UNIVERSITY OF BIRMINGHAM

BIRMINGHAM ENERGY INSTITUTE

DOING COLD SMARTER

Presentation to International Energy Agency
Workshop on Space Cooling

IEA Committee on Energy Research & Technology
Experts' group on R&D priority-setting and evaluation

17th – 18th May 2016

Dr. Gavin Harper

Energy Development Manager
Birmingham Energy Institute

BIRMINGHAM POLICY COMMISSIONS

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AIR CONDITIONING

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- Consumption of air conditioning to grow by factor of 30 by 2100
- US uses as much electricity on air con as Africa uses on everything
- Air con is 40% of electricity use in Mumbai
- In UK relatively minor ~15%.
- Inter Governmental Panel on Climate Change estimated demand will rise to 4,000 TWh in 2050 ~10 time UK electricity bill

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AIR CONDITIONING

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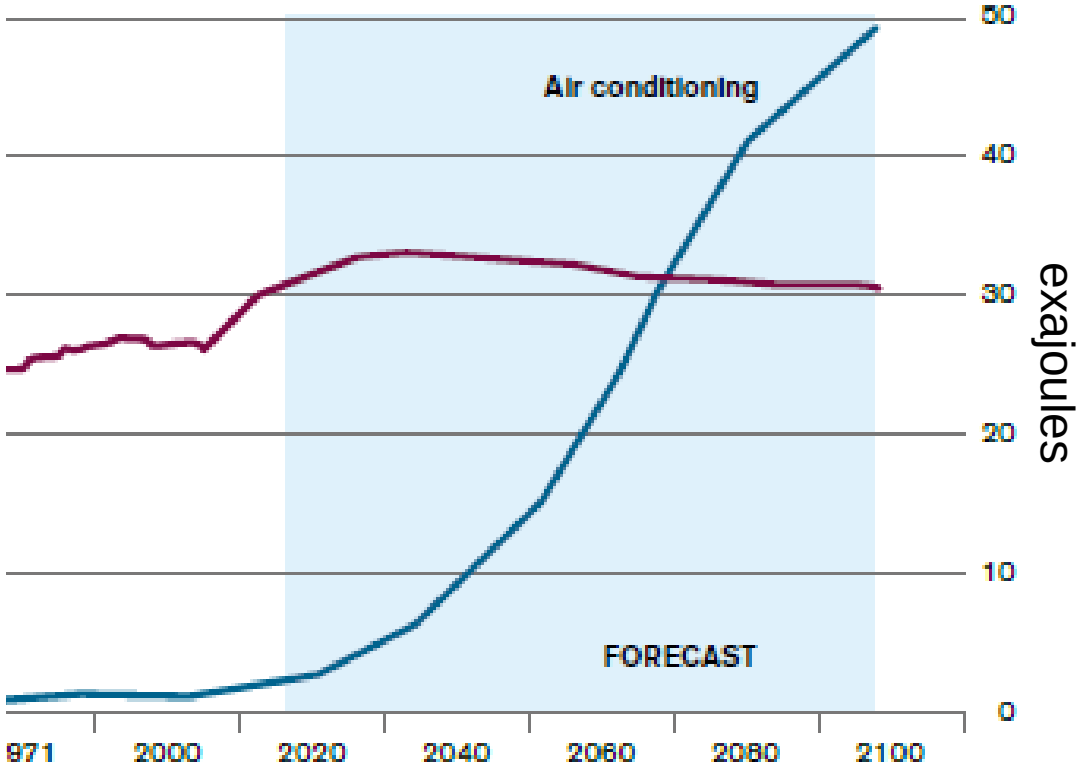
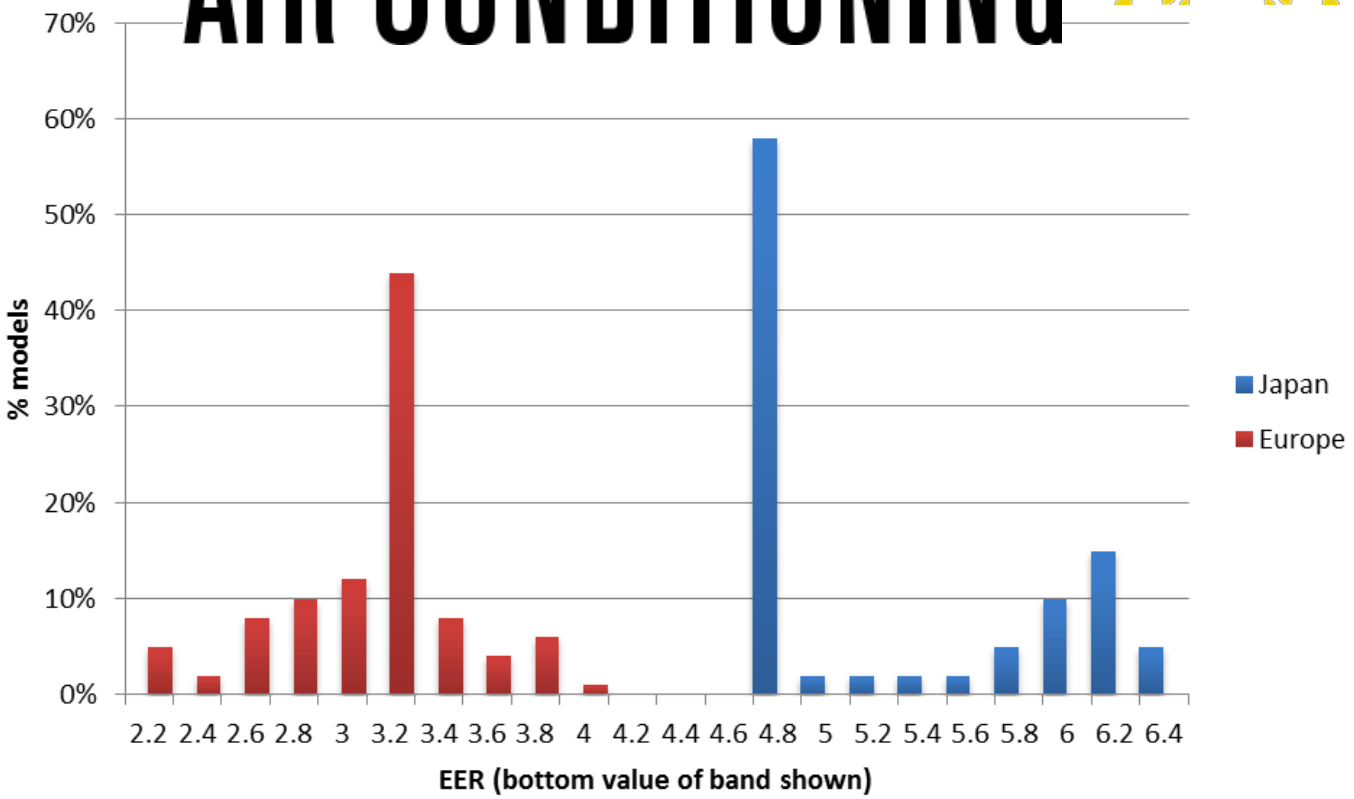


