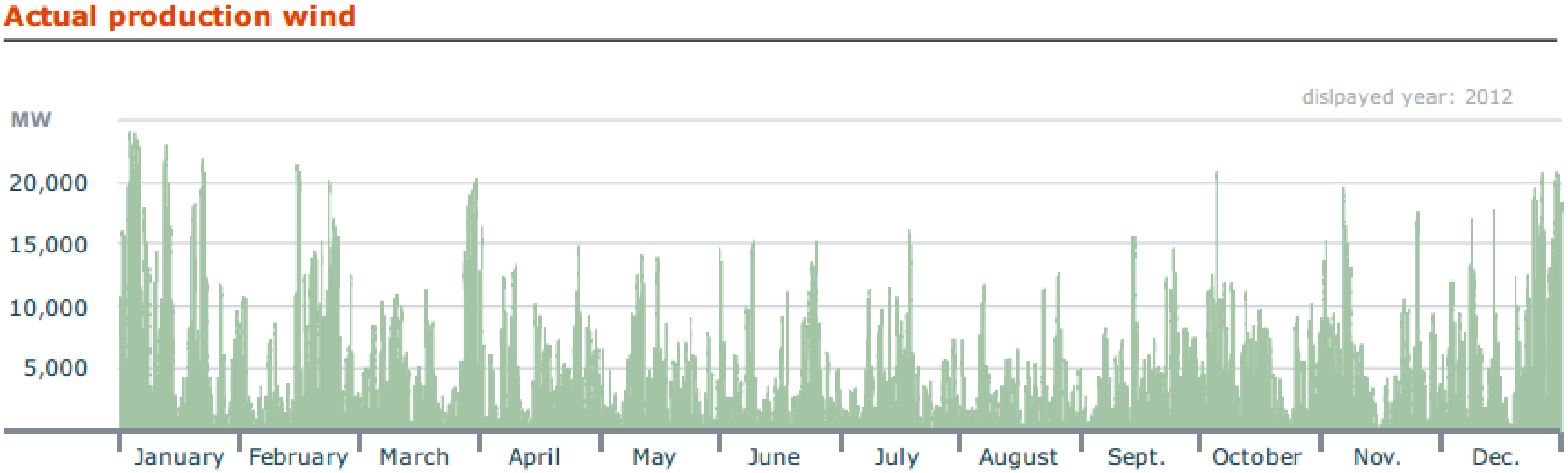
Expanding intermittent renewable generation

Figure 18. World net electricity generation by energy source, 2010-2040



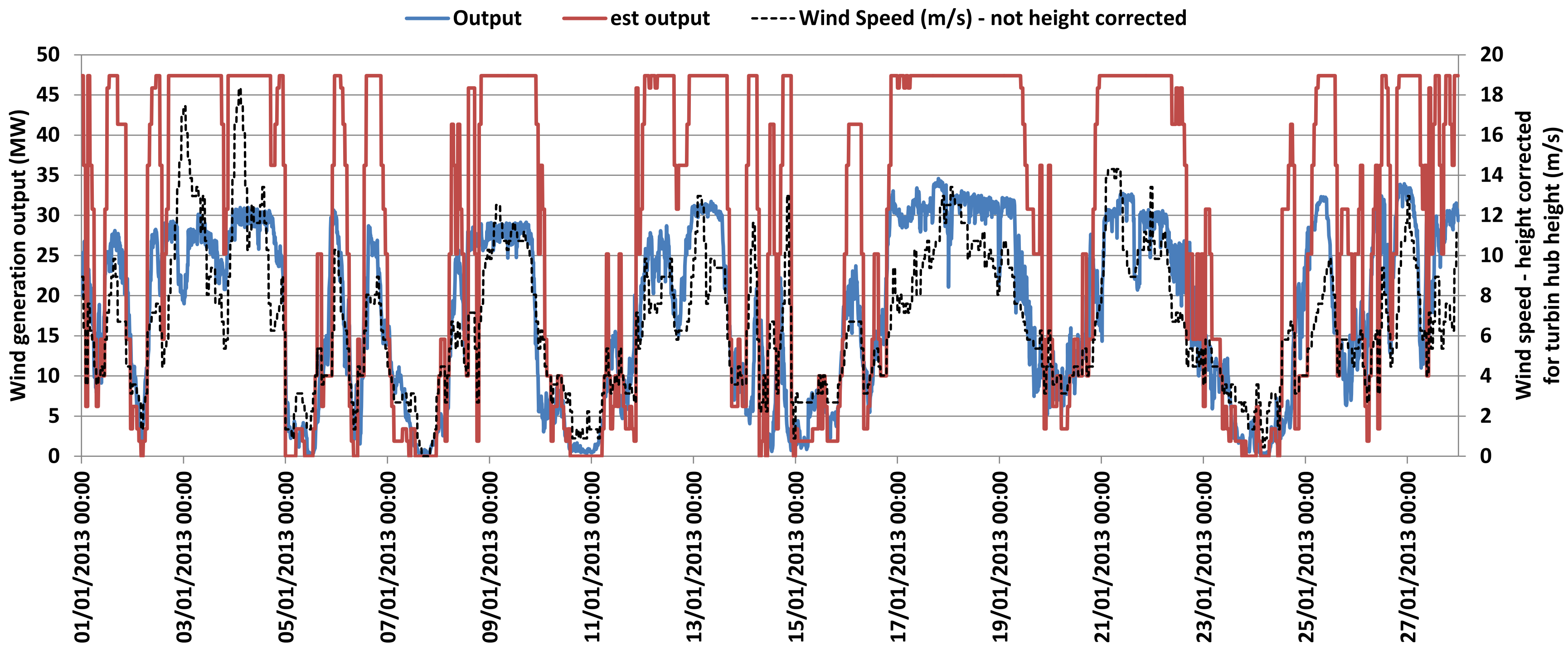
U.S. Energy Information Administration

German Wind Generation 2012
Capacity Factor = 18%



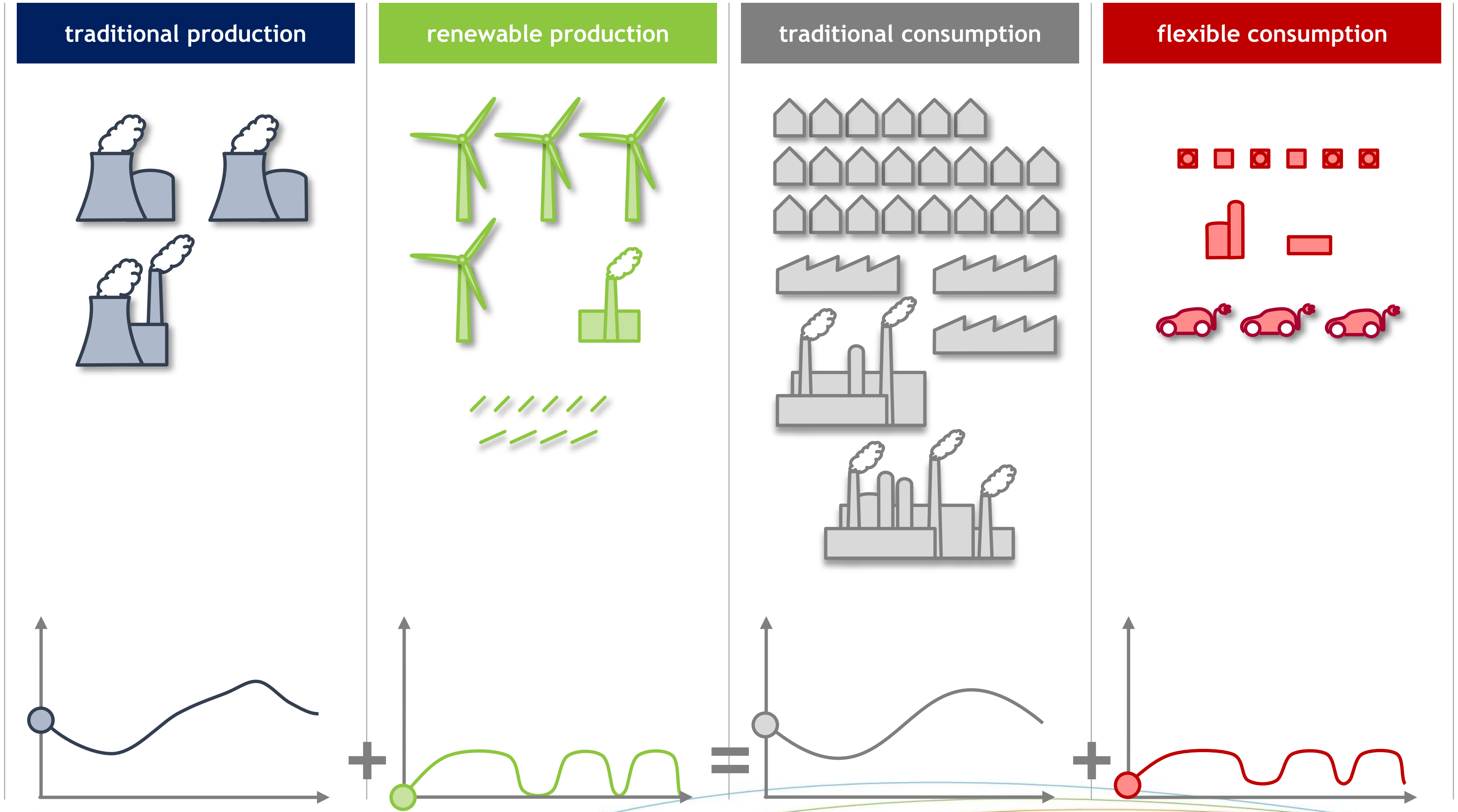
http://theenergycollective.com/schalk-cloete/259876/intermittent-renewables-and-electricity-markets

Grid Curtailment / Too much




Flexibility in demand timing will increase the proportion of renewable energy that we use.
Supply management “stores” energy
Demand management “stores” demand
Sara Campagna

Living with Intermittent Generation

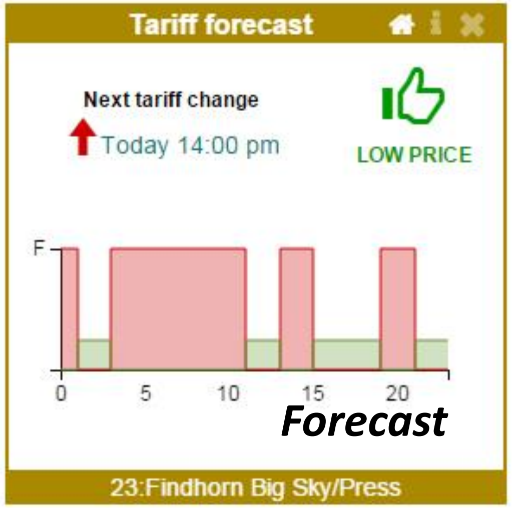


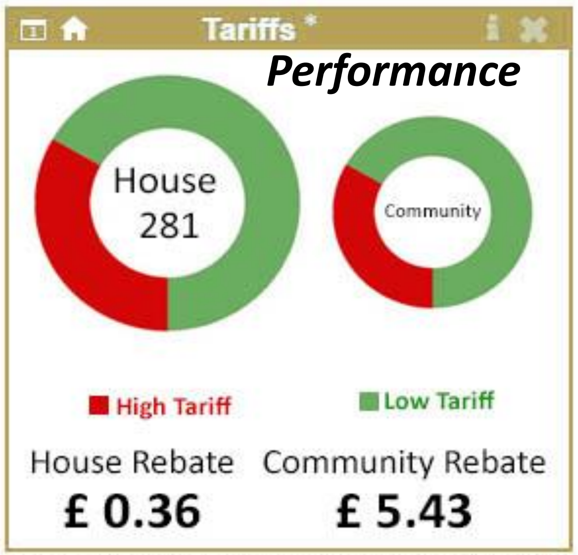
ORIGIN Project

- Demand Side Management at a community scale – automated and active participation

- Encouragement of “Active” participation via variable tariffs
- High Carbon 17p/kWh, low Carbon

Before 17h (00:00 to 16:59)





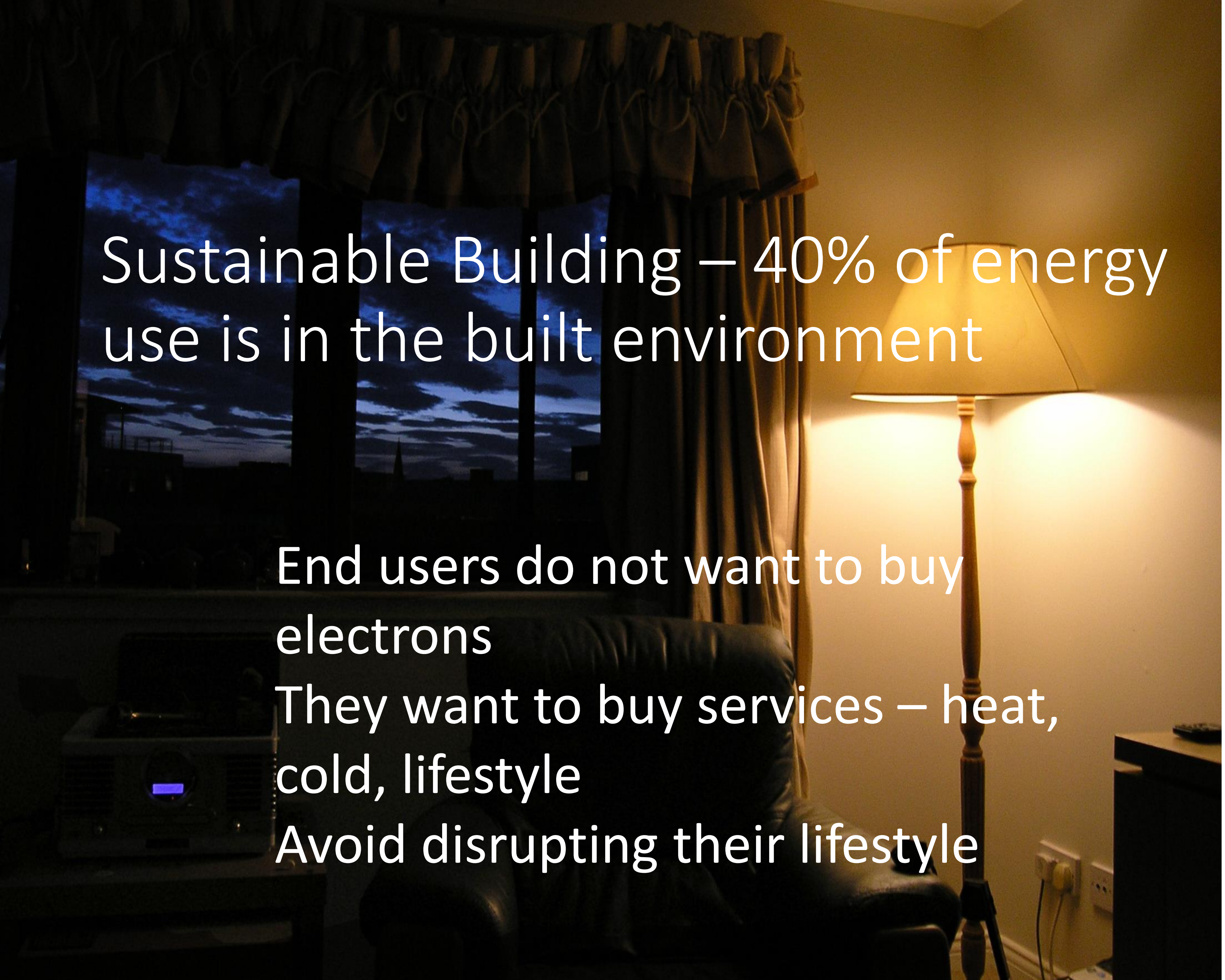
* This gadget will show info according to time scale: Yesterday, Montlhy, Since start of tariff experiment

Demand response project	Type of response	Percentage increase in use of Community Renewables	GHG Emissions Savings / $kgCO_2e$ per annum
Household electrical demand (Findhorn)	Informational – incentivised	5.8%	12,900
Household thermal demand (Findhorn)	Actuated (Modelled)	11%	24,400
Community electrical demand (Findhorn)	Informational - with feedback (Measured)	2.5%	5,500
Total Response with tariff incentive (Findhorn)		16.8%	37,300

What are the “demand response” opportunities?

Most impact from automated systems:

- Electric Vehicles (7kW x 10m = 70GW Peak)
- Heat Pumps
- Hot Water Tanks
- Other truly dispatchable Loads



Sustainable Building – 40% of energy use is in the built environment

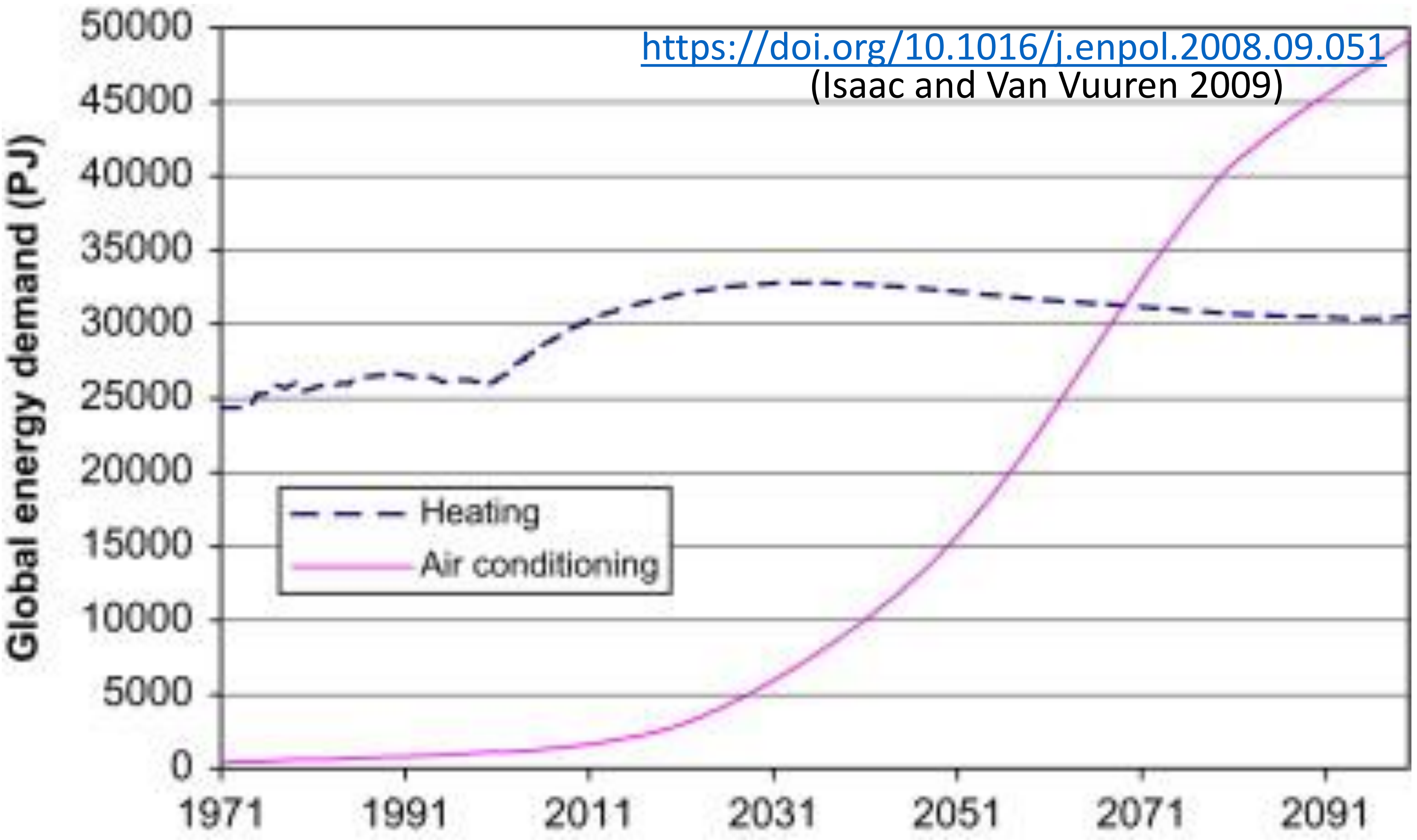
End users do not want to buy electrons

They want to buy services – heat, cold, lifestyle

Avoid disrupting their lifestyle

How do we make it happen?

- Variable Tariffs to reward “flexibility”
- New ways of selling energy
- Invisibility or “positive” visibility to the client
- Sell services – not energy!
- Build flexibility into the energy system



https://doi.org/10.1016/j.enpol.2008.09.051
(Isaac and Van Vuuren 2009)

Where does "Clean Cold" come into this?

- Cooling is often dispatchable
- It is therefore flexible within limitations and can be "orchestrated" with intermittent energy generation
- Cold Production – potentially valuable by-products including heat, and grid flexibility
- We have been focussed on heat – but its time to think clearly about cold

Professor Edward Hugh Owens

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THE COOLING LANDSCAPE

Michael Ayres, Flexible Power Systems

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The Cooling Landscape

April 2018 – Cool World

1st International Congress on Clean Cooling

University of Birmingham

Objectives of the Work

Develop a ‘clean cooling landscape study for the Kigali Cooling Efficiency Programme to support impact investors [and others] to enter into the clean cooling (refrigeration and air conditioning (RAC) sector – built environment and transport/logistics . The project will deliver:

- An understanding of the size of the challenge we need to address through clean cooling
- A market overview, incorporating potential disruptive technologies, applications, impacts (SDGs), growth projections, technology segmentation and an assessment of barriers to deployment
- An understanding of step-change technologies and cooling solutions
- A review of investment activity and levels, and perceived barriers to investing in the space
- An assessment of the interaction between social and policy factors and investing in the space
- A framework through which to assess technology oriented investment opportunities to understand their potential, impact and current status
- A web-based dissemination package

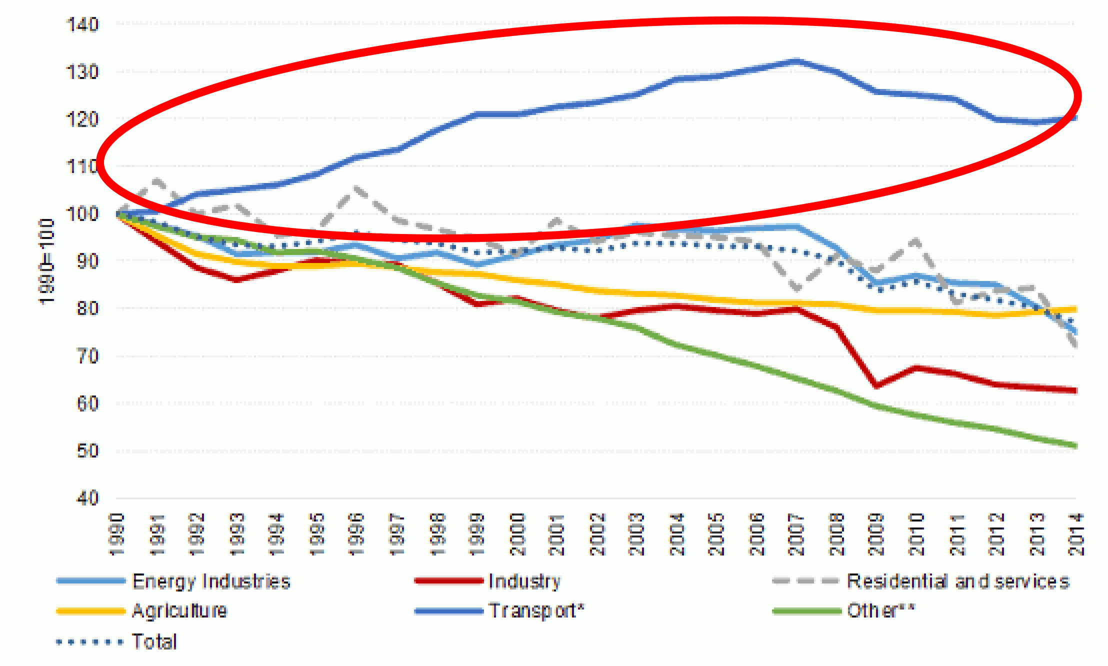
=> “clean cooling” as a defined category within clean tech, show the importance and opportunity and give an accessible start point for philanthropic investors who wish to learn more and then become active in the space

Engagement

- Over and above desk-based research, so far we have:
  - Profiled ~60 technology developers
  - Consulted several OEMs and Tier1s from cooling and refrigeration sectors.
  - Spoken to NGOs and trade associations with interests in energy efficiency and cooling.
  - Had input from financial professionals from private equity, intragovernmental, impact and philanthropic backgrounds.
  - Initiated dialogue with academics with technical, economic and policy backgrounds.
  - Engaged with a series of technology developers at different stages of the readiness cycle to build and test an assessment framework.

Flexible Power Systems

- Energy networks are changing as a result of very significant changes on both the supply and the demand side.
- At the same time, these networks are becoming ever more integrated.
- Even larger change is required to meet decarbonisation targets in many sectors – especially transport.
- FPS focuses on understanding the interaction between transport, thermal and electrical energy systems.
- We also study the changing technology and market landscapes in these sectors.
- Our understanding of market requirements and emerging technologies means we can bring a holistic systems approach to the ***design, delivery and management*** of energy, transport and thermal systems.
- We use this approach to help our customers improve their operations and develop new products.



European Environment Agency

This Session

We are working on a landscape study for Kigali Cooling Efficiency Programme (K-CEP) with Professor Toby Peters. The study focuses on market dynamics, emerging technologies, the investment climate and potential for impact. We have also been asked to develop an assessment tool to aid in understanding new technology offerings. One of our objectives is to find disruptive new technologies that can add to existing work on efficiency and natural refrigerants.

We would like to share and test some of our initial findings.

In many respects the sector suffers from scarce data, as a result we would welcome any feedback you have whether you want to give it at this session or offline.

We are going to talk about:

- Applications & Markets
- Technologies with the potential to address cooling
- Barriers

Cooling Applications

Flexible Power Systems

The segmentation on the right is the most common and is widely used in market assessments. Stakeholders engaged to date have proposed no substantial revisions.

Equipment Stocks are approximate as in many territories only limited sales records are kept.

Growth projections are typically interpolated from factors like GDP growth, income distributions, access to electricity and urbanisation etc

AC segmentation is more technology driven. We believe this is the result of scale factors

This segment covers an extremely disparate selection of equipment

Data seems particularly poor in relation to this strand

These sectors included for completeness, but not the focus of the study

Application	Segments	Number
Air Conditioning	Heat Pumps (reversible)	160m
	Unitary Air Conditioners	600m
	Chillers	2.8m
	Mobile Equipment	700m
Refrigeration	Domestic Refrigeration	1.5bn
	Commercial Refrigeration	~90m
	Industrial Refrigeration	
	Transport Refrigeration - Road	4m
	Transport Refrigeration – Containers	1.2m
	Marine Refrigeration & Processing	~88k*
Health	MRI Scanners	25k
Energy	LNG Receiving Terminals	110
	Liquefaction Trains	92
	Tanker Fleet	421
Leisure	Ice Rinks	13.5k

IIR/IIF market segmentation & estimates

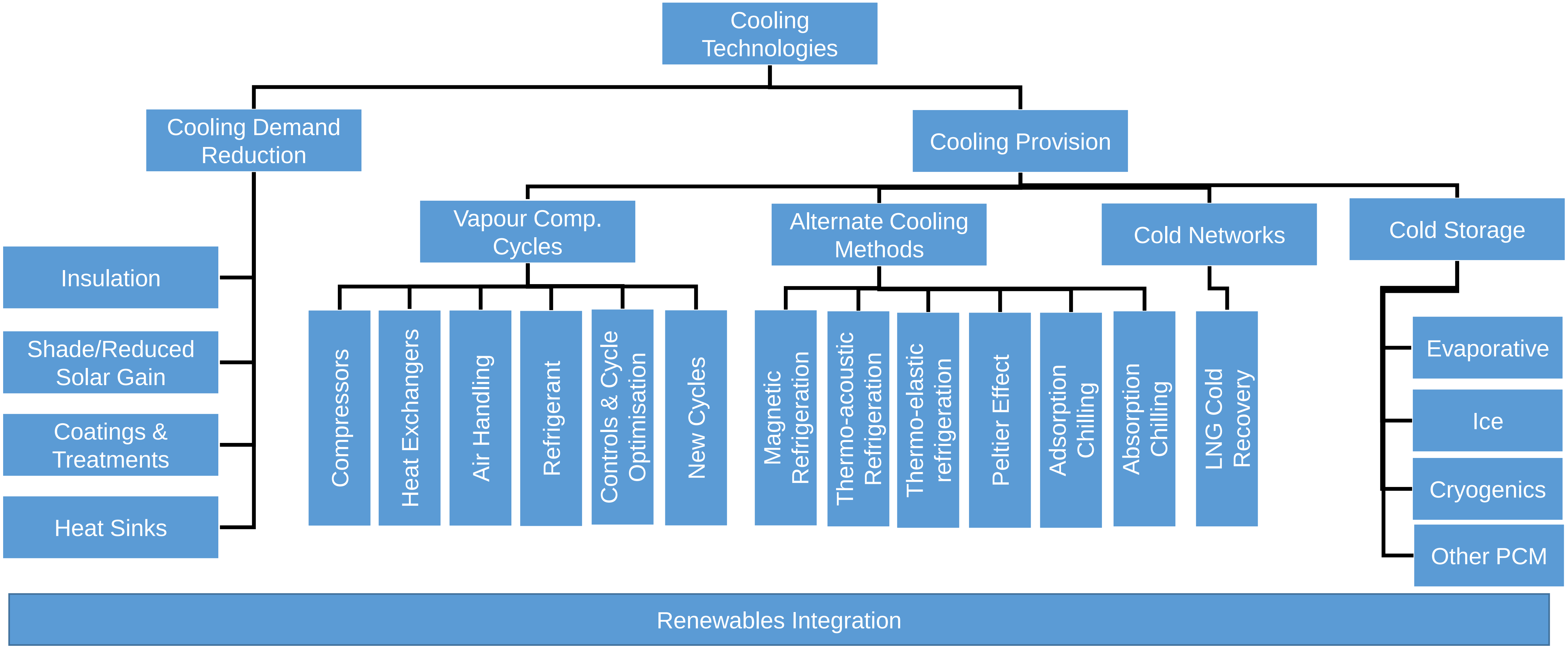
Cooling Application Questions

- Is there a data set beyond those offered by GIZ Proklima, IIR, Japanese Refrigeration and Air Conditioning Association we should be considering?
- Is the segmentation appropriate or should we be looking at something different like services or needs?
- What can be done to improve our understanding of:
  - Where we are today?
  - Where we are headed?

Technology Landscape

Flexible Power Systems

There is though a wide and growing toolkit of technologies with the potential to address cooling needs:



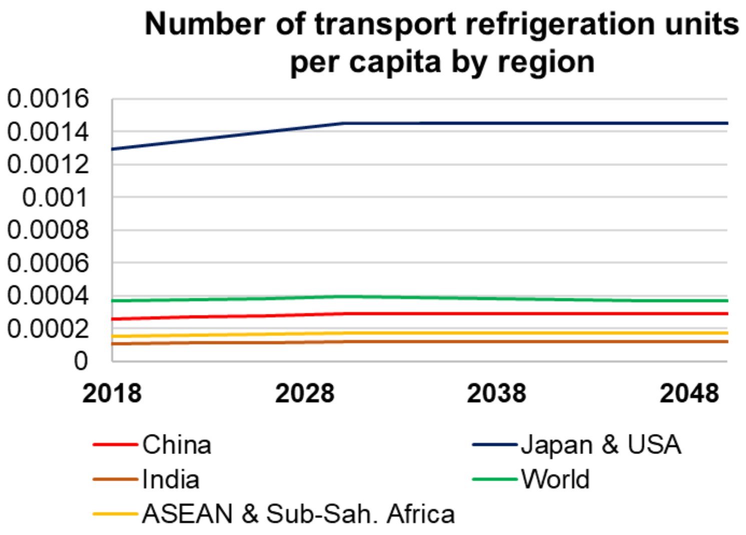
Technology Questions

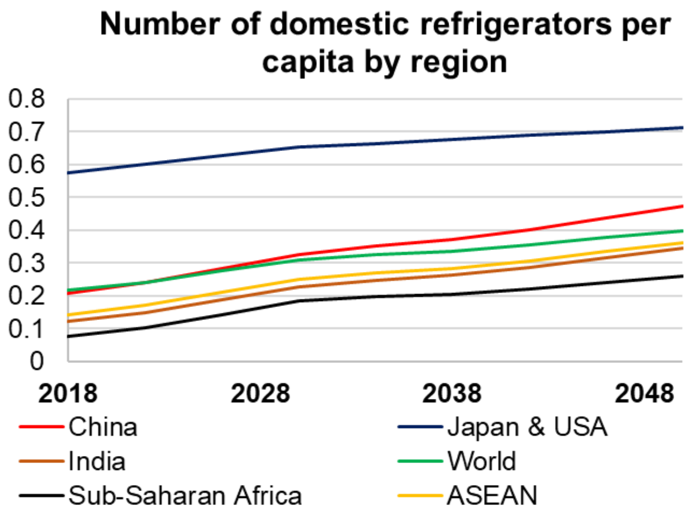
- Are we missing any major areas of current development?
- Is the segmentation appropriate?
- None of these technologies is a complete solution on its own. Do we currently have all the tools we need to match technologies to applications and energy sources to combine them into systems?
- Where do you think the gaps are in our technology toolkit (i.e. where do you think needs driven fundamental R&D may be required)?

Barriers – Cooling Equipment Uptake

Flexible Power Systems

- Access to cooling has enormous positive impacts from a human development perspective (e.g. comfort and health, food security, rural incomes).
- Even over a time horizon of decades access to cooling equipment is projected to remain low by many stakeholders over a period of decades.
- A number of barriers have been identified during the study have been proposed.





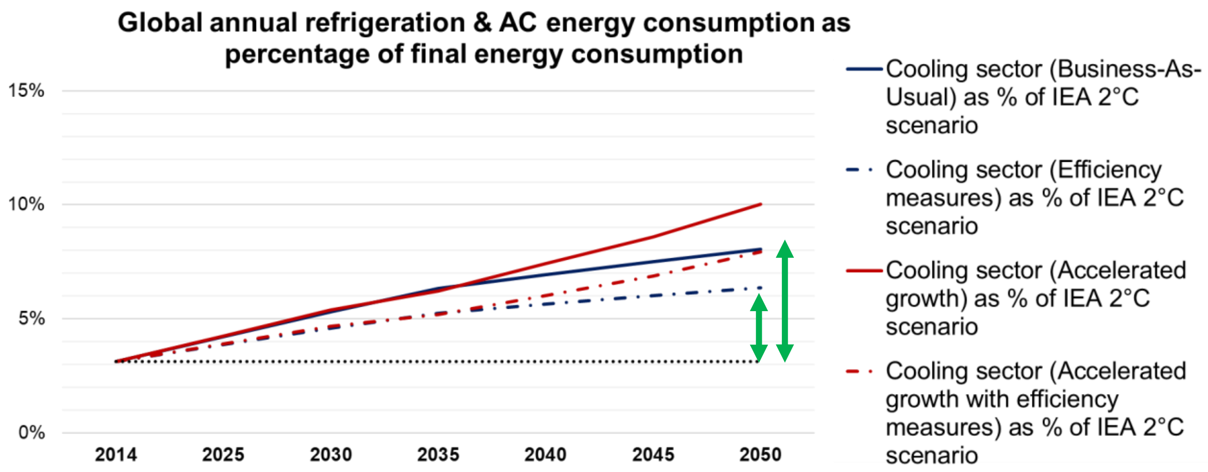
Issue	Description
Access to finance	Cost of cooling equipment too high for consumers
Culture vs. Refrigeration	Lack of understanding of need for cold chain*
Electricity Availability	Lack of reliable electricity to power devices
Skills	Shortages of skilled individuals who can install and maintain equipment and correctly use in service
Policy Impacts	Lack of understanding of potential +ve health, productivity & carbon impacts of access to cooling

*several stakeholders have indicated AC uptake seems to “just happen” with GDP growth; refrigeration requires cultural change

Barriers – Efficiency Implementation

Flexible Power Systems

- Very substantial improvements in cooling efficiency are required to meet climate change targets.
- Cooling equipment often has a lifetime of over a decade or more and so equipment purchase decisions made now could still be affecting emissions from the sector in 2030.
- A number of barriers to implementing current and future technologies have been proposed during the study.



Issue	Description
Purchase Price vs TCO	Consumer bias towards cheaper (& often) less efficient equipment
Service Networks	Often current service networks cannot cope with new technology – this can be real or customer perceived
National interest vs. MEPS	A national appliance manufacturer may lose market share if efficiency standards increase
Skills	Skills shortages may be exacerbated by more complex new technologies
Customer Education	Technology development is driven by customer requests, not all customers understand what to ask for.
Emissions measures	Not always understood that direct **and** indirect emissions are important
Pipeline	Lack of truly disruptive technologies in development from R&D to scale-up (many reasons for this)
Integration	Lack of real world proof of systems/integration benefits

Barriers Questions

Flexible Power Systems

Access to cooling

- Do you think that we are correct that access to cooling will not be universal even by 2050?
- Are there other barriers preventing this from happening?
- What should we do about it?

Cooling Efficiency

- Is there a problem?
- Are there other barriers we should be considering?
- What should we do about it?

Carrying on the Conversation

Flexible Power Systems

- So far we have:
  - Profiled ~60 technology developers.
  - Consulted several OEMs and Tier1s from cooling and refrigeration sectors.
  - Spoken to NGOs and trade associations with interests in energy efficiency and cooling.
  - Had input from financial professionals from private equity, intragovernmental, impact and philanthropic backgrounds.
  - Initiated dialogue with academics with technical, economic and policy backgrounds.
- We would welcome your input on anyone else we should be speaking to or on any of the focus areas.

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Back-up

Assessment Tool

|Flexible Power Systems

- The tool does not replace due diligence, it is intended to provide a start point for discussions between impact investors and innovators.
- It is intended to provide a holistic set of questions for people new to the space to ask so that they can understand where in the development cycle an innovation is.
- Some questions are inherent to applications and technology types whereas the "readiness" related questions are more progressive.
- Renewable and up-stream and down-stream considerations are derived from application and technical focus.

Proposition Assessment factors:

- **Applications/Markets** – Which application is being addressed and how big is it?
- **Innovation Family** – Does this fall into one of the technology categories & are "classic" challenges being addressed
- **Competitors –** What does the innovation compete with and are its advantages significant?
- **Impact –** Does the innovation offer a significant opportunity to impact on achievement of the sustainable development goals?

Development Status Assessment Levels

- **Technical Readiness** – how proven is the technology?
- **Manufacturing & Supply Chain Readiness** – can it be made? Can it be installed and serviced?
- **Commercial Readiness –** is the path to market defined?
- **Enterprise Readiness –** is the business that is developing the innovation sufficiently mature to achieve its goals?

Assessment Questions

Flexible Power Systems

- Is this a rational way to approach new innovations?
- Should we be looking at other factors?
- How do we manage the transition from a simplistic process driven assessment like this and detailed expert led due diligence?
- Are there other stakeholders that could make use of this tool?

Objectives of the Work

Flexible Power Systems

We have working with Toby Peters to develop a landscape study for the Kigali Cooling Efficiency Programme to support impact investors enter into the clean cooling (refrigeration and air conditioning (RAC)) sector. The project will deliver:

- A market overview, incorporating potential disruptive technologies, applications, impacts (SDGs) growth projections, technology segmentation and an assessment of barriers to deployment
- An understanding of step-change technologies and cooling solutions
- A review of investment activity and levels, and perceived barriers to investing in the space
- An assessment of the interaction between social and policy factors and investing in the space
- A framework through which to assess technology oriented investment opportunities to understand both their potential and current status
- A dissemination package (most likely a web tool)

The goal is an accessible start point for philanthropic investors who wish to learn more and then become active in the space

The Audience

The work has been commissioned from Professor Toby Peters by the Kigali Cooling Efficiency Programme (K-CEP).

K-CEP represent a group of 18 foundations who have pledged $52m to help increase the energy efficiency of cooling in developing countries. The group was formed to support the Kigali Amendment to the Montreal Protocol. More information about K-CEP is available at http://www.k-cep.org/.

K-CEP's parent organisation is ClimateWorks Foundation, a global NGO that seeks to strengthen philanthropy's response to climate change. Its core funders are The William and Flora Hewlett Foundation, KR Foundation, the John D. and Catherine T. MacArthur Foundation, the Oak Foundation, and The David and Lucile Packard Foundation. More information about ClimateWorks is available at http://www.climateworks.org/

The work is intended to inform philanthropic organisations like these who wish to make investments to support deployment of efficient and clean cooling technologies.

Flexible Power Systems

Flexible Power Systems works with customers to reduce their energy and fuel costs. We combine cutting edge technologies and systems thinking with a deep understanding of customers' operations and objectives to develop transformative energy strategies for our clients.

We then help our clients implement and manage energy technology strategies for maximum benefit.

To find out more visit us at www.flexpowerltd.com

or contact us at

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REDUCING THE ENERGY DEMAND FOR COOLING

A REAL WORLD CASE STUDY FROM INDIA

Helge Schramm, Danfoss

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REDUCING THE ENERGY DEMAND FOR COOLING – CASE STUDY FROM INDIA

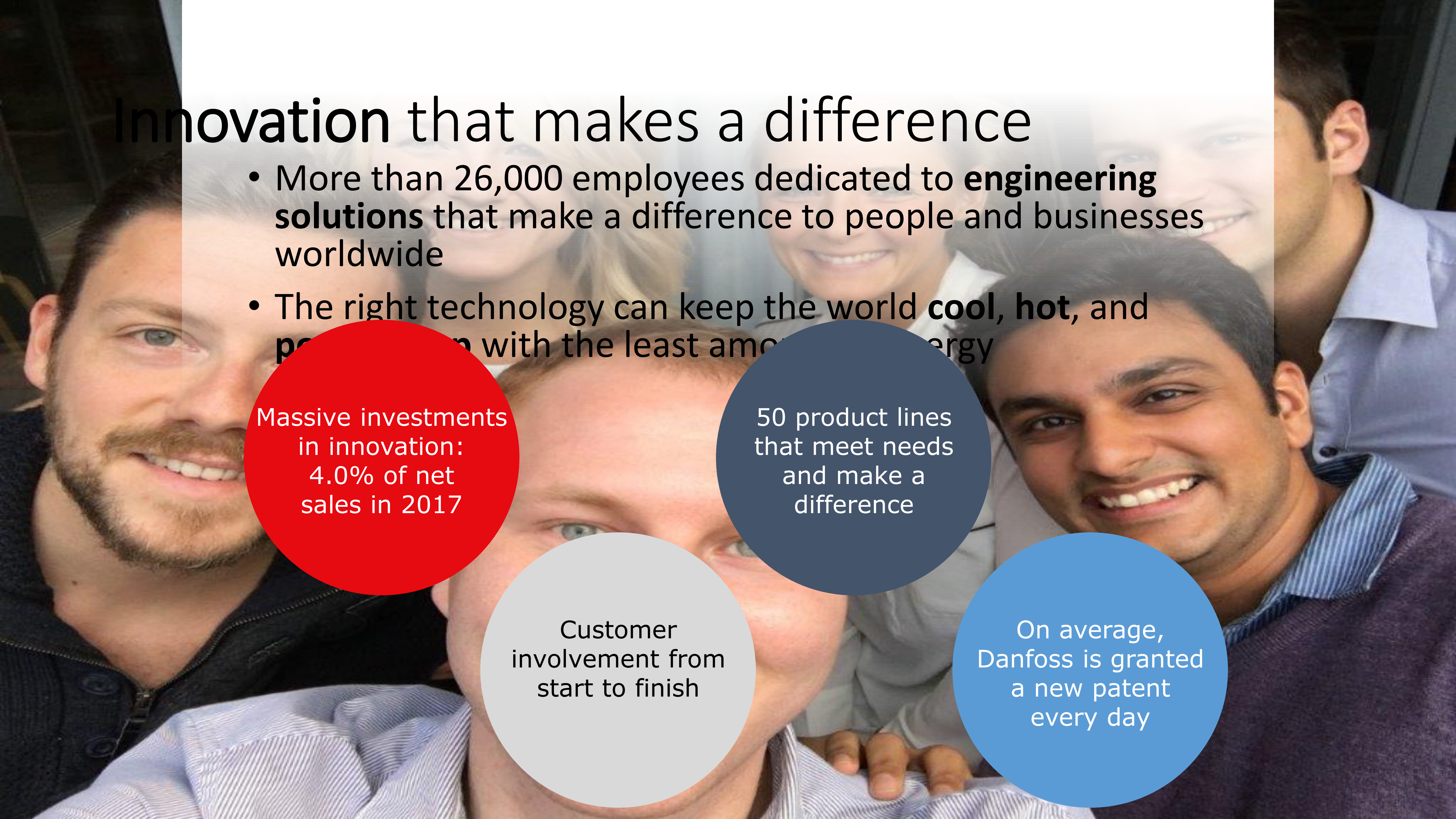
International Congress on Clean Cooling - April 19th, 2018

Helge Schramm, Sustainability & LCA Expert, Danfoss A/S

ENGINEERING TOMORROW

Danfoss

Content



Innovation that makes a difference

- More than 26,000 employees dedicated to **engineering solutions** that make a difference to people and businesses worldwide
- The right technology can keep the world **cool**, **hot**, and **p**... **n** with the least amo... ergy

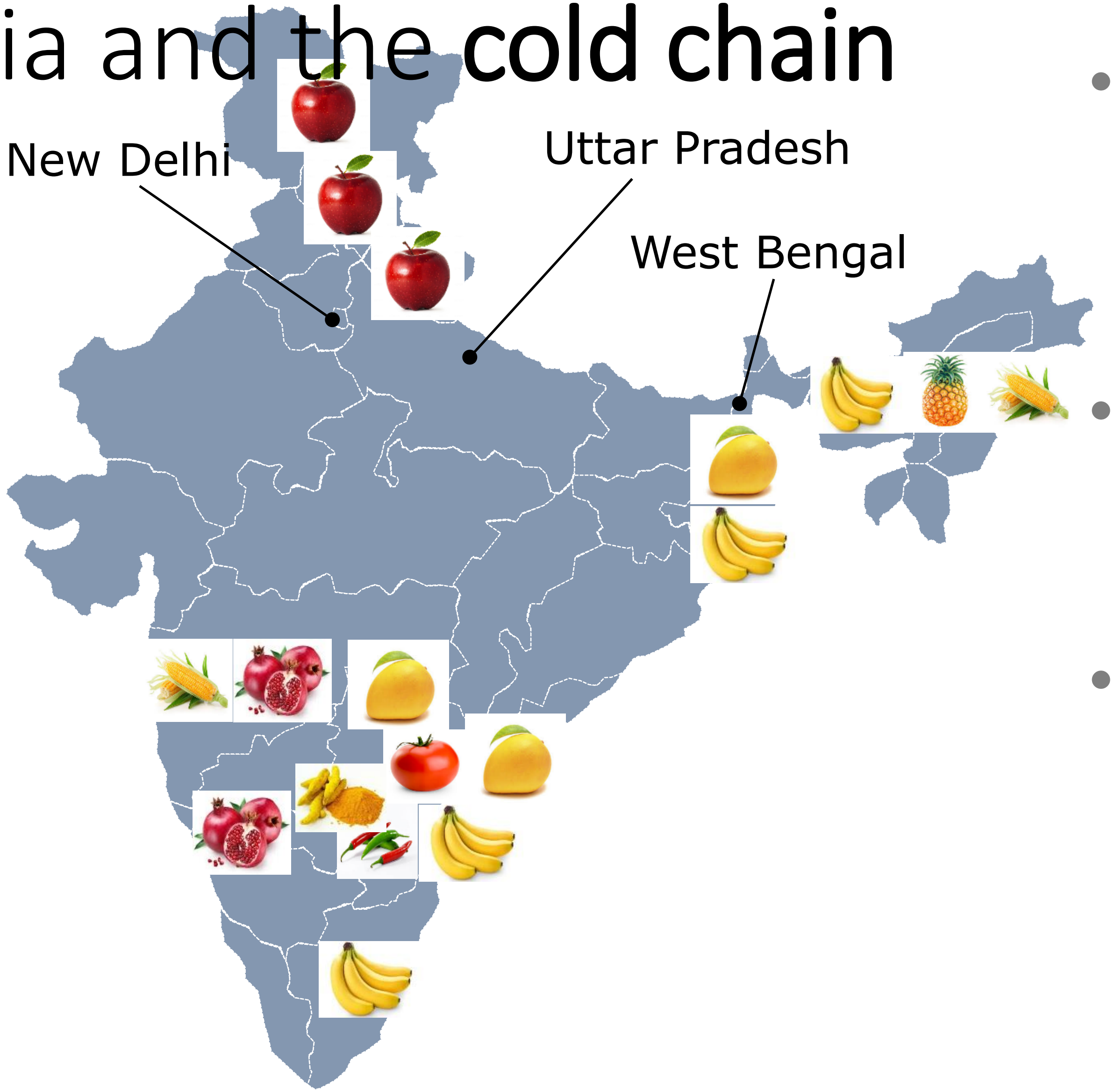
Massive investments in innovation: 4.0% of net sales in 2017

50 product lines that meet needs and make a difference

Customer involvement from start to finish

On average, Danfoss is granted a new patent every day

India and the **cold chain**

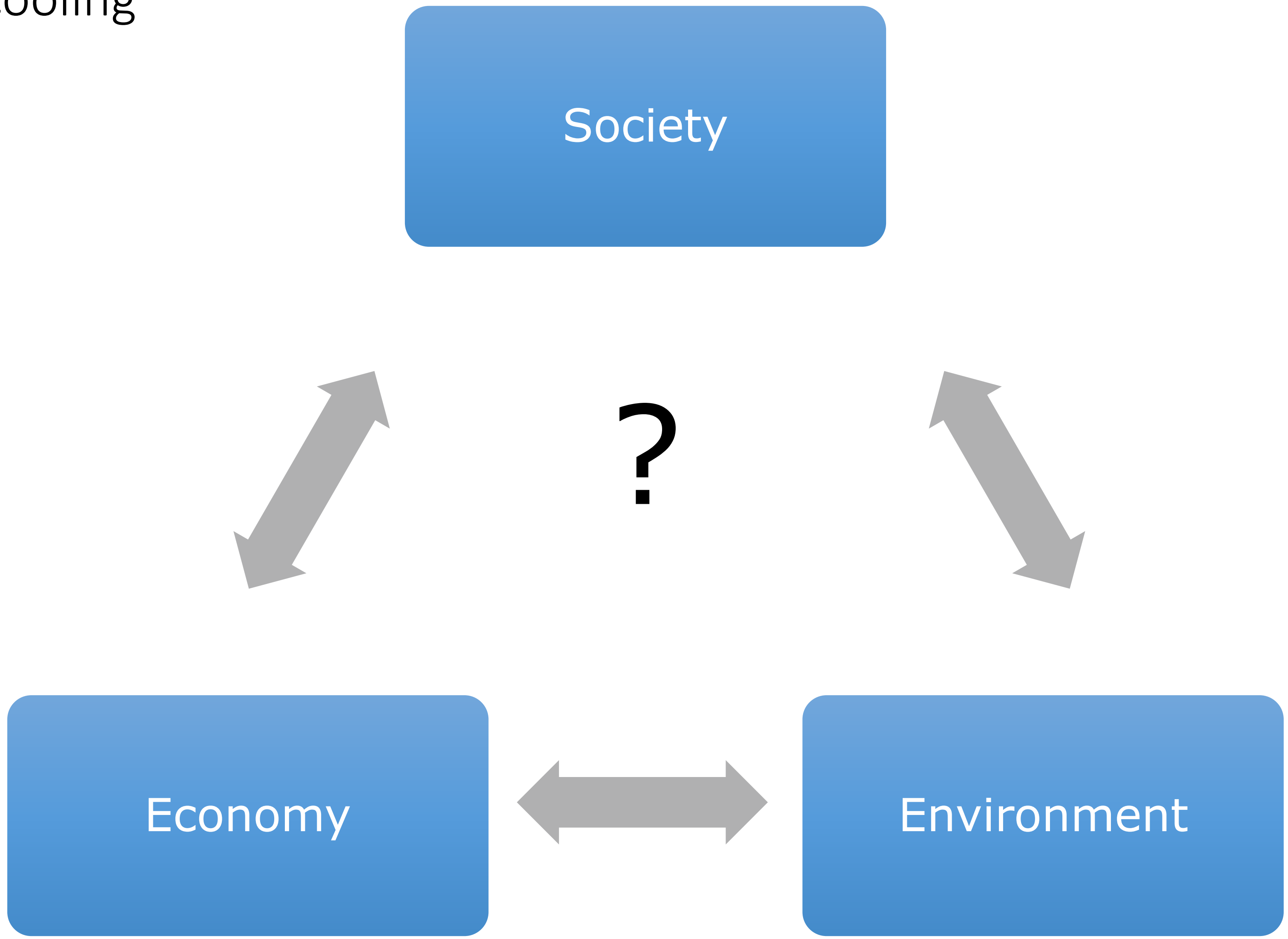


- World's second largest producer of fruits and vegetables (nearly **260 million MT**)
- Approx. **18% wastage** in fruits and vegetables annually
- Establishing a cold chain infrastructure using best available technology (BAT) could feed additional **15-30% of the population**

Cold storage facility in Sonipat, Haryana

- Multi commodity store, temp. range -25°C to +10°C
- Total investment of INR 250 million (~3.1 million EUR)
- Large capacity of 5000 MT
- Reduces energy footprint of cold store by 20%
- Fully automated storage center

Sustainable cooling



Sustainable cooling

Population growth – approx. **60% more food** needed by 2050

Roughly **one third** of food produced every year gets lost or wasted

Food loss and waste results in roughly **$940 billion economic losses** globally per year

Food loss and waste result in estimated **GHG emissions of 4.4 Giga tons CO_2eq**

Industry addressing challenges through innovation / education

Training Centre offered to GoI for training State Govt. Officers

Establishing **Centres of Excellence (CoE)** at Universities; R&D with institutes

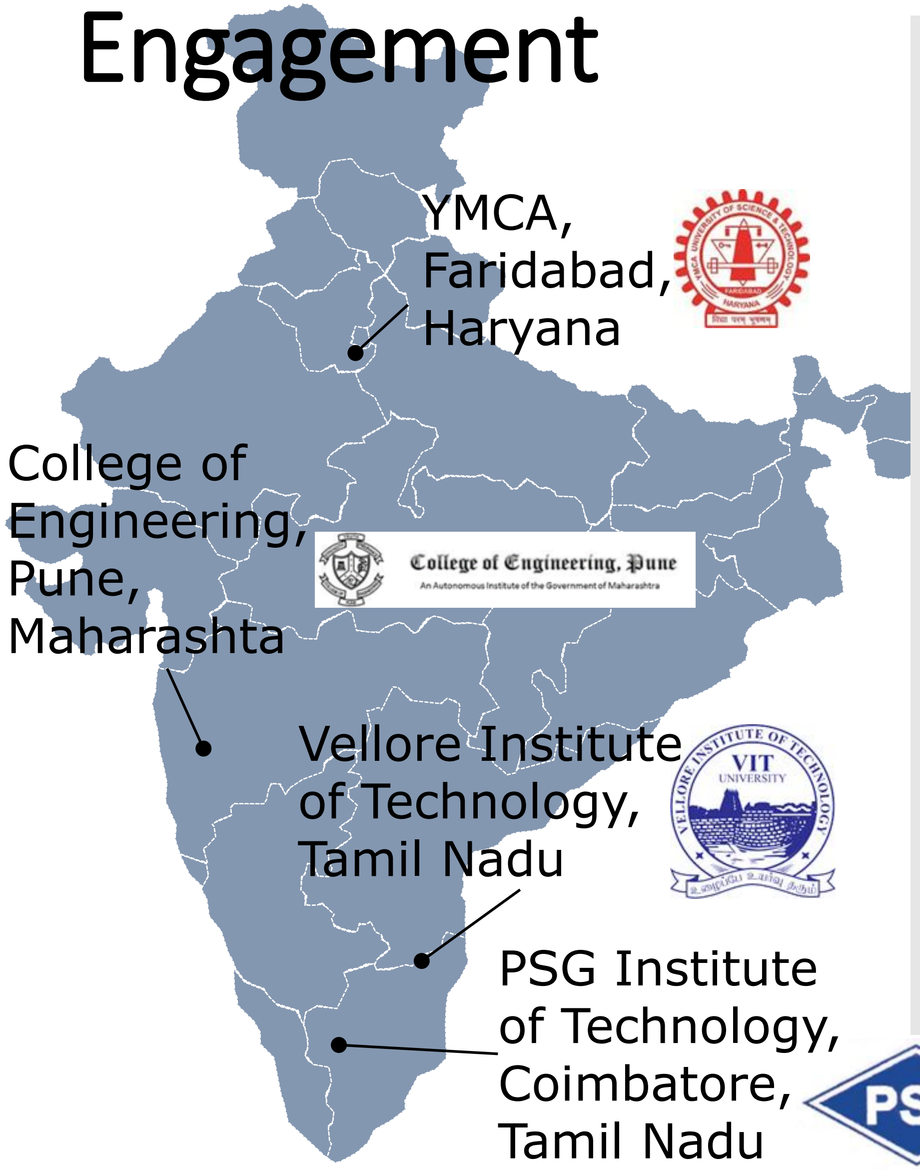
Working with local farmers/FPOs through **state specific initiatives/ innovations** (Banana Festival, Mango)

Engineering Tomorrow's Cold Chain

Recognizing early adaptors of efficient cold chain technology through **Danfoss ICE / CII cold chain awards**

Supporting Entrepreneurs with Technology – **Model Cold Storage** with best global technology developed

Building an Ecosystem – **University Engagement**



Sum up

Key messages

Improving the cold chain in India

- by establishing a cold chain infrastructure using BAT could feed additional 15-30% of the population
- by applying and optimizing BAT could reduce the energy demand of cold storage facilities by 20-30%
- means to think long term, engagement with multiple stakeholders, education, living labs, and **innovation that makes a difference** (Start ups!)

ENGINEERING
TOMORROW

Danfoss

Many thanks for your time and attention !

https://www.danfoss.com/en/

http://www.danfoss.in/cold-chain/

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THE WHOLE SYSTEM IS GREATER THAN THE SUM OF THE PARTS

THE SYSTEMS LEVEL IMPACT OF CLEAN COLD CHAIN – FINDINGS FROM A NEW GFCCC REPORT

Juergen Goeller, Global Food Cold Chain Council

To include questions with Helge Schramm (Danfoss), Juergen Goeller (GFCC) and Dr Lisa Kitinoja (The Postharvest Education Foundation).

Dr Tim Fox to chair (IMechE)

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Global Food Cold Chain Council

Expanding the food cold chain for a healthier planet

initiative SAVE FOOD Solutions for a world aware of its resources

GLOBAL FOOD COLD CHAIN COUNCIL

An Industry-led Initiative

- UNSG Climate Summit, New York City, September 2014: a coalition of major companies from around the world launch the **Global Food Cold Chain Council (GFCCC)**
  - to reduce greenhouse gas emissions in the processing, transportation, storage and retail display of cold food and
  - to stimulate global demand for energy-efficient low-GWP technology
- GFCCC committed to work with UNEP's Climate and Clean Air Coalition (CCAC) to advance broad-based public-private collaborative solutions to reduce HFC emissions in the food cold chain
- Successful implementation will generate economic and social value from:

Human health
Food supply, safety, quality
Sustainable agriculture practices
Workforce development
Manufacturing
Economic activity

Food waste
H_2O consumption
GHG emissions

A Sustainable Food Cold Chain:
An Economic, Social and Environmental Net-Positive

Food Loss Prevention (Pre-consumer)

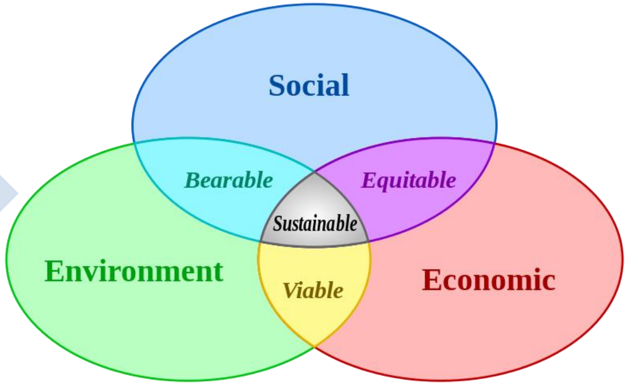
- Wider use of refrigeration equipment

Equipment Enhancement

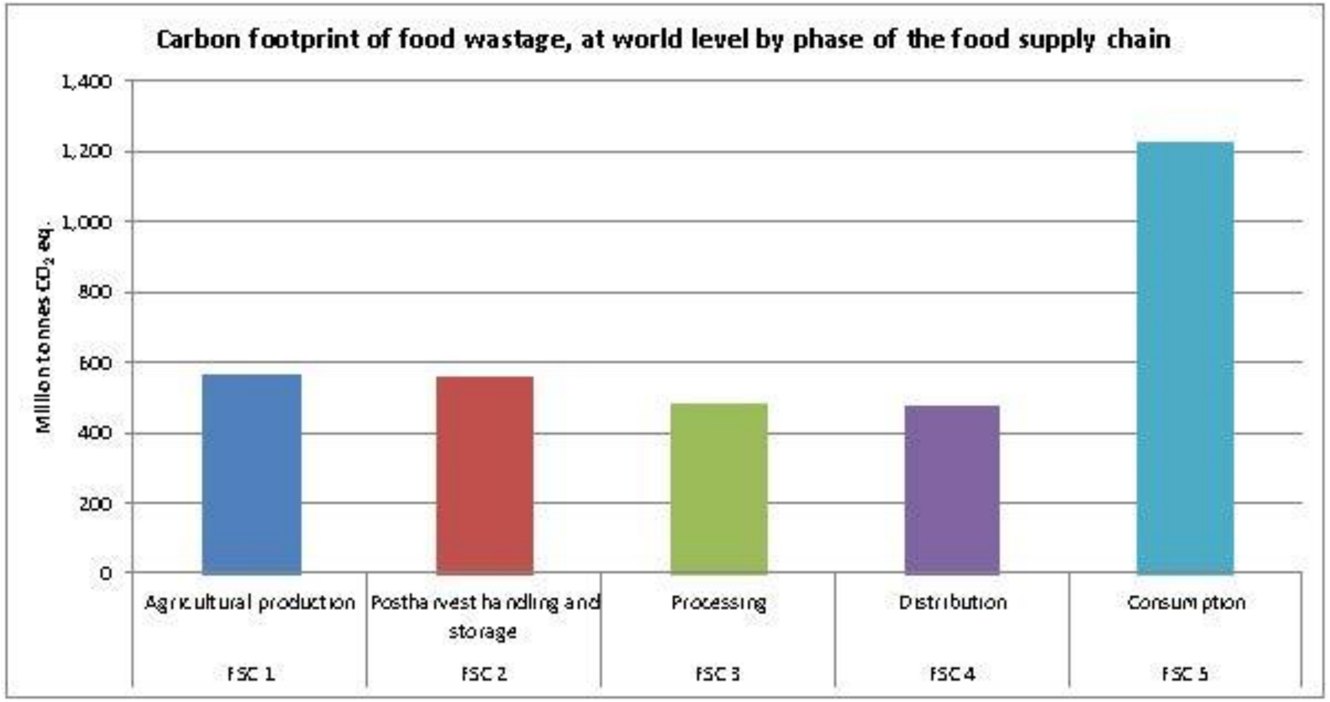
- Improvement in refrigeration equipment energy efficiency
- Reduction in refrigerant GWP
- Improvement in energy efficiency of transportation used to move food

Food Waste Prevention (Post-consumer)

- Food Safety
- Food Quality
- Food Preservation to meet people's needs and reduce environmental impact



Food Loss and Waste is Inefficiency



4.4 Gigatonnes CO2e annual carbon footprint of food loss and waste by life-cycle phase

Sources: http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/FWF_and_climate_change.pdf

http://www.fao.org/docrep/018/ar429e/ar429e.pdf

DELOITTE Food Cold Chain Research

Description of methodology

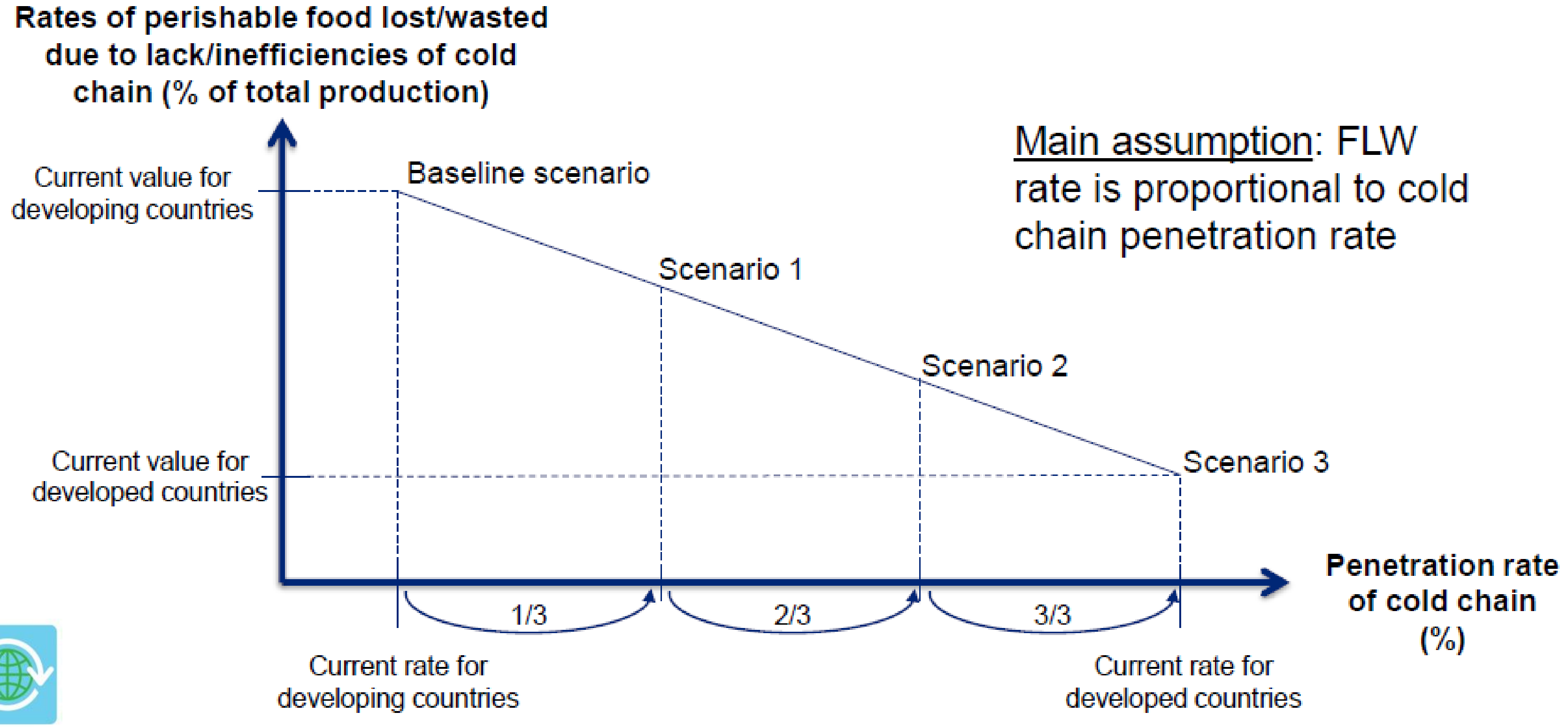
A three-step approach to estimate the potential GHG emissions 'savings' through the development of cold chain

Steps	Tasks
1. Definition of scenarios	• Characterise the **baseline** scenario and the 3 **prospective scenarios** with increasing market penetration rates of cold chains in developing countries
2. Estimation of the gross GHG emissions 'savings'	• Model, for these 3 scenarios, how the development of the cold chain sector could help reduce the carbon footprint of FLW • Estimate resulting GHG emissions 'savings' for the 3 scenarios
3. Estimation of additional GHG emissions from transport and storage	• Model, for these 3 scenarios, the increase of transportation distances and energy consumption due to the use of refrigerated trucks and cold storage • Estimate the supplementary GHG emissions due to cold storage and transport

DELOITTE Food Cold Chain Research

Definition of the 3 prospective scenarios

The scenarios are based on the difference of the average penetration rates of cold chains in developing and developed countries



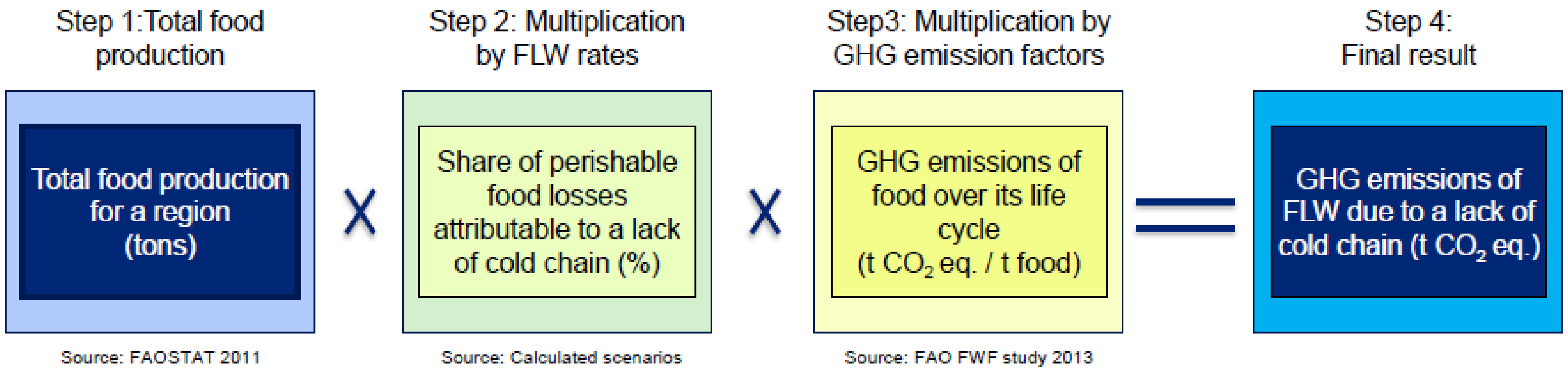
DELOITTE Food Cold Chain Research

Estimation of GHG emissions 'savings' through food waste reduction

Calculation of the carbon footprint of FLW for a scenario

The figure below describes the methodology for calculating GHG emissions "embedded" in FLW for each product group and each region

For an individual scenario, the total FW carbon footprint is the sum of the carbon footprints for all food categories in all regions



This calculation is done for the baseline scenario (current situation) and for the 3 prospective scenarios (progressive increase in cold chain penetration rates)

The total GHG 'savings' for a given prospective scenario is the difference between GHG emissions for the baseline scenario and the GHG emissions for this scenario

DELOITTE Food Cold Chain Research

Estimation of additional GHG emissions from transport

GHG emission factors (EF) for refrigerated and non-refrigerated transport

- For non-refrigerated food, a unique GHG EF for transport is used:
  - Representative of lorry with 16 tons of load
  - GHG emissions = 1.03 kg CO_2 eq./km[1]
- For refrigerated food, a new EF for transport is calculated, based on:
  - GHG emissions for a lorry of 16 tons of load
  - Additional emissions due to overconsumption of diesel for the refrigeration system: +21% diesel consumption[2]
  - Additional GHG emissions due to refrigerants production and leakage[3]:
    - R404A refrigerant used for calculation
    - Composition of R404A : 44% R125, 52% R143A and 4% R134A
    - Refrigerant leakage: 14% per year
  - Calculated GHG emissions = 1.29 kg CO_2 eq./km

Sources:
1 – Data from EcoInvent database
2 – ADEME (French Environment and Energy Agency) 2012
3 – Data from University MINES, 2009. Inventory of emissions from refrigerants

DELOITTE Food Cold Chain Research

Estimation of additional GHG emissions from storage

GHG emission for the refrigerated storage systems along the chain

- It is assumed that there are no GHG emissions due to storage in case of non-refrigerated food chain.
- Moreover, due to the lack of information, the energy consumed by pre-cooling equipment in packhouse facilities was not taken into account.
- According to a study carried out by the FRPERC, the total energy consumed by UK cold storage for refrigeration represents 19% of the total energy used in refrigerated transport for UK[1].
- Using this figures the calculated emissions related to energy used for cold storage represent about 25% of the emissions related to the energy used for refrigerated transport (based on GHG emissions factors for electricity and diesel representative of Europe).
- This ratio enabled the team to use the calculated emissions factor for refrigerated transport as a basis for the emissions related to storage within cold chains.

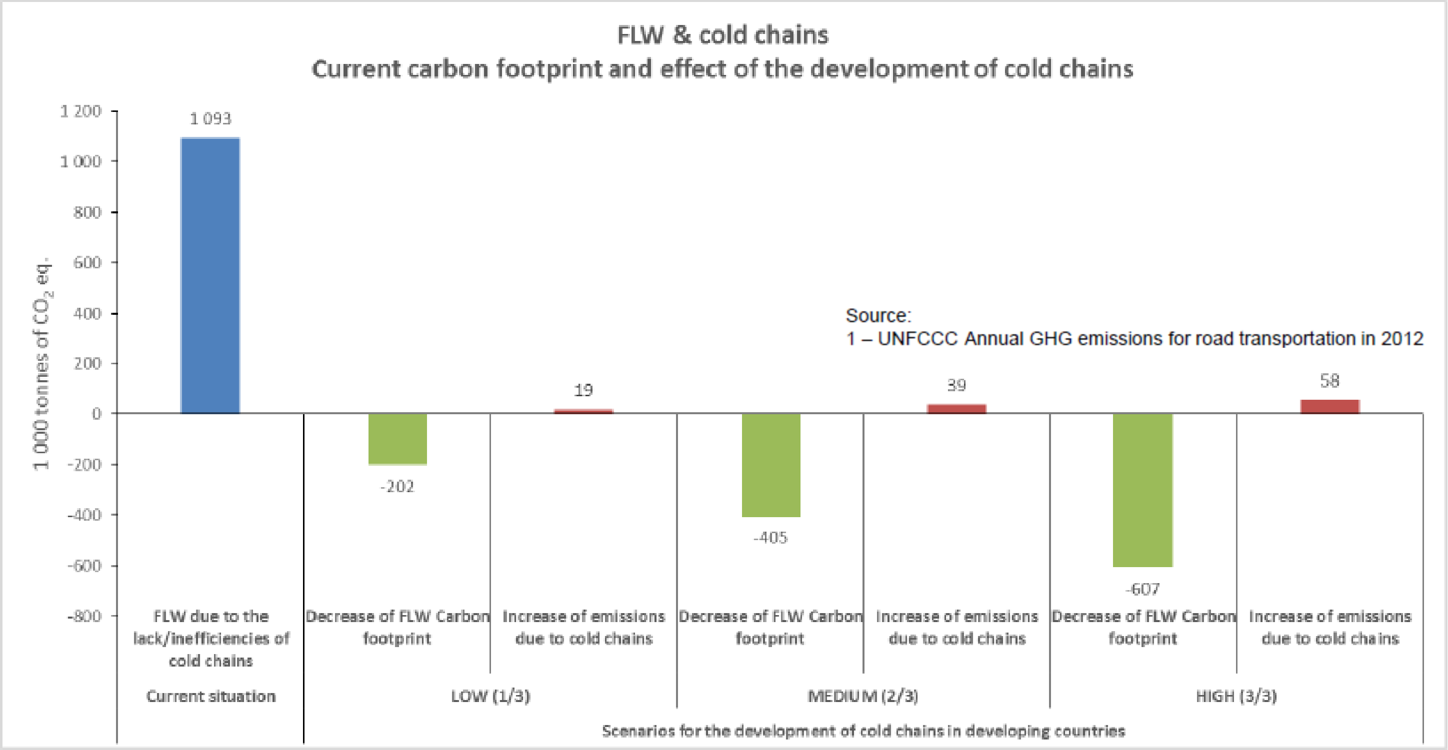
Source:

1 – Food Refrigeration and Process Engineering Research Centre (FRPERC), 2008. Energy use in food refrigeration - Calculations, assumptions and data sources

DELOITTE Food Cold Chain Research

Results from the model (1/3)

According to the model used, in all prospective scenarios, the decrease of FLW carbon footprint from cold chain expansion clearly outbalances the newly created emissions, by a factor 10 approximately.

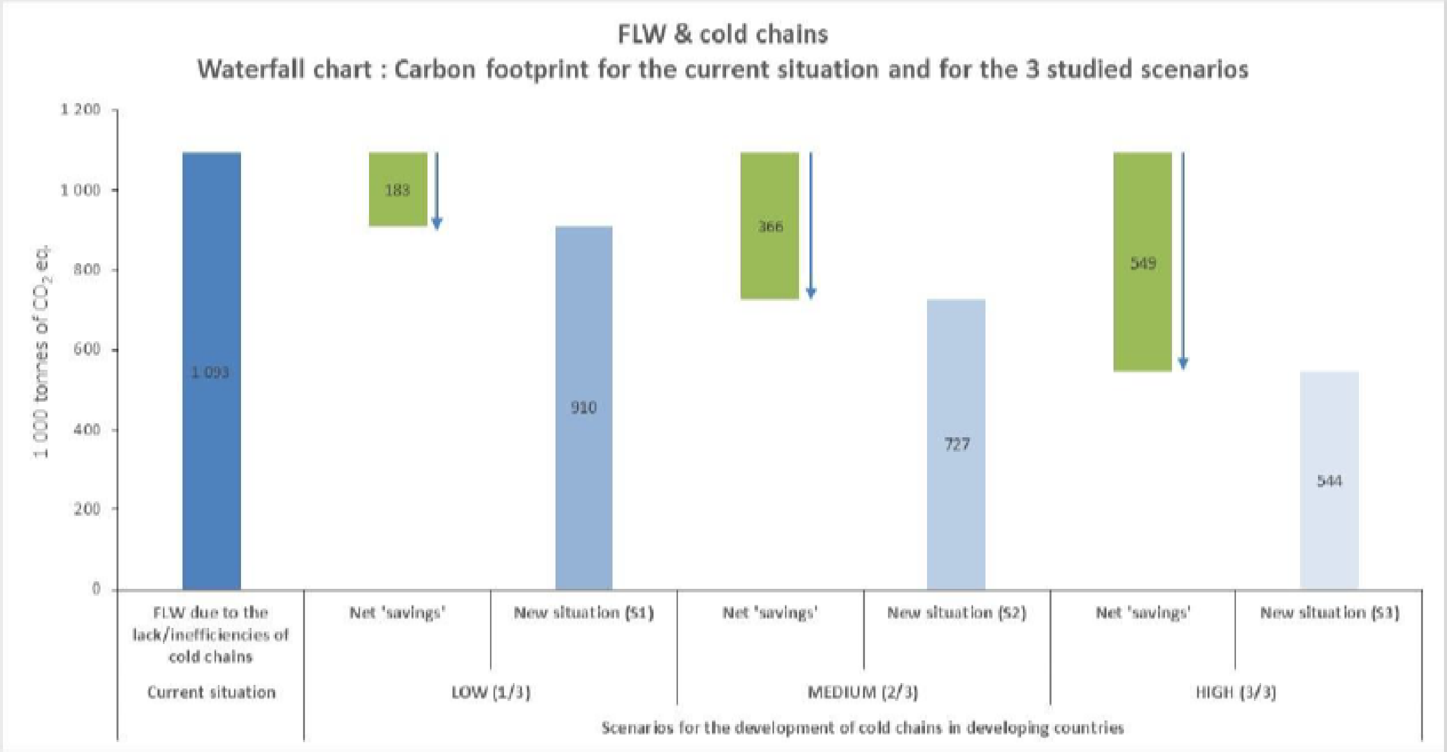


The total amount of food wastage in 2011 has generated about 1 Gtons of CO_2 equivalent, an amount comparable to the total GHG emissions of road transportation in the EU (0.9 Gt)[1].

DELOITTE Food Cold Chain Research

Results from the model (2/3)

According to the model used, net GHG 'savings' are observed for the 3 prospective scenarios



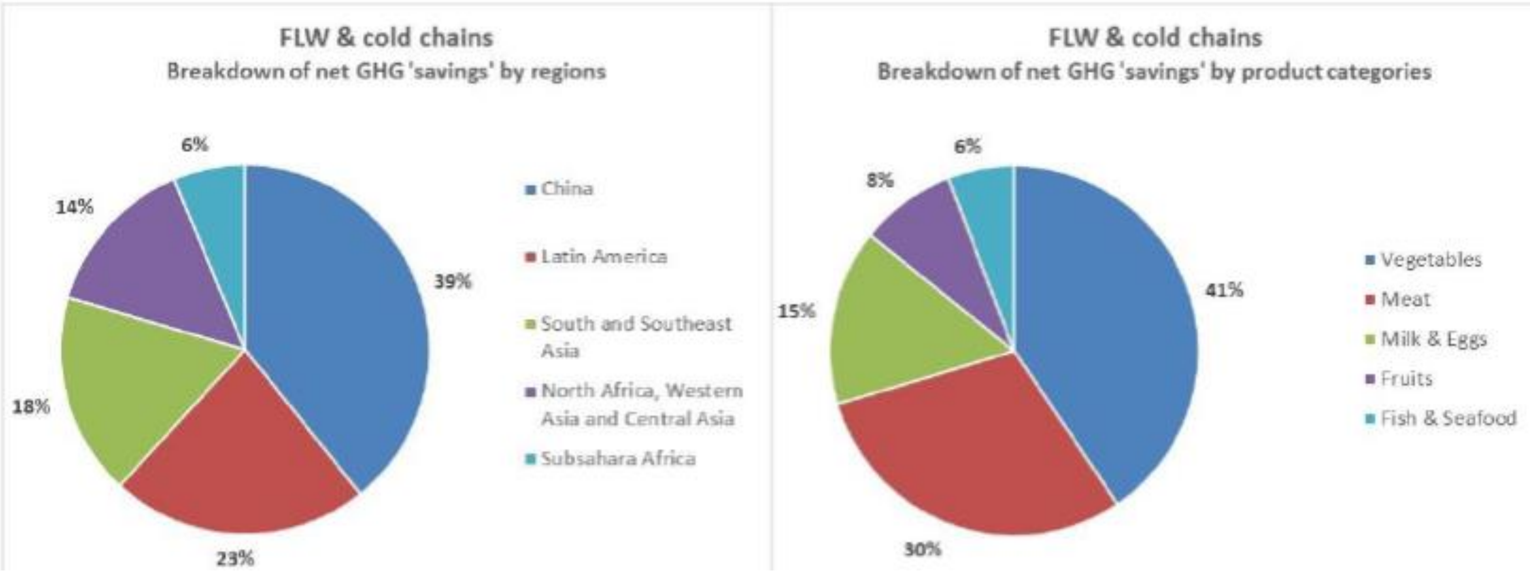
In scenario 1, the net GHG 'savings' would represent circa 180 Mtons of CO_2 eq. In scenario 3, the net 'savings' would represent circa 550 Mtons of CO_2 eq. As an illustration of the magnitude of these results, they can be compared to the total emissions of France – i.e. circa 450 Mtons of CO_2 eq. in 2012[1].

Source:
1 – European Environment Agency (EEA), June 2014

DELOITTE Food Cold Chain Research

Results from the model (3/3)

Breakdown of net GHG ‘savings’ by regions / product categories



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Potential Partners

Government

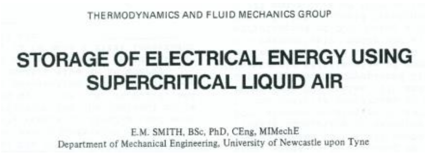
- CCAC
- UNFAO
- UNFCCC
- UN SAFE FOOD
- Montreal Protocol MLF
- Green Climate Fund
- UNEP & OzonAction
- World Bank
- Commission for Environmental Cooperation
- ICAO
- IMO

Nongovernment

- Champions 12.3
- Global Cold Chain Alliance
- ReFED
- World Resources Institute
- International Council on Clean Transportation
- Smart Freight Centre
- LixCap
- National Centre for Cold Chain Development (India)

LIQUID AIR AS EXAMPLE OF NOVEL ENERGY VECTOR / CAN WE HARNESS THE WASTE COLD OF LNG?

Dr Rob Morgan, University of Brighton, Professor Milind Atrey (IIT Bombay)
Professor Judith Evans (LSBU – the Cryohub Project) and Scott MacMeekin (Dearman)


THERMODYNAMICS AND FLUID MECHANICS GROUP

STORAGE OF ELECTRICAL ENERGY USING SUPERCRITICAL LIQUID AIR

E.M. SMITH, BSc, PhD, CEng, MIMechE
Department of Mechanical Engineering, University of Newcastle upon Tyne

1970's

2005-2009

2010-2014

2015-2020

Highview

Dearman

The CryoHub project

Judith Evans (LSBU)





This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 691761.

A Cool World

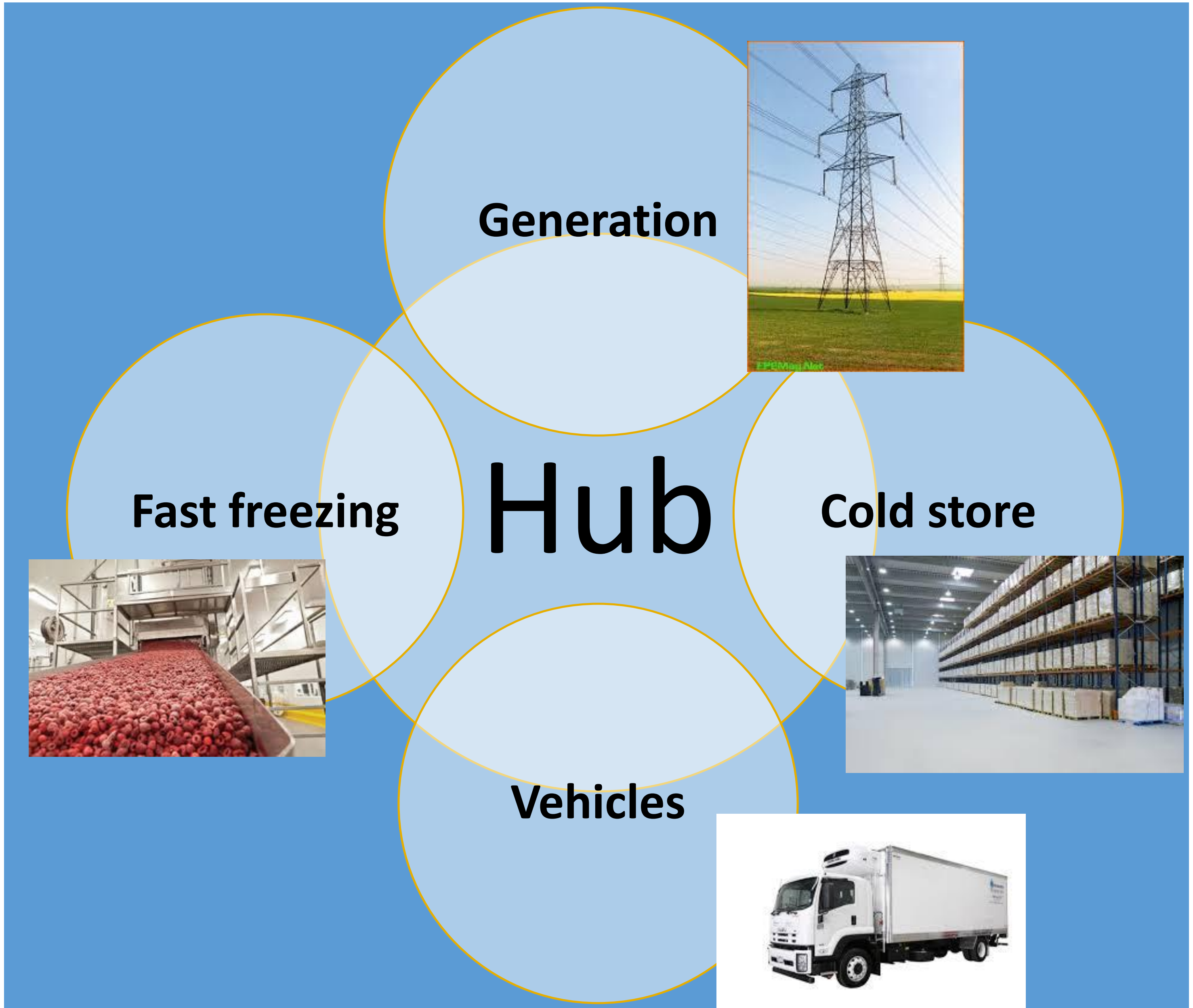
19.04.18

EU aim to generate 20% of the energy used in Europe from renewable sources by 2020

More RES

"A next-generation smart grid without energy storage is like a computer without a hard drive: severely limited." Katie Fehrenbacher, GigaOm

The CryoHub concept



Further information:

www.cryohub.eu

Judith Evans – project coordinator:
j.a.evans@lsbu.ac.uk

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 691761.

THE VALUE OF MAINTENANCE

Andy McPhun, Wave Refrigeration

#CoolWorldCongress
WWW.BIRMINGHAM.AC.UK/ACOOLWORLD

The Value of Refrigeration Maintenance

Andy McPhun MInstR

Technical Consultant, Wave Limited

19th April 2018

The Value of Maintenance Overview

- About the Presenter and
- Sustained Performance – uptime & efficiency
- Refrigerant Leakage
- Example Findings
- Summary

Andy McPhun

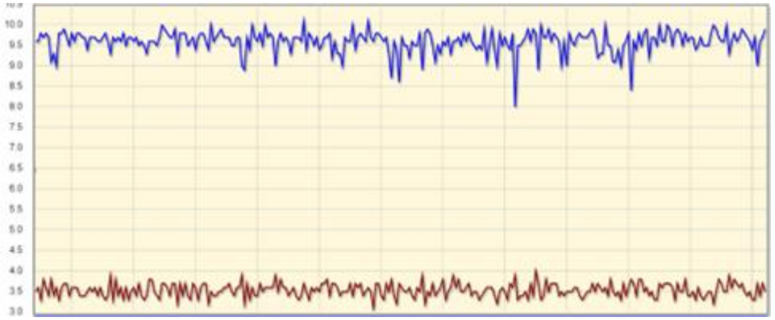
- Joined the industry in 2009 as a trainee Design Engineer working in the retail sector.
- Learned technical refrigeration as a Design Engineer and gained some experience in the industrial sector.
- Joined Wave Refrigeration in July 2017
- Keen on energy efficient solutions, latest technologies, and longevity of solutions through proper design engineering

wave

- James Bailey began Wave in 2015 working as a freelance refrigeration consultant to several well known retailers
- Wave has a branch in India which supports our UK operation with a range of capabilities including CAD operators, technical design reviews, system equipment selections and many others
- 5 senior Design Engineers and Project Managers in the field but we are growing every day
- Not just Design Engineers and Consultants, Wave can also offer services such as pressure test witnessing, Fault finding and investigation, and can act as Professional Witness in legal cases

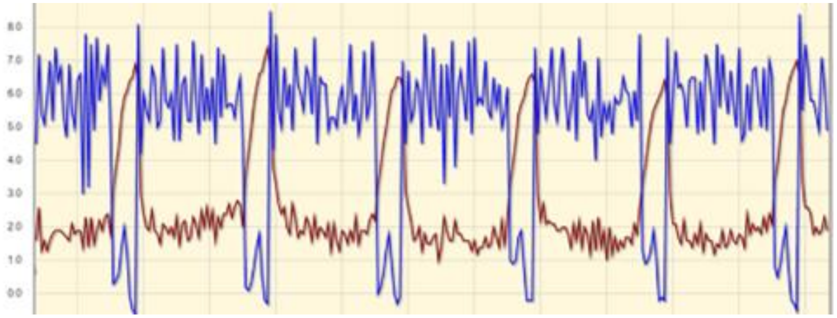
The Value of Maintenance

Sustained Performance – uptime & efficiency (Indirect Emissions)



- Suction pressure (bar)
- Discharge pressure (bar)

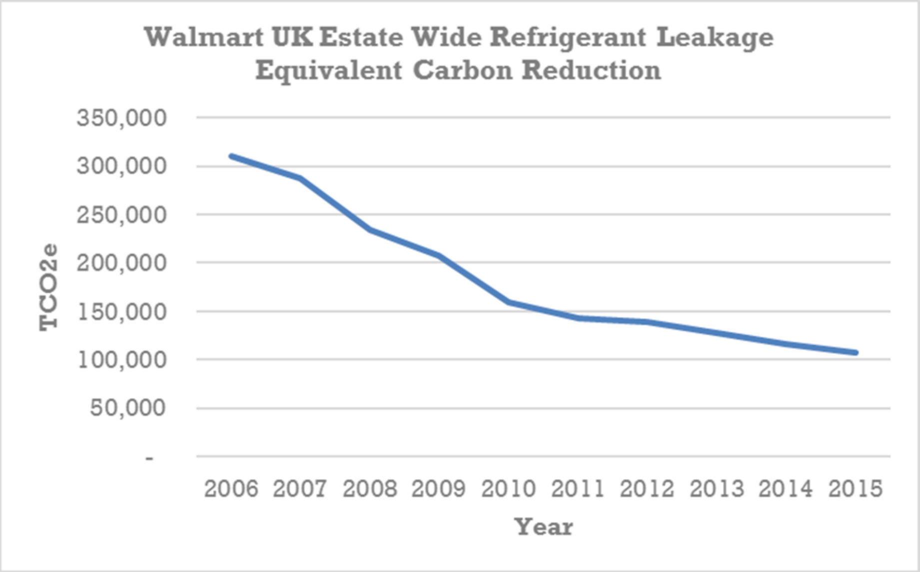
- Discharge temperature (°C)
- Ambient temperature (°C)

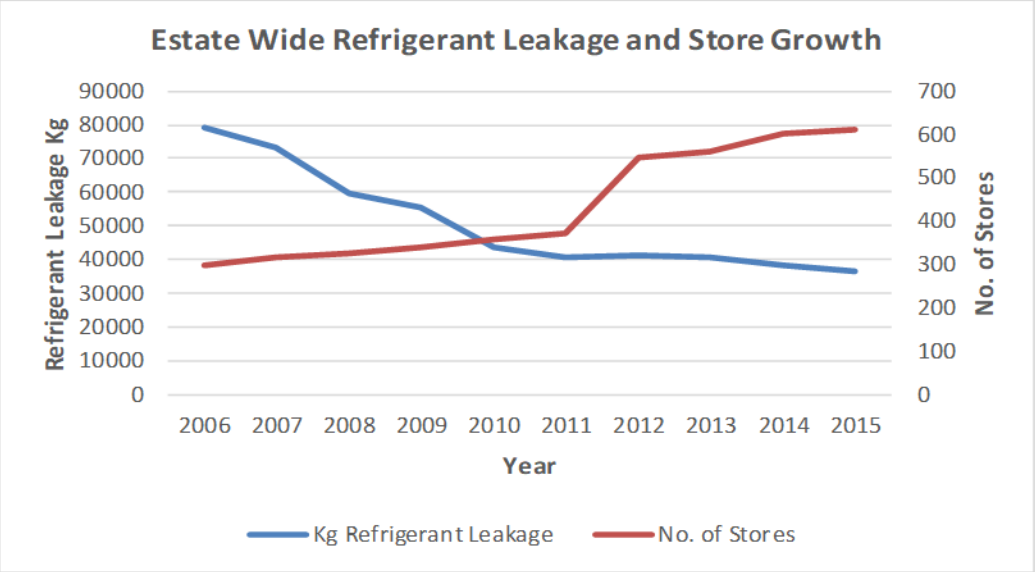


- Control temperature (°C)
- Superheat (K)

The Value of Maintenance

Refrigerant Leakage (Direct Emissions)





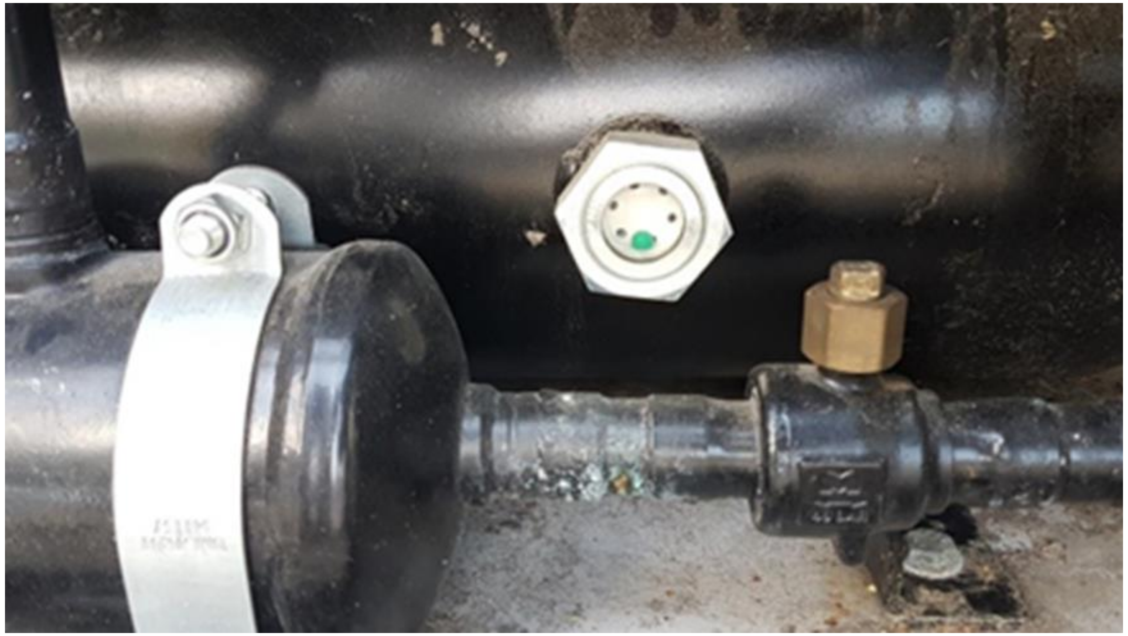
To put the above into perspective the direct carbon emission savings are equivalent to a Boeing 747 carrying 346 passengers flying from London to New York a staggering 489 times! – Based on 1.2 TCO2e per passenger (source www.eta.co.uk)

The Value of Maintenance

Example Findings

The Value of Maintenance – Example Findings

Example Findings



The Value of Maintenance – Example Findings

Example Findings

The Value of Maintenance – Summary

- $Q = M. \times cP \times \Delta T$ - This fundamental formulae is for calculating work achieved in a system. It is clear from this formulae that any reduction in Mass flow must result in an increased temperature differential to achieve the same duty

- Every 1°C in rise in condensing temperature or 1°C drop in evaporating temperature results in approximately 3 - 4% increase in energy consumption

- Undercharged / leaking refrigeration systems will cause a significant increase in energy consumption as well as lost gas contributing to the global warming crisis

- Simple things like degraded suction line insulation, blocked condenser coils etc will have a detrimental energy impact

- Good maintenance will provide tangible energy benefits & promote environmental stewardship through reduced carbon emissions

- Regular maintenance visits and checks also help with pre-planned maintenance as the engineers can better assess the expected lifespan of components and can schedule the replacement of items accordingly

The Value of Maintenance

Questions

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PRACTICAL ASPECTS OF A TRANSITION TO CLEAN COOLING IN RETAIL

Dr Thomas Tomski, Emerson Commercial & Residential Solutions

#CoolWorldCongress

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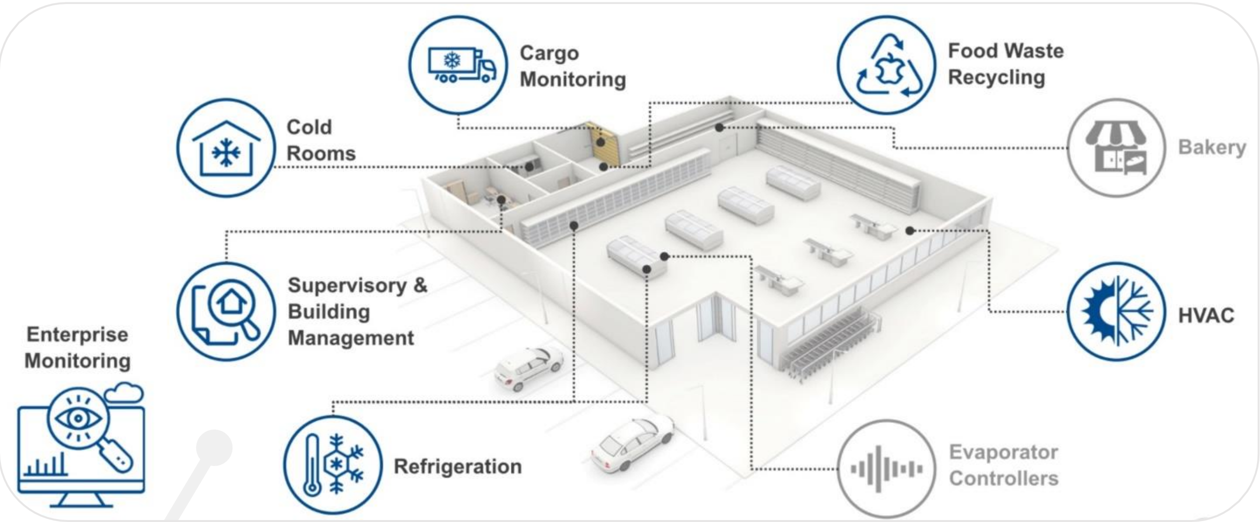
PRACTICAL ASPECTS OF A TRANSITION TO CLEAN COOLING IN RETAIL

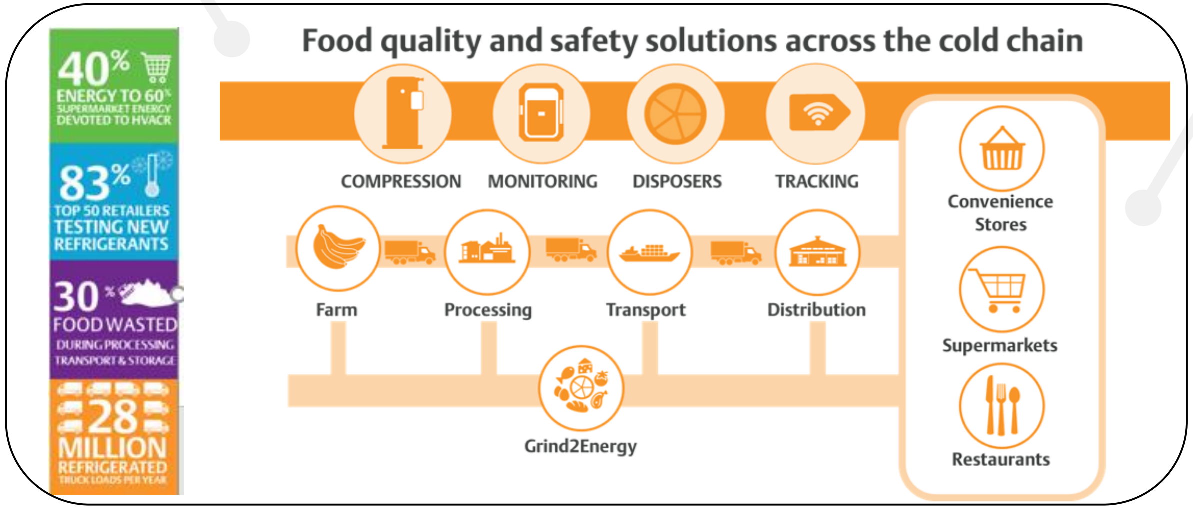
Dr. Thomas Tomski

Emerson Commercial & Residential Solutions

1st International Congress on Clean Cooling
18th – 19th April 2018, University of Birmingham

Emerson (2016): 2 Business Platforms: Automation Solutions and Commercial & Residential Solutions, $14.5B Turnover, 74k Employees





Our Brands include

Copeland

Alco Controls

Dixell

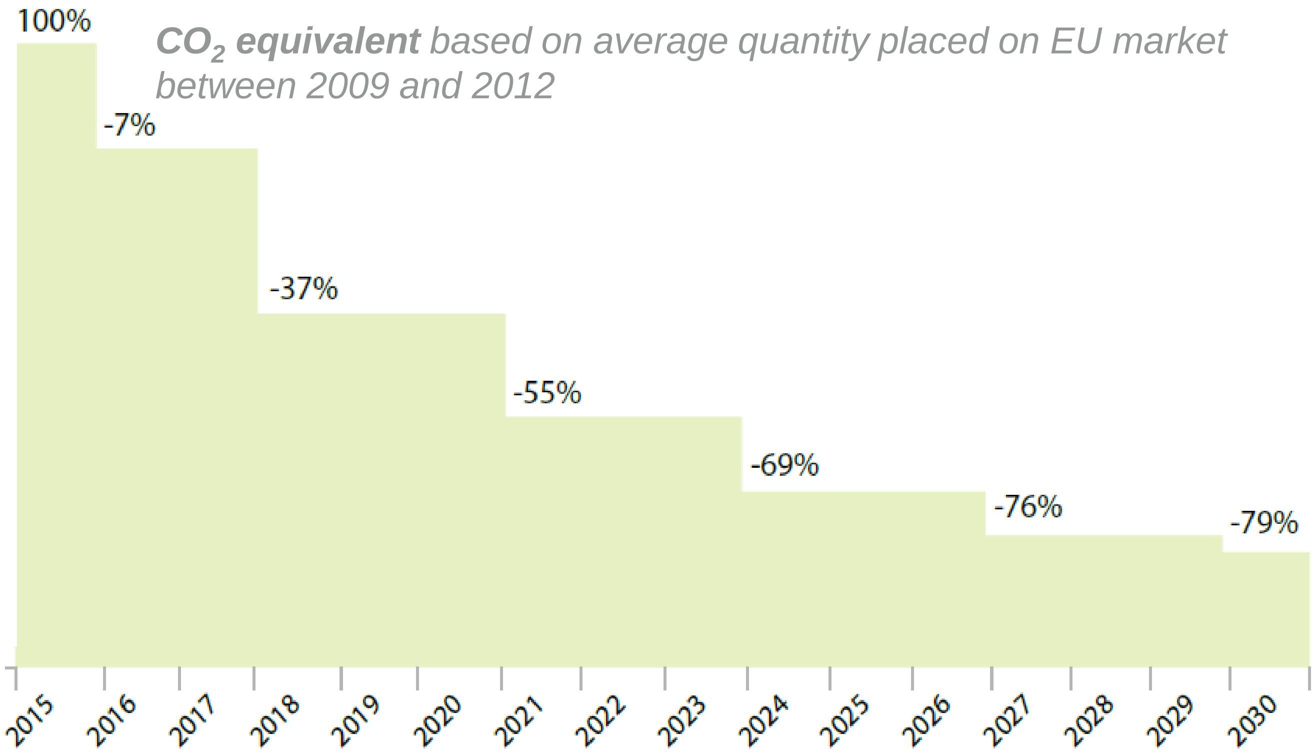
InSinkErator

ProAct

RIDGID

EU F-gas Regulation Creating Impact Through Its First Major HFC Quota Cut in 2018

- EU F-gas Regulation targets are **ambitious but achievable**
- EPEE* Gapometer Roadmap suggesting focus on **four core measures**
    - Use of lower GWP refrigerants in new equipment
    - Reduction of leakage from existing equipment
    - Retrofit of high GWP refrigerants in certain types of existing equipment
    - Recovery and reclaim of waste refrigerant
- EU F-gas **price rise** (>500% for R404A) driving fast market reaction – immediate choice may not be best
- **Centralized CO2 booster system** the **preferred** „future-proof“ solution in large retail but market overall still dominated by solutions >>150 GWP
- Survey findings showing **gap between EU policy maker intentions and market activities**

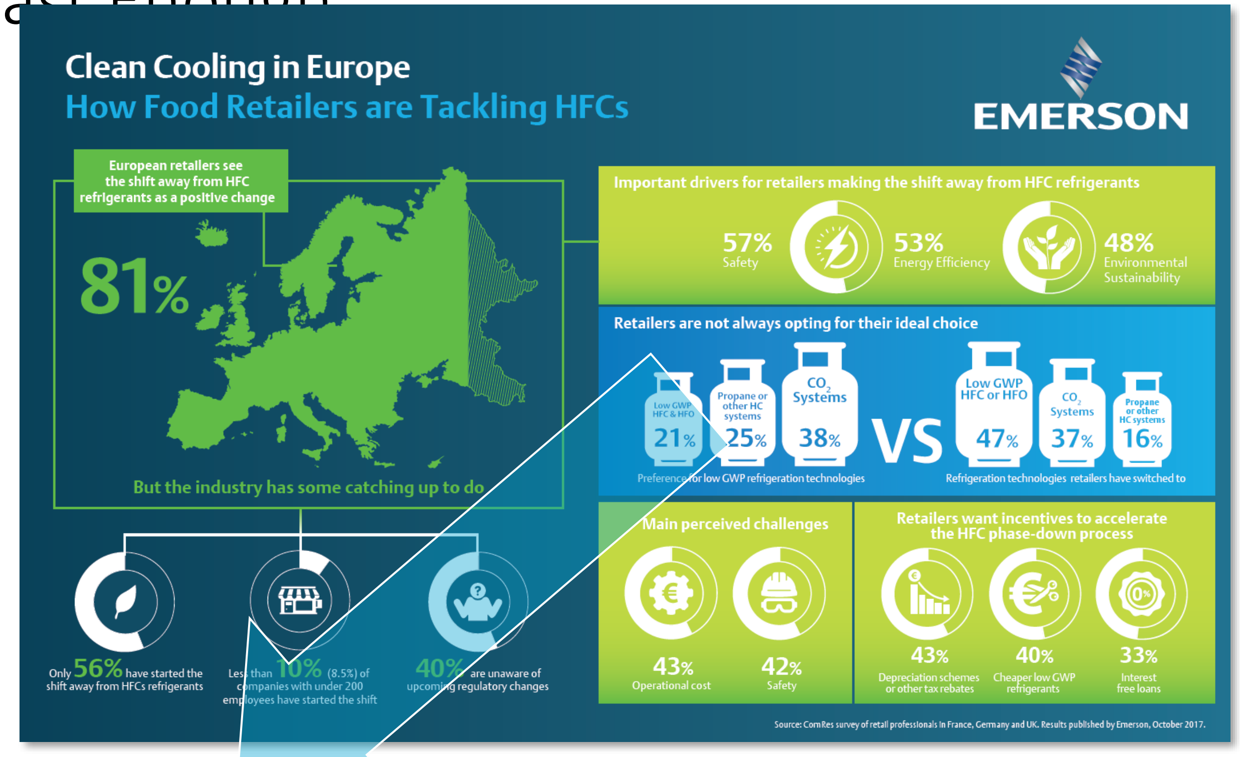


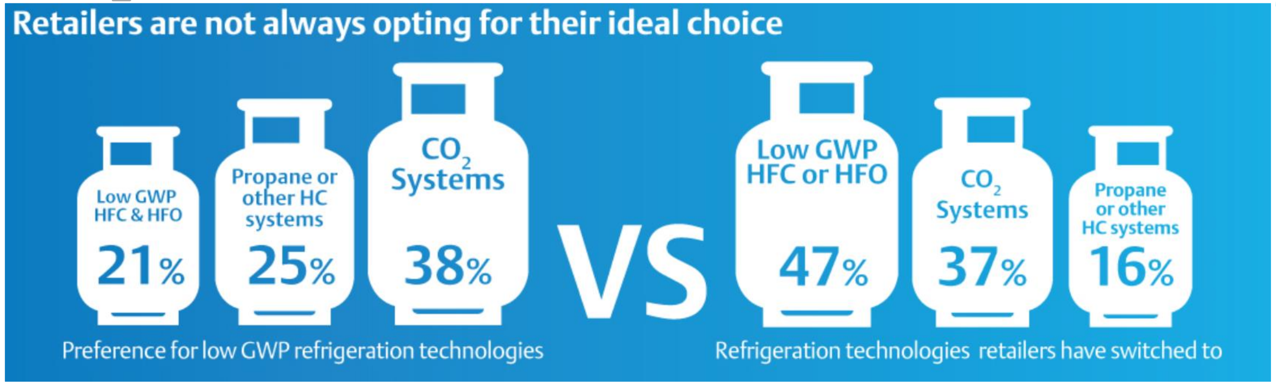
Phase-down of HFC refrigerants allowed to be placed on the EU market

**EPEE European Partnership for Energy and the Environment*

Survey Highlighting Retail End User Gaps Between Willingness and Ability to Tackle the HFC Transition Fast Enough

- 81% of European retailers see a **shift to lower GWP refrigerants** as a **positive change**
- Only 56% have started transferring, small **businesses are struggling** and there are **gaps in awareness of regulatory changes**
- Key **decision making criteria** are **safety, energy efficiency & environmental sustainability**
- **Retailers** who are making the shift, haven't gone with their first choice, indicating they **may be rushing into the wrong decisions**





Survey conducted by ComRes on behalf of Emerson, August 2017, 140 participants with retail purchase decision making responsibility, Germany, France, UK

EU Commission Calls For Acceleration in Natural Refrigerants Training to Close Skill Gap

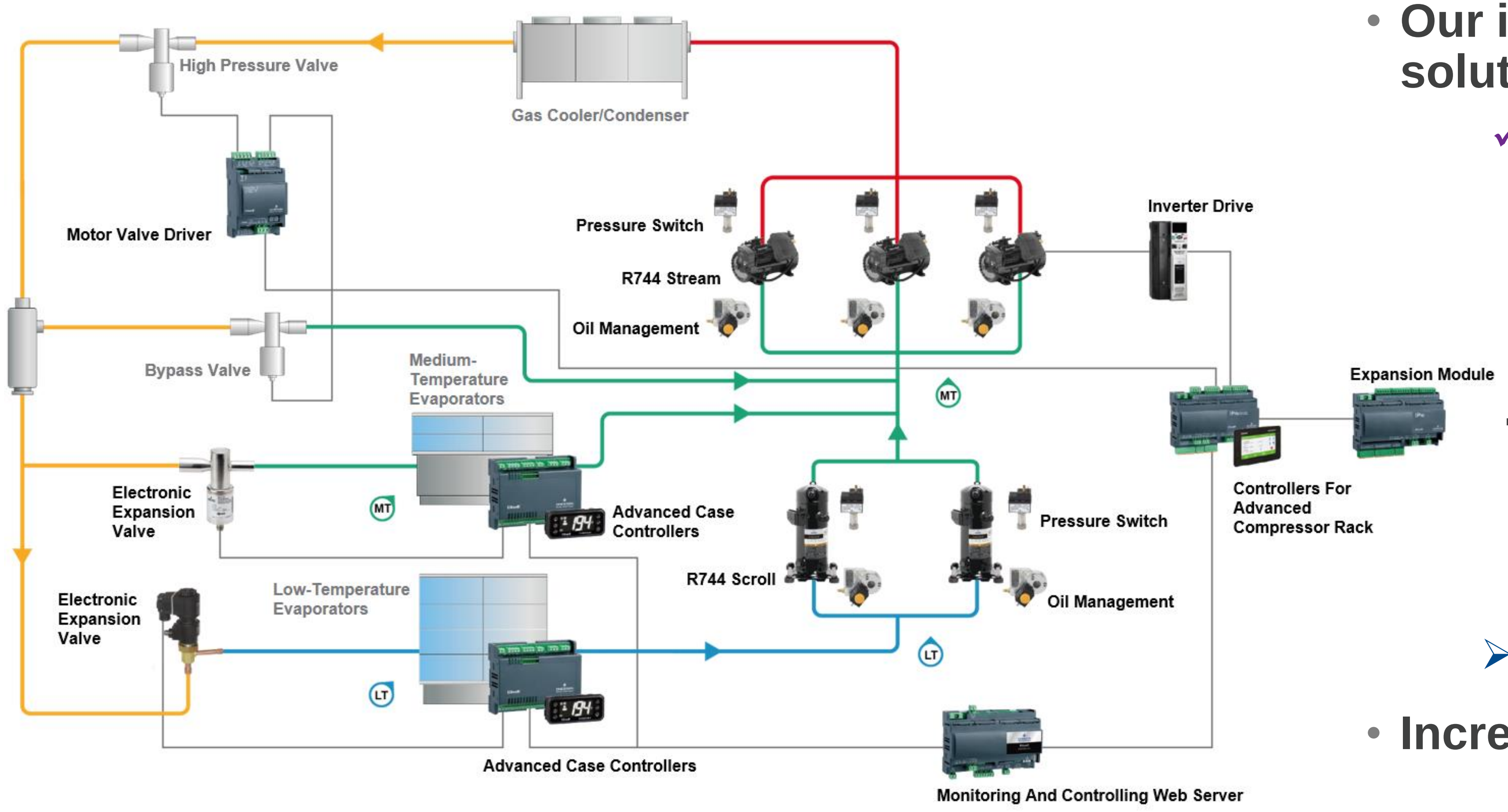
EU Commision survey on training for natural/alternative refrigerants covering 22 EU member states	Ammonia	CO2	Hydrocarbons (small hermetic)	Hydrocarbons (large systems – split/chillers)
Training available in country	71%	52%	48%	35%
Proportion of certified F-gas personnel training in natural refrigerants	**2.3%**	**2.2%**	**0.7%**	**0.05%**

*From **European Commission Report (2016)** on availability of training for service personnel regarding the safe handling of climate-friendly technologies replacing or reducing the use of fluorianted greenhouse gases, survey covering 22 EU member states*

- 160,000 certified F-gas technicians serving EU-22 population of 400 mio people
  (approximate EU-22 population covered by survey)
- 8,000 – 10,000 technicians trained on natural refrigerants in 2015
  (Shecco, Guide to Natural Refrigerants Training in Europe, 2017)
- How would this translate to emerging economies like India with a population >1.3 bio people?

Designing technology for simplicity in operation, service and maintenance can help further in closing the skill gap!

Converting the Legacy Remote System Architecture From HFC to CO_2 Is One Answer



- **Our industry is great in finding solutions....**
  - ✓ **Ejectors**
  - ✓ **Parallel compression**
  - ✓ **Standstill pressures**

...to technical challenges

- ➢ **Seasonal Efficiency**
- ➢ **System resilience**
- ➢ **Rising pressures**

- **Increasing complexity is the price!**

But it may not be the best possible answer to all needs!

The Proliferated European Market Requires More Than One Technology Solution to Match Individual Needs

Investment Cost

Lifecycle Cost

Operating Cost

Compliance & Sustainability

Revenue Impact

Space Constraints

Safety Aspect

Refrigerant Charge

Skill (Design)

Cases Door

Regional Service Infrastructure

Skill (Installation)

Skill (Operation)

Budget (Capital)

Regulatory Updates

Local Regulations

Ease Of Installation

Regional supply Infrastructure

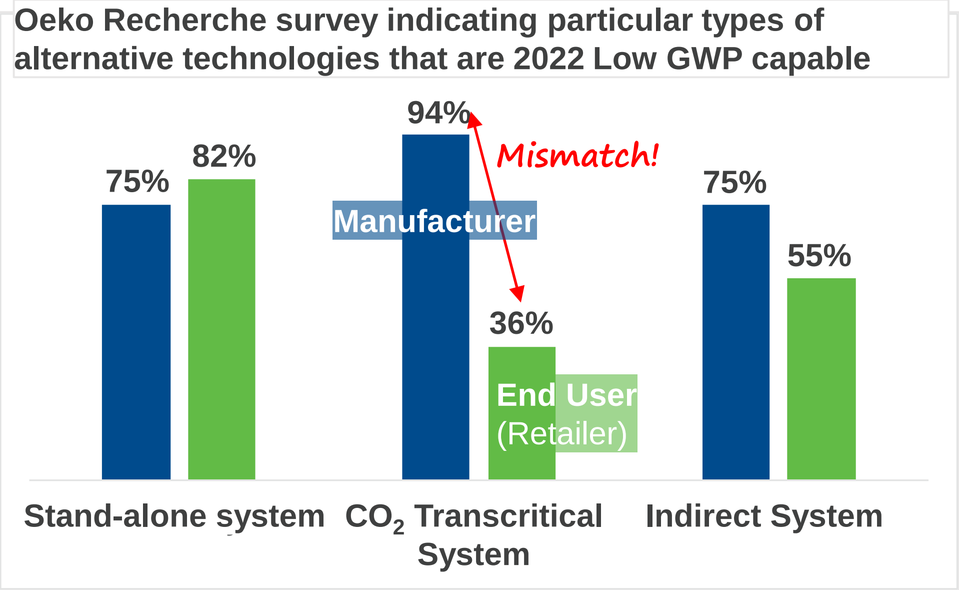
Reluctance to Change

Retrofitability

Refrigerant Cost

Supermarket Format

Store Opening Re-opening Speed



Data from Öko-Recherche Briefing Paper: Availability of alternatives to HFCs in commercial refrigeration in the EU, Nov 2016

Technology Proliferation

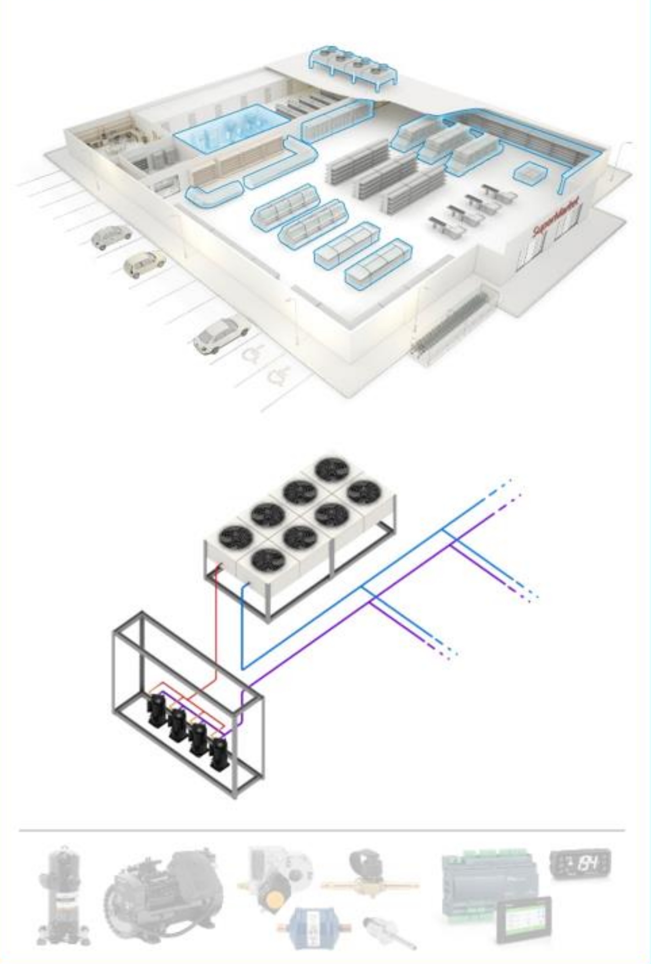
Remodeling Frequency

Component Availability

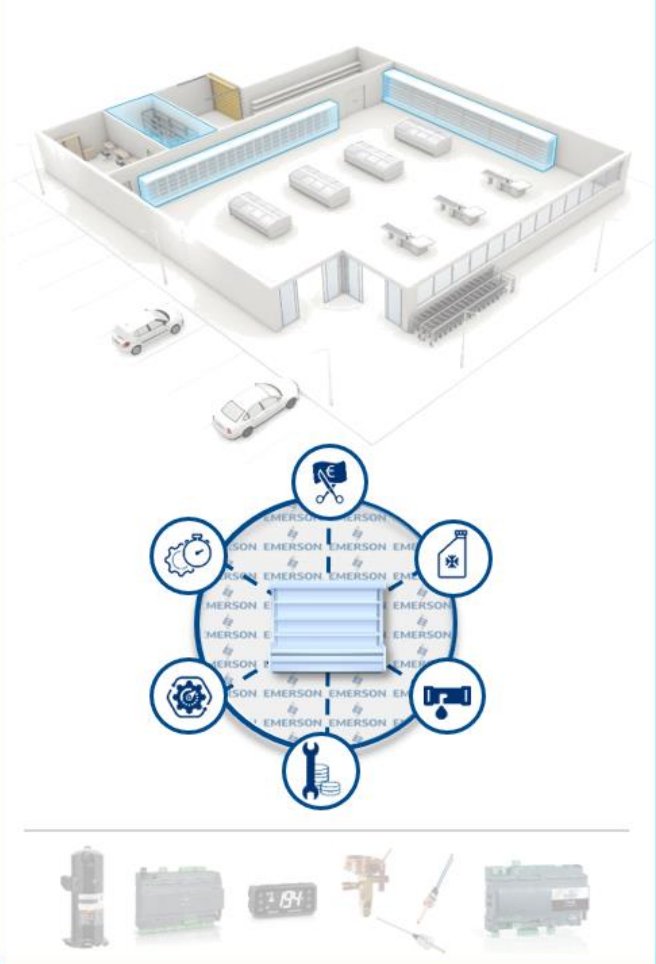
End users need to carefully analyse their needs and make a conscious decision – taking into account their own needs as well as their supply chain infrastructure and environment

Three System Architectures That Should Be Thoroughly Assessed By Retailers Before Making A Technology Decision

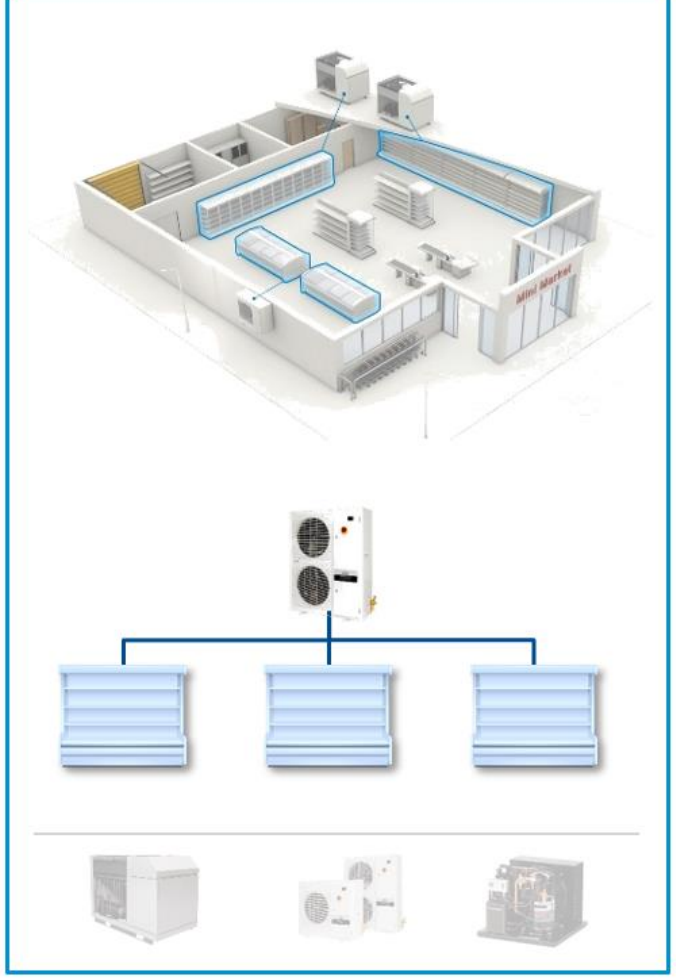
Centralized



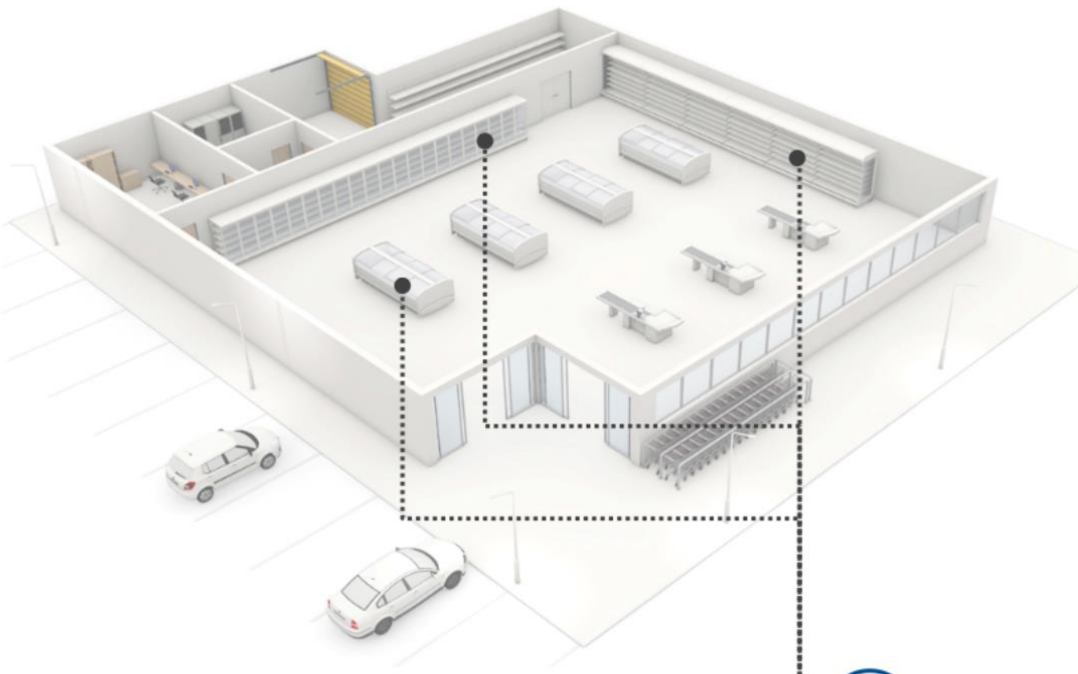
Self Contained



De-centralized



Self-contained Display Case & Cold-Room Store Architecture With Waterloop Condenser

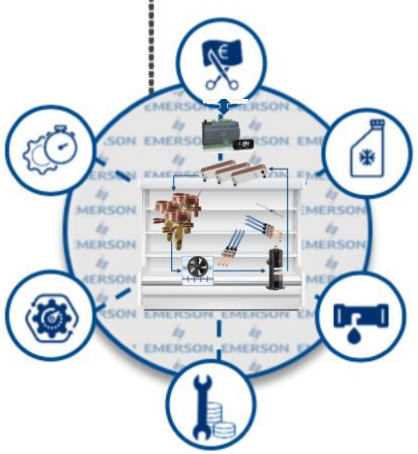


- Refrigeration system integrated into cabinet
- Natural hydrocarbon refrigerant pre-charged in factory
- Condenser heat dissipated via waterloop
- Free-cooler / chiller option
- Heat recovery / heat pump option

- Reduced overall store refrigeration charge
- F-gas compliance beyond 2022
- **Factory producted & tested** – avoiding on-site refrigeration engineering
- **Enhanced flexibility** during store construction and refurbishment improving business results!

- *Comparison versus CO2 booster system*

Emerson self-contained diplay case solutions accelerate time-to-market and optimize system design



Quantitative Assessment of R290 Self-contained System Architecture Vs Remote R744 (CO_2) System – Lifecycle Cost

10 Year life cylce cost, avg 10 display cases per store (€)	System A **R744 Remote**	System B **R290 Integral**	System B **Saving**
Investment	142,294	113,090	29,204
Energy	148,928	139,835	9,093
Service, maintenance, insurance	35,104	28,675	6,429
Decommissioning	6,296	4,282	2,014
3 days earlier opening			1,800
Cost of shut down due to refurbishment			1,800
Loss of performance due to leaks			715
10 Years saving per store	**332,622**	**285,882**	**51,055**

510 M€ lifecycle cost saving

for a discounter with 10 000 stores – 10 years lifespan

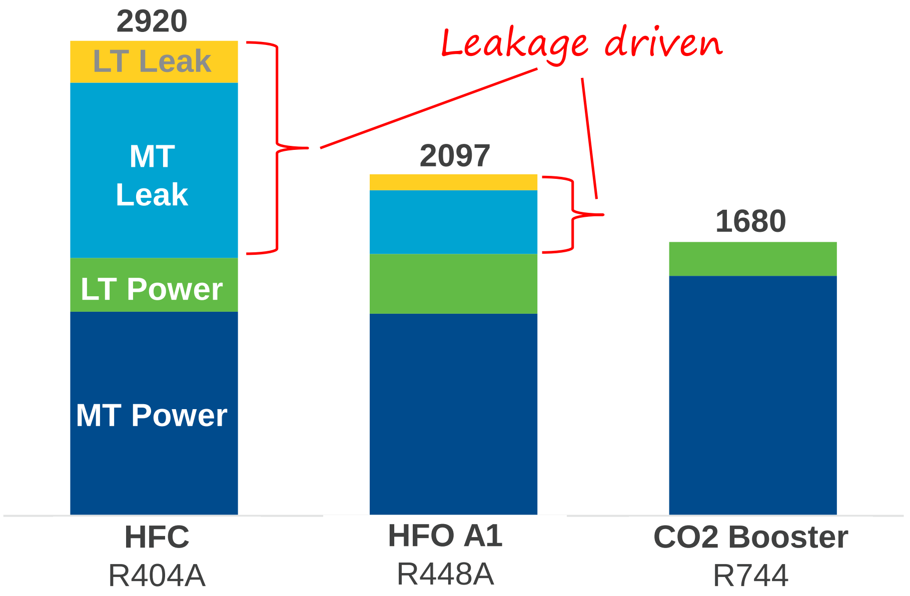
Study Assumptions Discounter Store, Munich Area

- Discounter store, Munich/Germany area, medium temperature display cases only, 1,000 m2 vending area, integral Copeland Scroll compressors, comparative CO2 booster system using 3 x Stream CO2 transcritical (1 x inverter); minimum condensing: 10°C, 50 kW useful refrigeration capacity

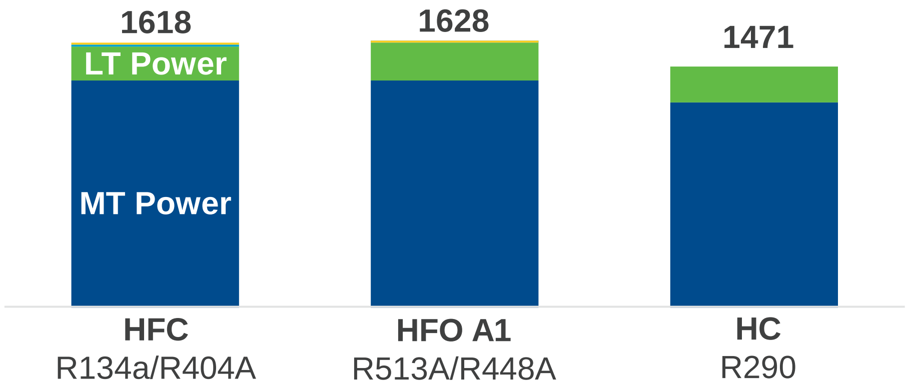
Investment	**Energy Consumption**	**Service & Maintenance**
Planning, rack, free cooler, cost adder for ref circuit in display cases	*Temperature profile, Munich/Germany, compressor power, free cooler, condenser, pumps*	*Maintenance contract for regular service, hygenic cleaning, reactive maintenance according to VDI2067/1*
Decommissioning	**Earlier Store Opening**	**Loss of Performance / Leakage**
Both systems out of service after 10 years	During refurbishment, daily turnover 20 k€, EBIT 3%	Deteriorating system performance due to running at lower evaporating temperature for the remote rack, 2 K lower for accumulated 1 year during 10 year lifespan

Study for Investment, Energy, Service & Maintenance & Decommissioning conducted by independent institute ILK Dresden/Germany

With Natural Refrigerants Direct GWP Becomes Negligible - With Transitional Refrigerants Charge Reduction Has Significant GWP Impact



Central system TEWI [tons CO2e] – transitioning from HFC over HFO to CO2

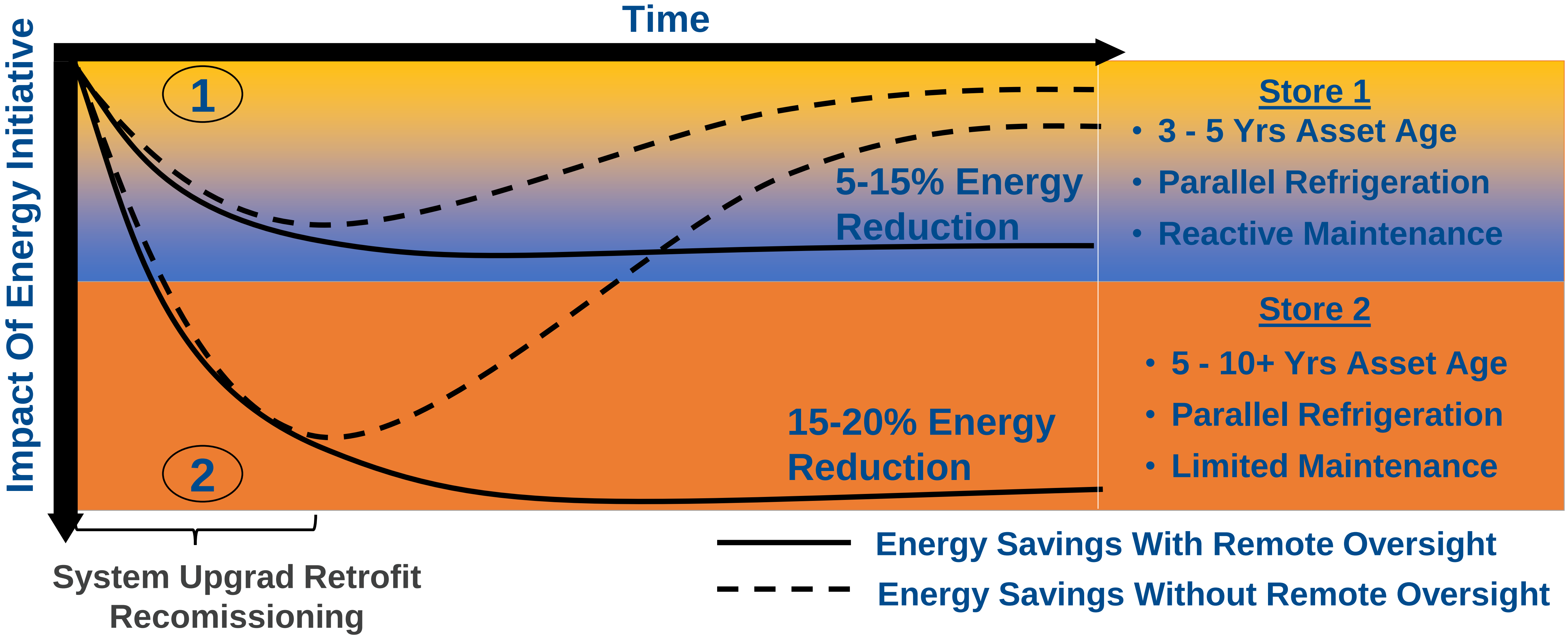


Self-contained system TEWI [tons CO2e] – transitioning from HFC over HFO to HC

TEWI Analysis, Source: Emerson, Right Balance Tool; Northern Europe, MT: 89 kW, LT: 12 kW, leakage rate central system: 10%, leakage rate self-contained: MT/LT 1%/3%, centralized system using Copeland Stream/Discus compressors, self-contained system using Copeland Scroll compressors

- Reduced charge systems are an important contributor to GWP emission reduction as the industry transitions from HFCs to Natural refrigerants
- Leakage avoidance is important also with Naturals – as it affects safety, system reliability and efficiency

Sustain Savings Through Oversight



Without continuous Oversight Benefits Are Compromised Within 12-18 Months

Conclusions

- F-gas transition is a challenge but also an opportunity
- End users should not rush into quick technology decisions but analyse carefully total business impact for their individual case
- Integral display cases may have significant saving potential for retailers with more than 50 k€ per store over its lifespan – more than 500 M€ for 10 000 stores
- Recommended features for any technology of choice are:
  - Increased degree of factory production and avoid on-site refrigeration engineering
  - Reduced refrigerant charge and piped joints – even for natural refrigerants!
  - Complexity reduction and simplicity of design, service and maintenance help to address skill shortages

Thank You!

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WHAT SHOULD COOLING LOOK LIKE IN 2030 AND HOW MIGHT WE ADVANCE MANUFACTURING TO GET THERE – GLOBAL SCIENCE, LOCAL SOLUTIONS?

Professor Yulong Ding (University of Birmingham),

Dr Kamelia Atefi Monfared (University at Buffalo) and Peter Corby (Manufacturing Technology Centre)

To include questions with Dr Thomas Tomski (Emerson Commercial & Residential Solutions)

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Dark cold sky ~-270°C

Cooling technologies for 2030

Yulong Ding

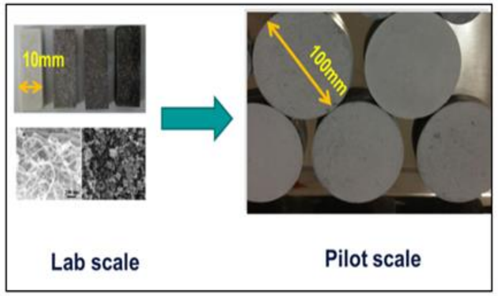
Chamberlain Professor of Chemical Engineering
Royal Academy of Engineering - Highview Professor of Cryogenic Energy Storage

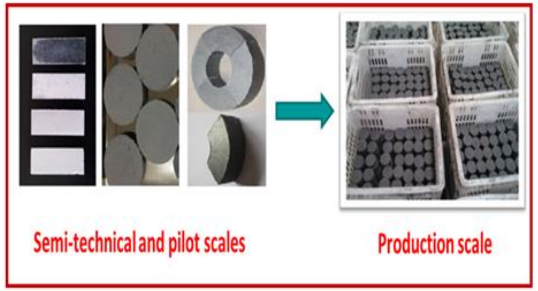
Birmingham Centre for Energy Storage (BCES)
University of Birmingham
Birmingham, UK
y.ding@bham.ac.uk

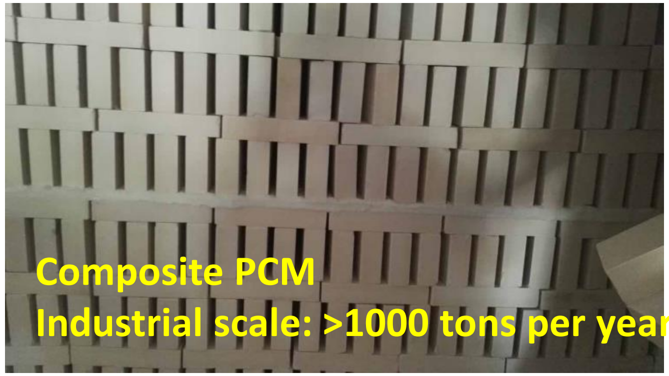
Bright hot sun surface ~+6000°C

Main research areas: thermal energy storage (2004-Present)

TES materials manufacture & scale-up: composite phase change materials



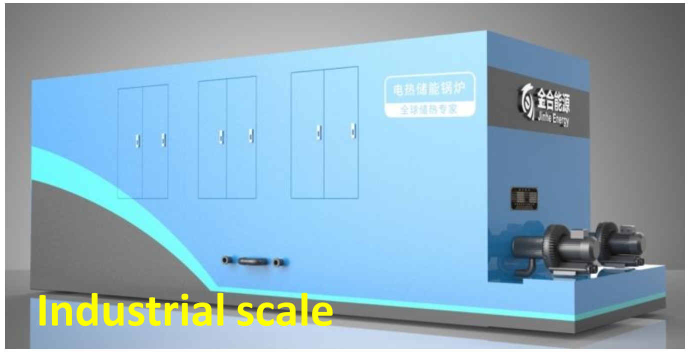




System integration and applications: composite phase change materials

25kW/100kWh cold storage based on CO_2 (2004-2008)

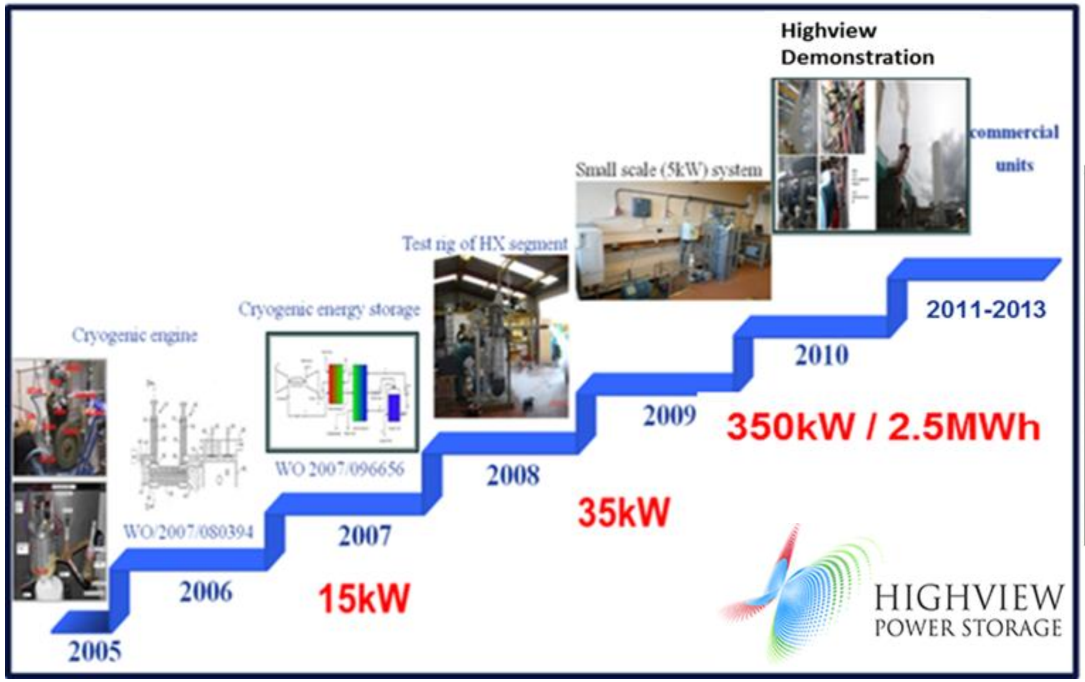
200kW/2MWh heat and electrical storage (2009-2013)



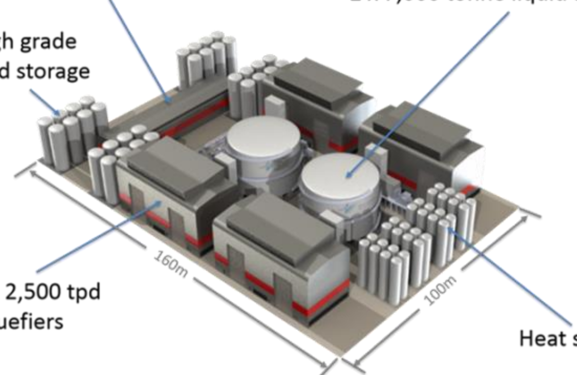
6M / 36MWh discarded wind power for space heating (2010-2016)

Main research area - liquid air energy storage (2005-Present)

Invented 12 years ago by my team - currently in commercial demonstration stage



5MW/15MWh Commercial Demonstration in Manchester (2015~2018)



Next 5 years -

- Larger scale systems e.g. 200MWh/1.2GWh
- Enhancement of round trip efficiency by 15-20%

Essential requirements for mankind

Thermal comfort, quality of life & healthcare -

- Winter – heating, not relevant to this conference!
- Summer – cooling, highly relevant to this conference!
- All seasons – cold chain for food and medicine, highly relevant to this conference!

Unfortunately,

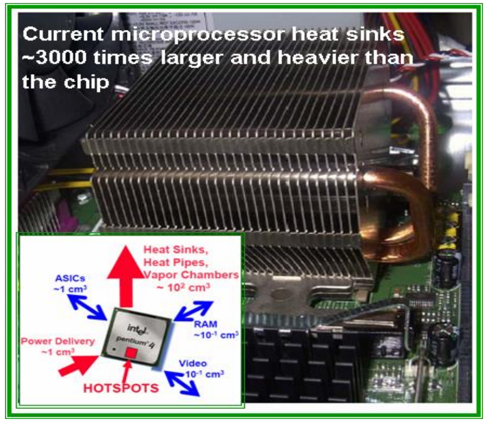
- these requirements are not always what the nature is made to give us!
- technologies are therefore needed to meet the human needs, which are currently highly energy intensive and hence the problems facing us – environmental pollution and global warming!

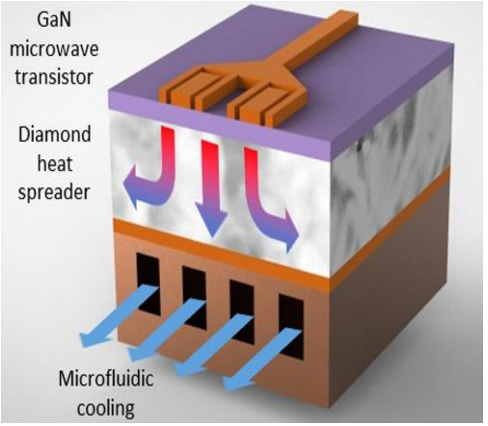
Less essential requirements for mankind

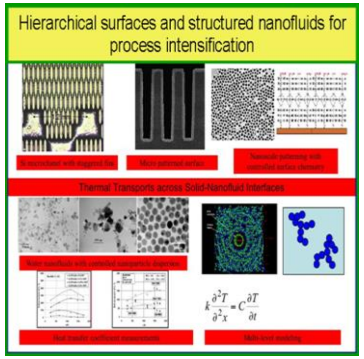
Device reliability & functionality and pleasure -

- X-band radar
- Computer chips
- High power laser
- Data centres
- 5G/6G communications
- High power lasers
- Weapon systems
- Space exploration
- High power battery

  thermal management
- …. ….

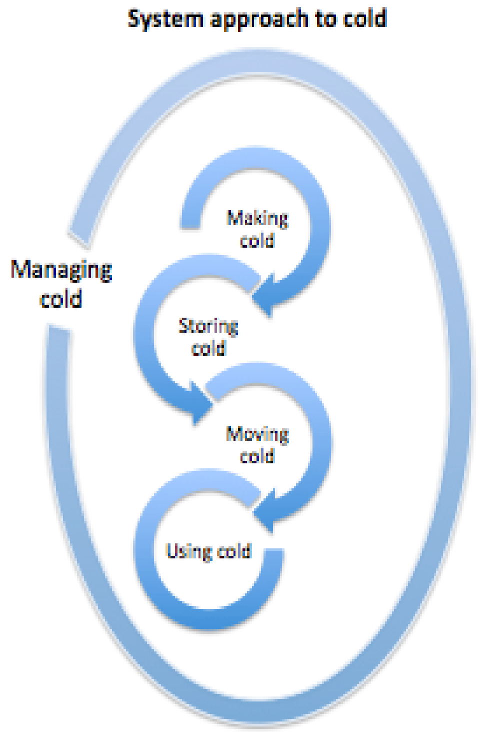






Cooling technologies essential for mankind

- Smart, flexible, adaptive, clean and economical technologies for
  - Generation of cold
  - Storage of cold
  - Transport of cold
  - Utilization of cold including waste cold
  - Efficient management of cold



- Some talks yesterday indicated technologies are there already
- My view is that current technologies are far from good enough either or both economically and technologically!

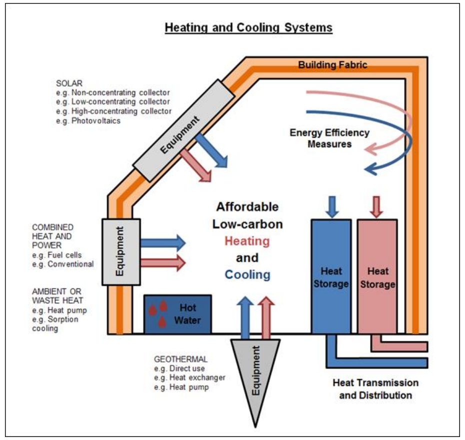
Something on technologies for discussion (I)

Mission Innovation challenges -

#	Challenge	Australia	Brazil	Canada	Chile	China	Denmark	EC	Finland	France	Germany	India	Indonesia	Italy	Japan	Mexico	Norway	Republic of Korea	Saudi Arabia	Sweden	The Netherlands	UAE	UK	USA
1	Smart Grids Innovation Challenge	Participant	Participant	Participant		Lead	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Lead		Participant	Participant	Participant	Participant	Participant	Participant		Participant	Participant
2	Off Grid Access to Electricity Innovation Challenge	Participant	Participant	Participant		Participant		Participant	Participant	Lead		Lead	Participant	Participant		Participant	Participant	Participant	Participant	Participant	Participant		Participant	Participant
3	Carbon Capture Innovation Challenge	Participant		Participant		Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Lead
4	Sustainable Biofuels Innovation Challenge	Participant	Lead	Lead		Lead		Participant	Participant	Participant		Lead	Participant	Participant		Participant	Participant			Participant	Participant		Participant	Participant
5	Converting Sunlight Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Lead	Participant		Participant	Participant	Participant	Participant		Participant	Participant	Participant	Participant	Participant	Participant
6	Clean Energy Materials Innovation Challenge	Participant		Lead			Participant	Participant	Participant	Participant	Participant	Participant		Participant		Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Lead
7	Affordable Heating and Cooling of Buildings Innovation Challenge	Participant	Participant	Participant		Participant	Participant	Lead	Participant	Participant	Participant	Participant		Participant		Participant	Participant		Participant	Participant	Participant	Lead	Lead	Participant

Lead
Participant

Affordable Heating and Cooling of Buildings Innovation Challenge No 7 led by the UK

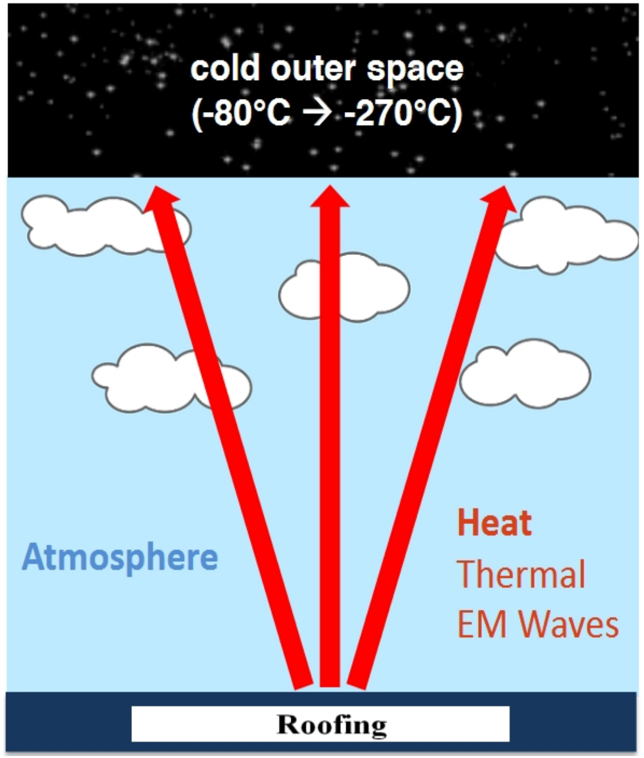


- Objectives are not ambitious enough!
- The implementation plan does not go far enough to achieve the objectives!

- This one is - could a £400bn plan to refreeze the Arctic before the ice melts really work?

Something on technologies for discussion (II)

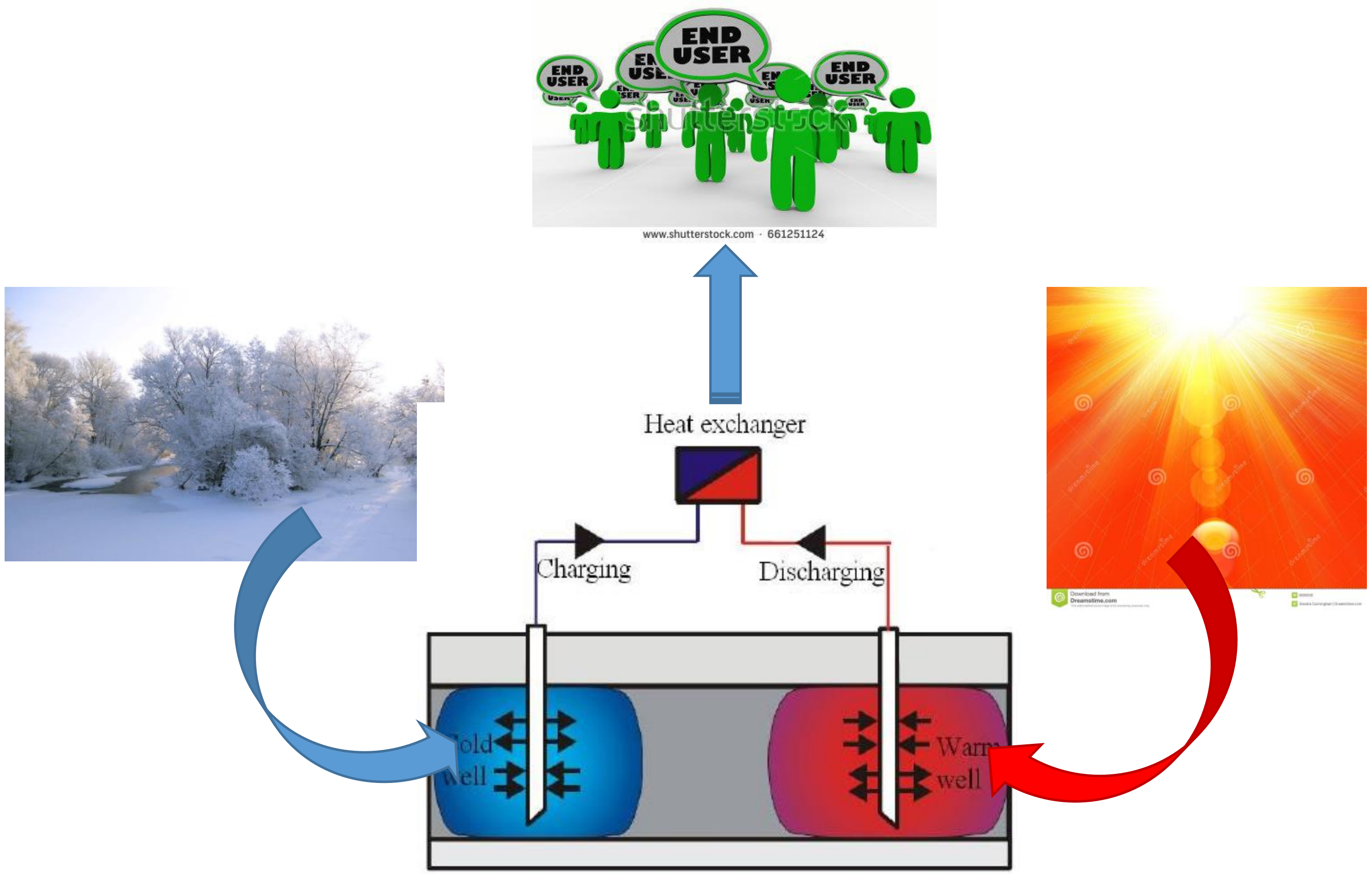
Generation / Harvest of cold: all seasons



This could also be a solution to ‘refreeze the Arctic

Something on technologies for discussion (III)

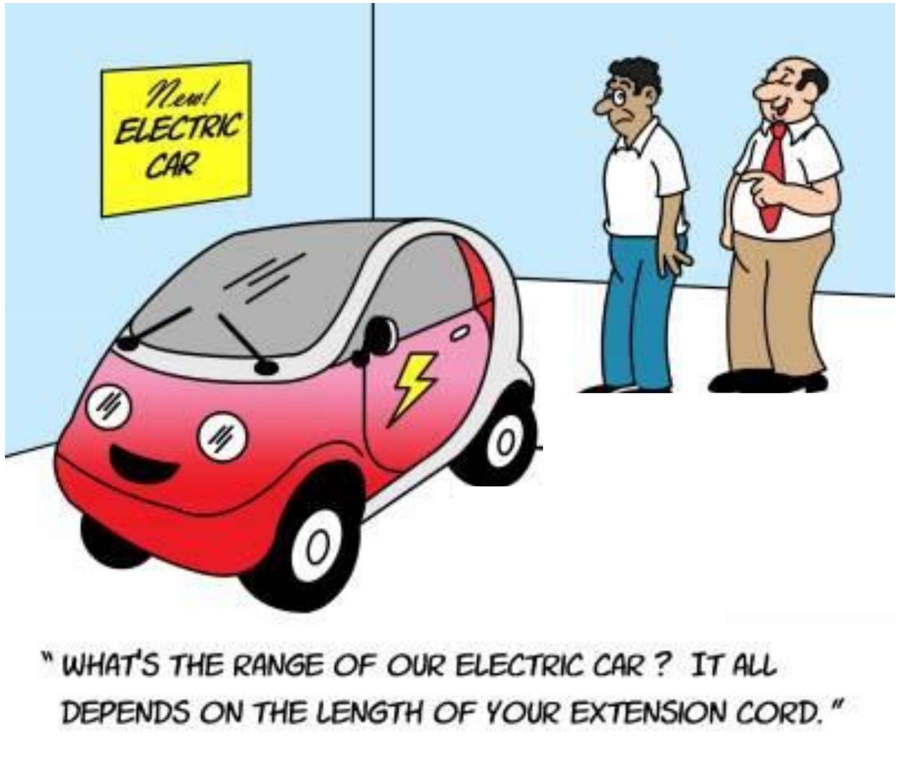
Harvest/Storage of cold: summer and winter



Across season thermal energy storage

Something on technologies for discussion (IV)

Transportation/Utilisation/Management of cold



- Electrical batteries + **Thermal Batteries**;
- Electrical and thermal charge in **energy charging station;**
- Air conditioning in energy charging station;
- **Range increase** by up to 30-40%;
- **COP increase** by >2-3 times;
- Use of **AI & Telecommunication**

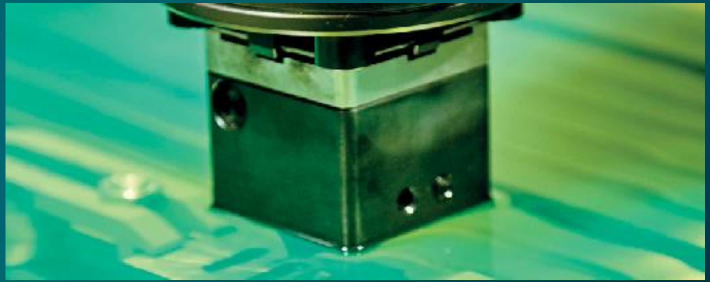
Thermal energy based temperature regulation technologies for Electrical Vehicles including delivering trucks


Apprentice training
Engineer upskill training
Conferences & Events
Technical solutions
Research & Development
Projects
Operational efficiency
Product manufacturing incubator
SME support
mtc
Manufacturing Technology Centre

MANUFACTURING INNOVATION

Component Manufacturing

Additive Manufacturing



Non-Conventional Machining

High Integrity Fabrication

Assembly Systems

Advanced Tooling and Fixturing

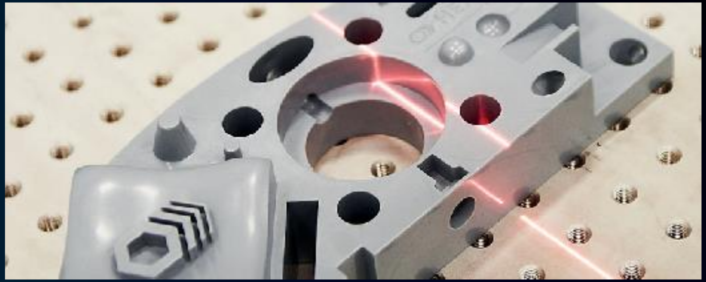
Electronics Manufacturing

Robotics and Autonomous Systems

Data Systems

Design and Simulation

Manufacturing Informatics



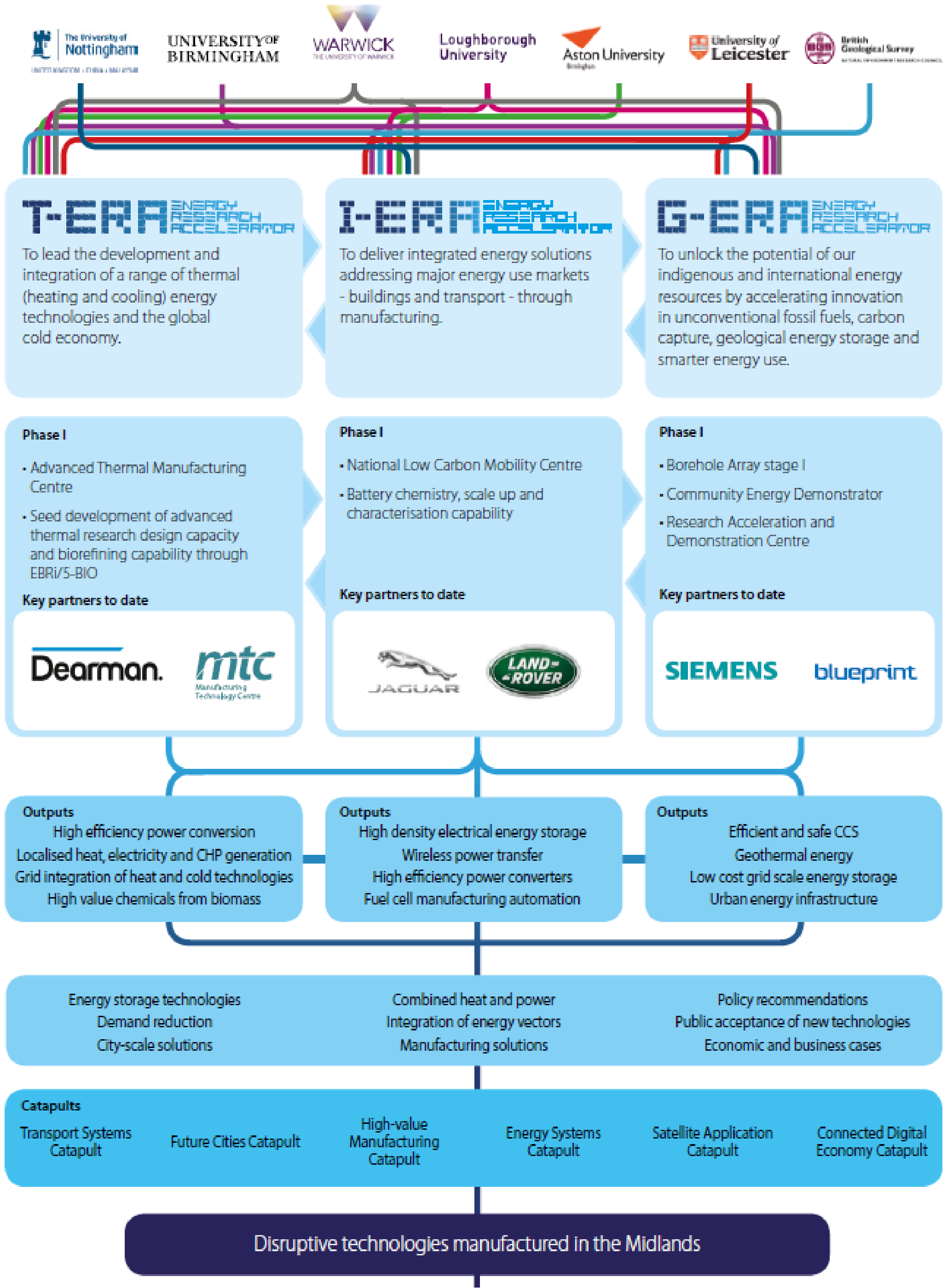
Metrology and NDT

T-ERA: THERMAL ENERGY RESEARCH ACCELERATOR

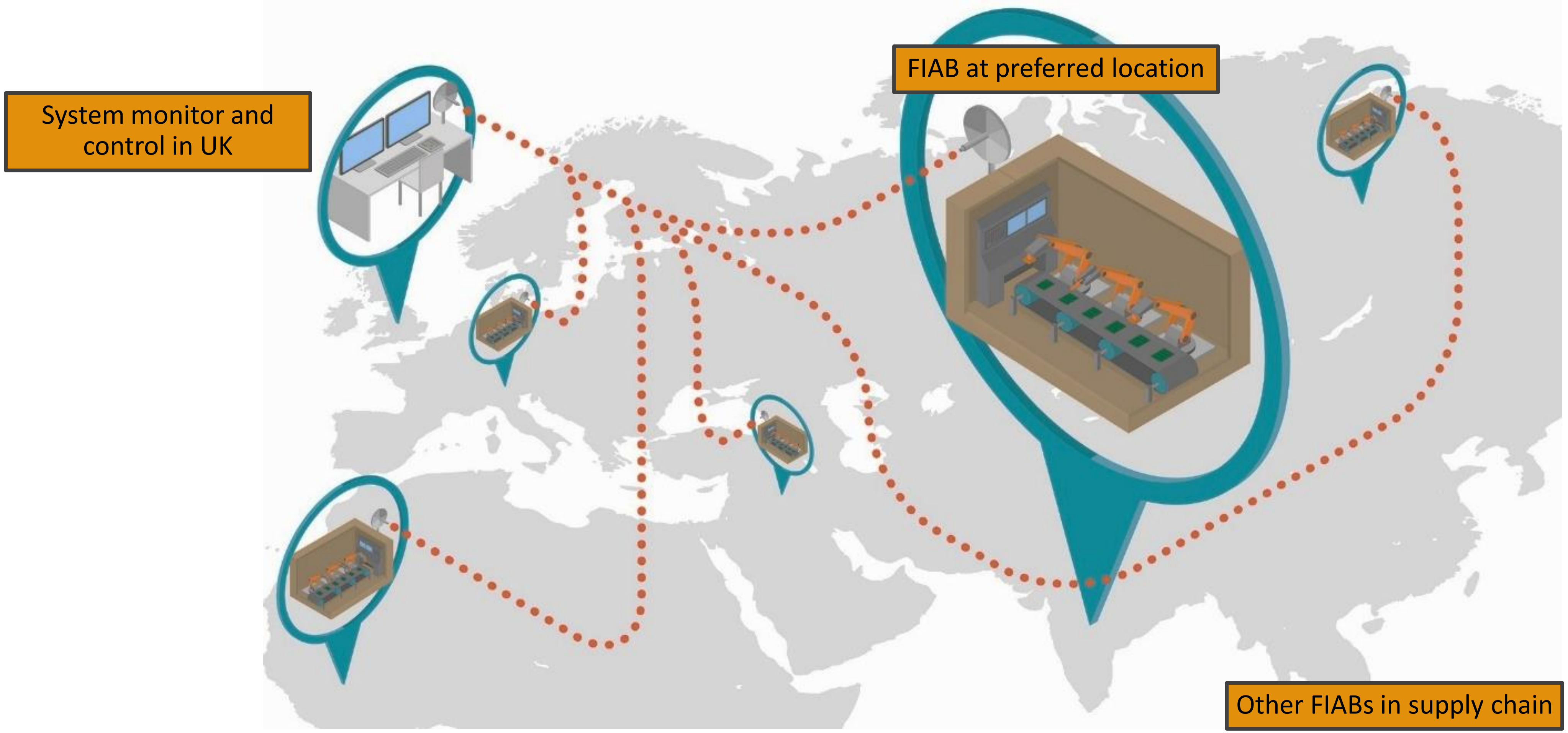
- Midlands Energy Research Accelerator (ERA):

A research hub delivering UK expertise and leadership giving the UK a competitive advantage in energy research and development.

- **Provide critical enhancements to the thermal energy sector supply chain.**
- Demonstrate how FIAB Manufacture can unlock the ability of UK thermal energy SMEs to industrialise their thermal energy products.



CONCEPT OVERVIEW



Enabling scalable growth through rapid deployment to desired market of unmet supply chain needs

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LEVERAGING FINANCE FOR CLEAN AND SUSTAINABLE COOLING

David Aitken, Carbon Trust

Unlocking Finance for Efficient Clean Cooling

David Aitken, Associate Director, Programmes and Innovation, Carbon Trust

19 April 2018

Agenda

1. Framing the finance challenge
2. Aims of this session
3. Cooling efficiency finance examples
4. Kigali Cooling Efficiency Program
5. Questions and answers

1

Framing the finance challenge

Scaling up energy efficiency markets and finance is critical to achieving climate goals

Energy efficiency is the lynchpin that can ‘keep the door to 2°C open’ (IEA)

Save the global economy trillions; reduce air pollution; boost productivity

Requires $550 billion/year by 2030 – a doubling in investment from today’s levels

Markets are hampered by significant barriers which need to be overcome

In 2015, MDBs committed $2.9 billion to energy efficiency programmes

Is there enough finance? Is it having the desired impact? What new support is needed?

2

Aims of this session

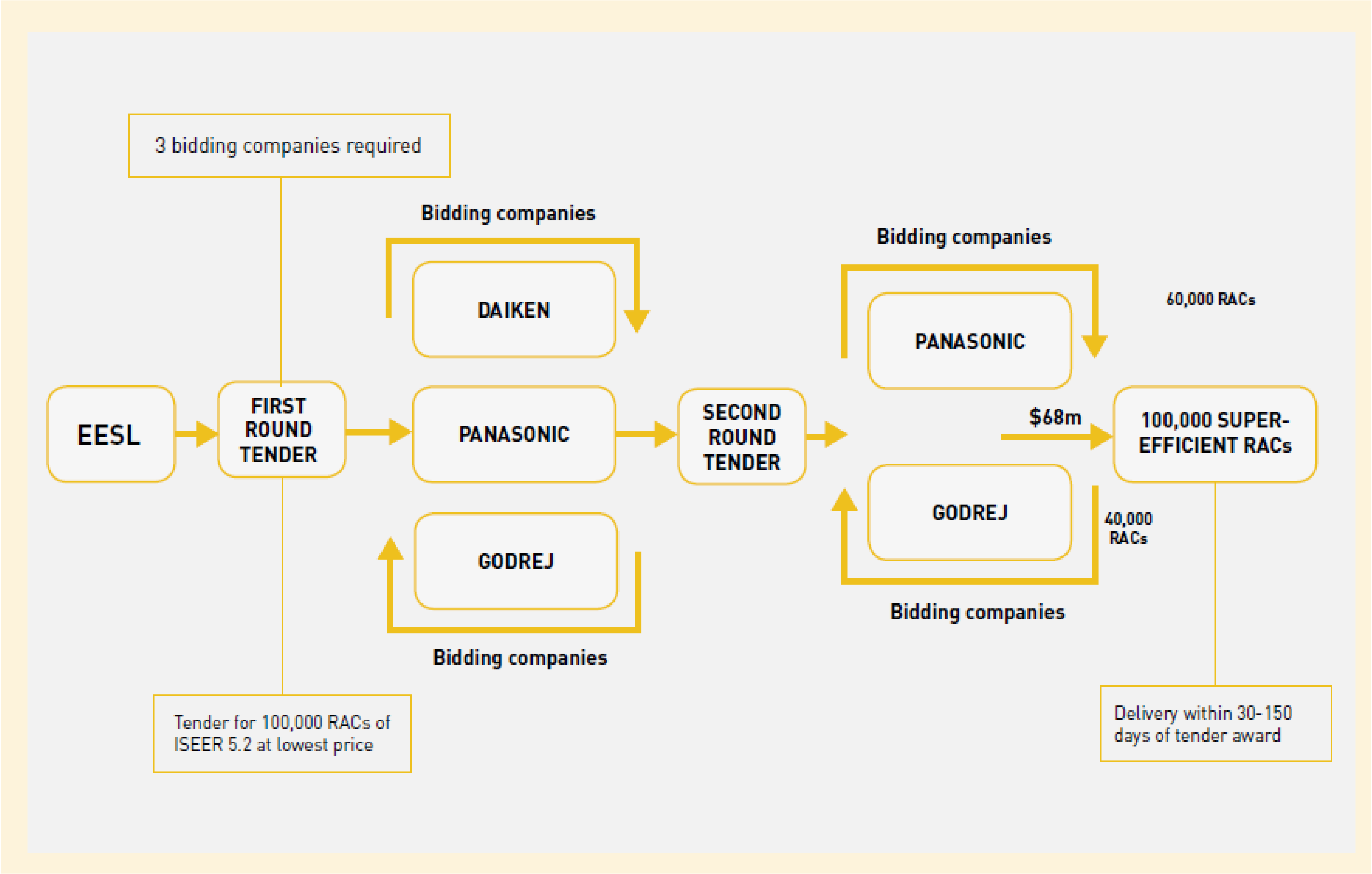
We are keen to catalyse discussion on efficient clean cooling finance barriers and solutions

- Overcoming finance barriers is key to advancing energy efficiency in cooling solutions
- Key questions include:
  - What’s working (and what’s not)?
  - Barriers?
  - Potential solutions?
- We will review three different cooling efficiency finance program examples to start exploring these key questions
- We will then look at how the Kigali Cooling Efficiency Program plans to help unlock finance for efficient, clean cooling
- These examples will hopefully catalyse discussion on cooling efficiency finance experiences, barriers, and potential solutions

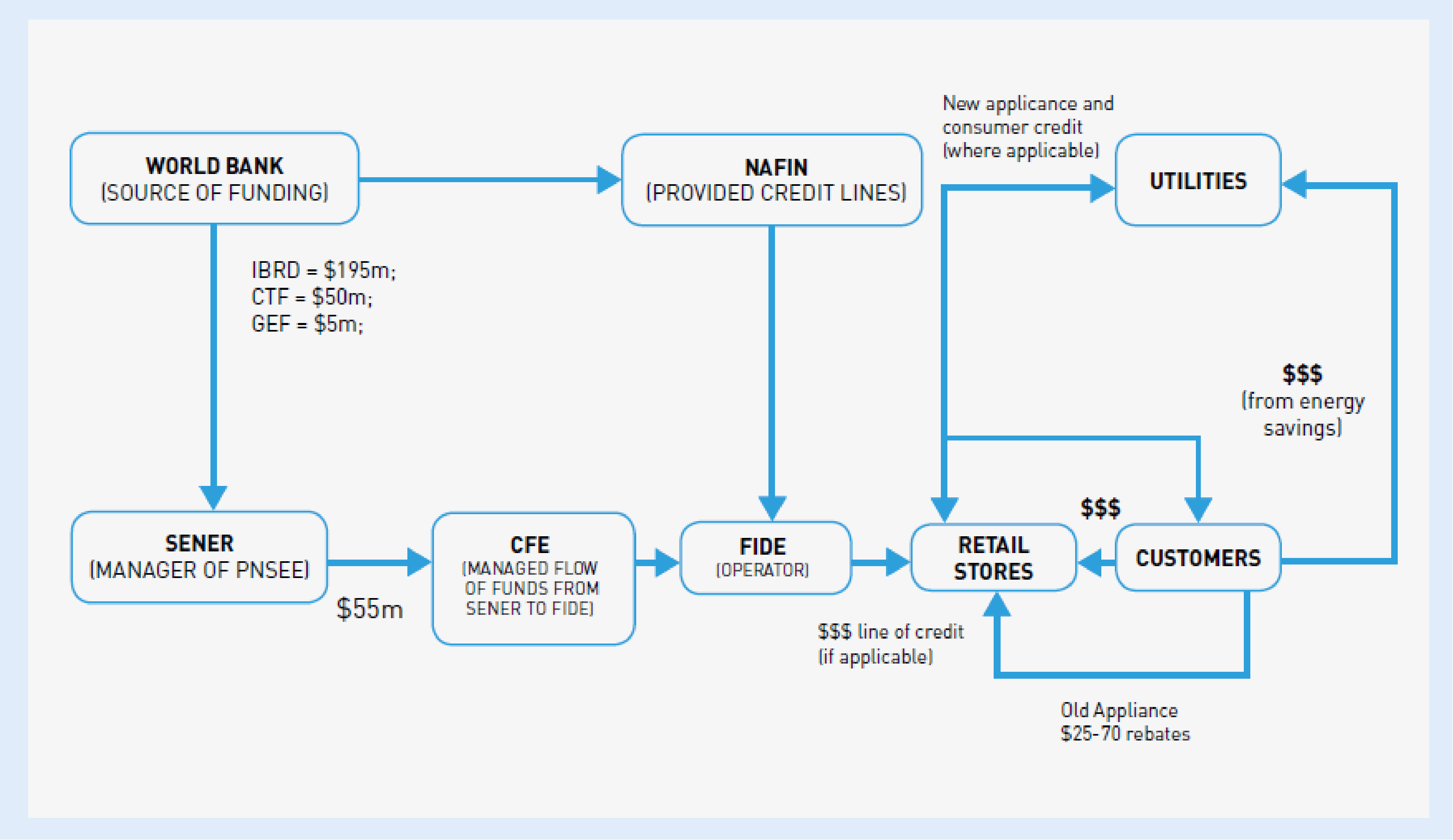
3

Cooling efficiency finance examples

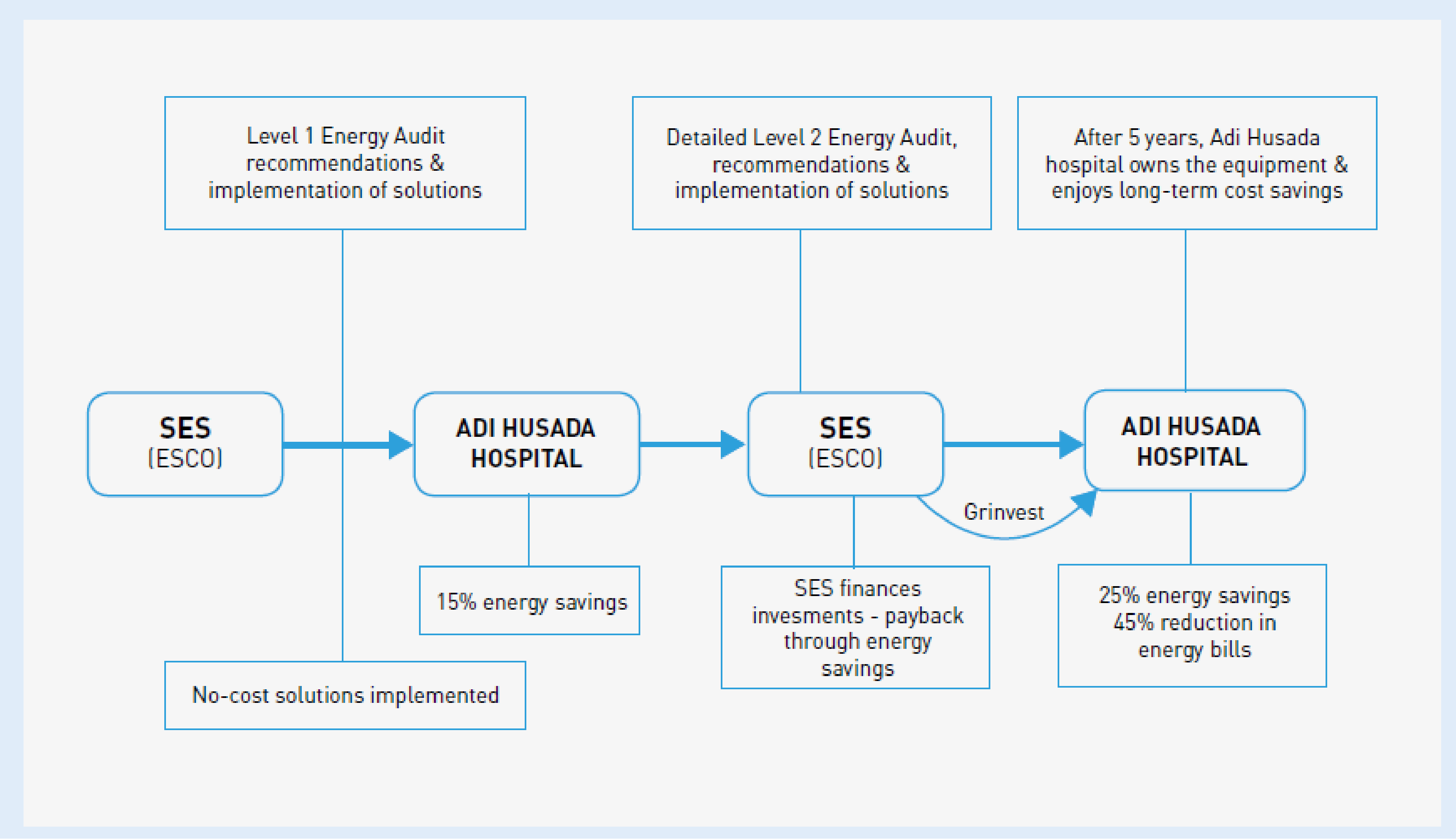
Competitive bulk procurement – EESL Super Efficient Air Conditioning Program, India



Early replacement, on-bill financing, refrigerant recycling - Programa Nacional de Sustitución de Equipos Electrodomésticos (PNSEE), Mexico



Energy Audit/Energy Services Company (ESCO) – Adi Husada Hospital, Indonesia



4

Kigali Cooling Efficiency Program

Kigali Cooling Efficiency Program supports energy efficient, clean cooling in developing countries

<table>
<tr><th></th><th>Technology improvements</th><th>Policy, regulatory and information</th><th>Financial and related incentives</th></tr>
<tr><td>Focused K-CEP support</td><td>Enabling technology projects
• Support to RAC manufacturers and supermarkets to enhance efficiency while phasing down F-gases</td><td>National cooling plans
• Support to develop cooling plans that can inform HPMPs and NDCs
Standards and labeling
• Minimum energy performance standards and labeling for commercial and residential RAC
Model standards for RAC technology
Compliance
• Monitoring, verification, and import controls</td><td>Identifying finance needs and incentives
• Bulk procurement, rebates and/or other financial mechanisms
Finance window
Report on cooling market and investment landscape</td></tr>
<tr><td rowspan="2">Cross-cutting K-CEP support</td><td colspan="2">Training and capacity building
Support to ozone and energy policy makers, RAC SMEs, service sector</td><td></td></tr>
<tr><td colspan="3">Cooling for all
Identifying the best solutions to make efficient, clean cooling accessible to all</td></tr>
</table>

RAC = refrigeration & air conditioning, HPMPs = HCFCs Phase-Out Management Plans, NDCs = Nationally Determined Contributions

K-CEP is looking for compelling proposals to unlock finance for efficient, clean cooling

- K-CEP has allocated up to USD 10 million to unlock finance for efficient clean cooling under Window 3
- Aim is to demonstrate how targeted grants can unlock the extra finance needed to integrate efficiency improvements with the F-gas transition
- Window 3 expects to provide USD 2 million to USD 5 million in funding to successful applicants.
- Support can be used to provide a range of technical assistance (e.g. to create bankable propositions, raise awareness, provide technical

5

Questions and answers

Thank you and we look forward to questions on financing efficient, clean cooling!

- We look forward to your questions and feedback including on the three cooling efficiency finance examples

- Please also feel free to ask questions about the Kigali Cooling Efficiency Program's support for unlocking finance for efficient, clean cooling

- Any additional queries or comments that we don't have time to cover please feel free to email coolingefficiency@carbontrust.com

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THE RIPPLE EFFECT AND UNINTENDED CONSEQUENCES

Dr Rosie Day, University of Birmingham

#CoolWorldCongress
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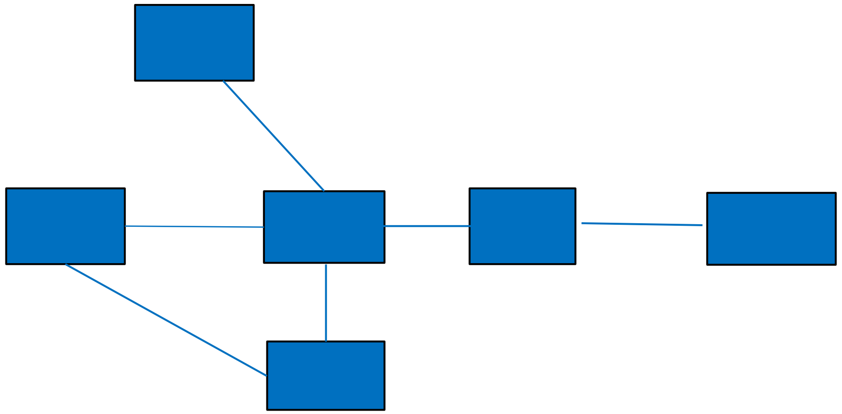
Ripple effects and unintended consequences

Dr Rosie Day

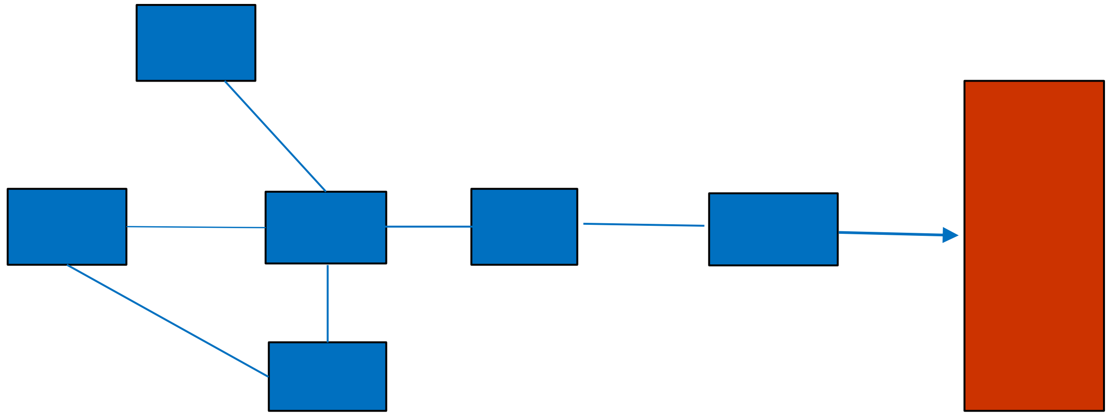
School of Geography, Earth and Environmental Sciences

University of Birmingham

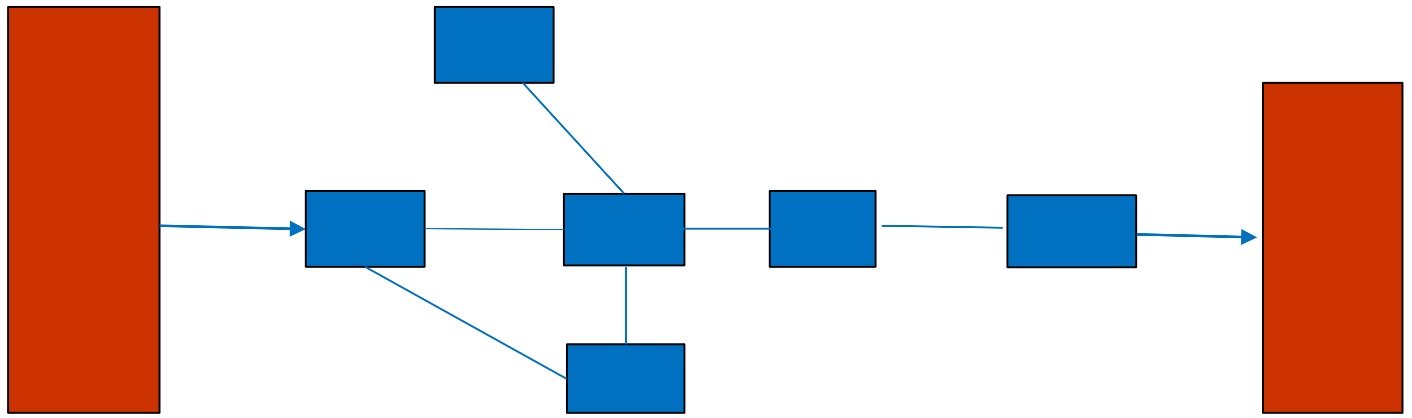
Cooling system (simplified)



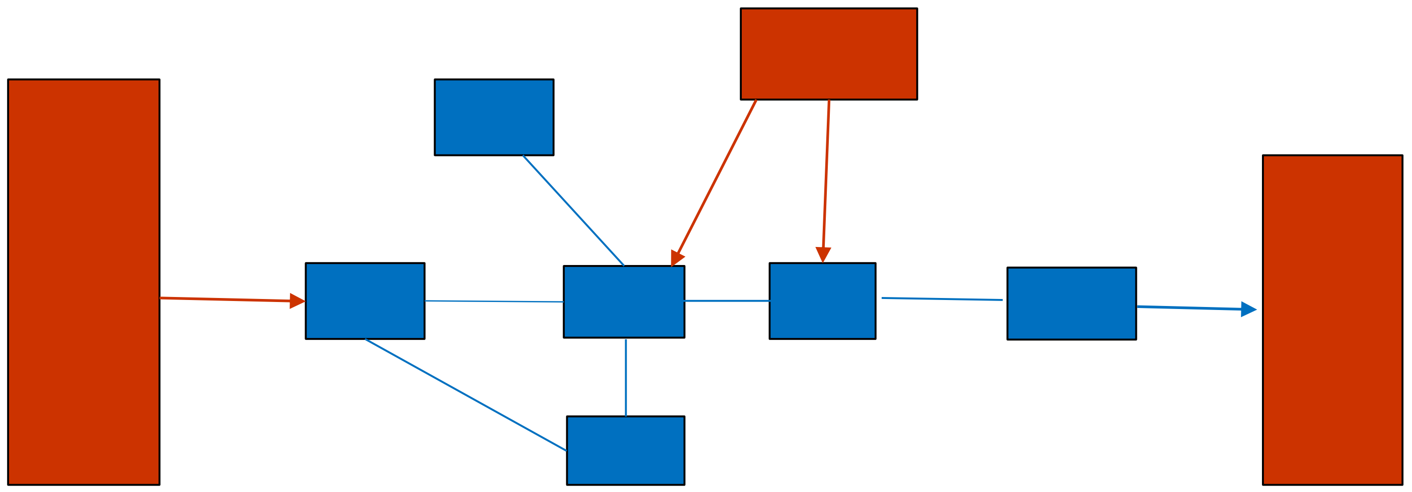
Cooling system (simplified)



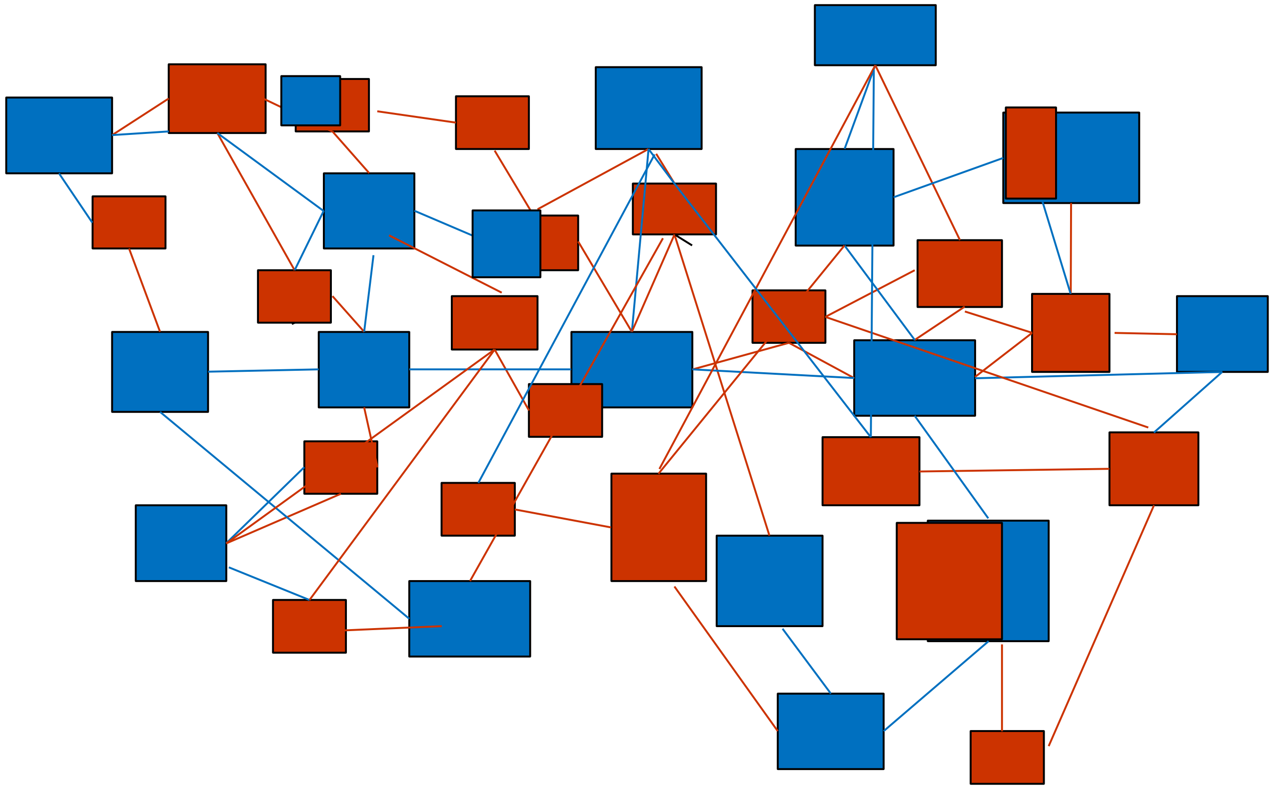
Cooling system (simplified)



Cooling system (simplified)



Socio-technical assemblage



This means that:

- Society and technology co-evolve and co-construct each other
- Changes in one element have all kinds of knock-on effects that might be quite unpredictable
- We need to be thinking about social and technical elements from the start, *and the ways in which they interact*
- Needs adequate social science and real inter-disciplinary engagement

- Positive outcomes may not be quite as expected
- There will almost certainly be unexpected disbenefits (and potentially unexpected benefits)
- While research might allow us to anticipate some effects, others will be more unknowable
- They will unfold over time

Example 1: Urban building cooling

- Intended benefits:
  - Better health
  - Improved comfort
  - Increased productivity
  - Improved quality of life
  - Economic growth

Redacted for copyright reasons – picture of older southern US house with many sash windows and a large sub porch running the length of the house

Redacted – new house in Alabama with double garage at the front of the house, no porch, small windows. Designed for mainly internal living with air con.

Redacted – image of men in Indonesia wearing traditional sarong and loose shirt, as is common across SE Asia

Redacted – image of office workers in Kuala Lumpur wearing western style suits and ties (in an air conditioned environment)

Example 2: food chains

- Intended benefits:
  - Reduced food wastage
  - Improved farmer income
  - Improved food safety and nutrition
  - Positive impact on economy and health

Possible 'knock-on effects'

- Cold storage makes different crops viable: farmers switch to higher value crops that demand more water
- Change in crop patterns affect soil fertility
- Landscape change
- Refrigerated transport enables reaching new markets: increased transport including air freight
- Farmers reach markets better as organised groups: potential exclusion of some due to gender, ethnicity, caste, religion - increased inequalities
- Change in available food plus more refrigeration leads to change in diets: more processed food, more meat and dairy

Categories of knock-on effects

Category	Example knock-on effect
Energy demand	Exponential increase in demand outstrips ‘clean’ provision: increase in fossil fuel use
Transport (including air)	Increased freight : increased congestion and emissions
Other environment (including water, soil, forest)	Overuse of groundwater; salt incursion; changes in soil fertility; nitrate pollution; deforestation; resource use for packaging, and linked increase in litter and pollution
Health	Decreased exercise as more time indoors (air con); increased intake of processed and higher calorie foods
Social capital	Decreased community as more time indoors
Social equality including gender	Existing inequalities may be exacerbated by differential access to technologies etc; accumulation of land and increase in farm size following rural capital accumulation
Architecture	Building styles change; building skills lost; lock-in
Landscape	Urban and rural landscape change
Culture	Changes in temporal organisation of activity; changes in clothing; less time spent outdoors
Local economy	Small businesses suffer due to various changes in eating, clothing, shopping and other activities

Ways forward

- Understand that cooling means social transformation
- Wider impacts need anticipating but also ongoing monitoring
- Demand management is crucial and demand needs unpacking
- Consider the wider sustainability impacts: how clean cooling connects to other systems. Develop sustainable systems e.g. freight, local supply chains.
- Prioritise needs and proceed carefully
- Pay attention to social inequalities before, during and after introduction of cooling
- Consult widely about needs, preferences and impacts

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GLOBAL COLLABORATION AND NEXT STEPS TO DELIVER ACCELERATED SOLUTIONS TO ACCESS TO COOLING FOR ALL

Professor Toby Peters, University of Birmingham

Ian Crosby, Cooling for All

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CONCLUSION AND CLOSE

Professor Martin Freer, Birmingham Energy Institute

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