In 2010 Chinese consumers bought 50 million air conditioning units; more than the entire of the US current domestic air conditioning fleet

AIR CONDITIONING



Coefficient of Performance (energy efficiency) of air conditioning units in Japan and Europe. Source: SIRAC

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FOOD REFRIGERATION

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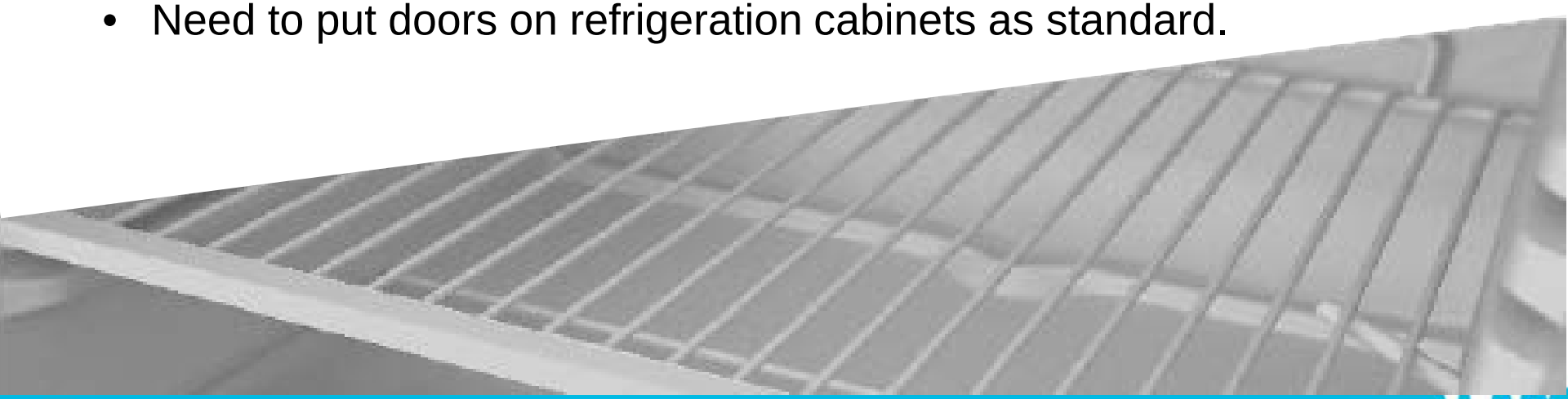
- ~1/3 of food is wasted between harvest and home – much due to imperfect refrigeration
- The global CO2 emissions (10%) associated with refrigeration and air con is greater than aviation and shipping combined. Need to focus on refrigerant leaks.
- Supermarket equipment buyers focussed on capital cost and not LCC
- Best in class equipment usage could improve efficiency by 30%.
- Doubling the UK efficiency could save the UK £1b.
- Need to put doors on refrigeration cabinets as standard.



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FOOD REFRIGERATION

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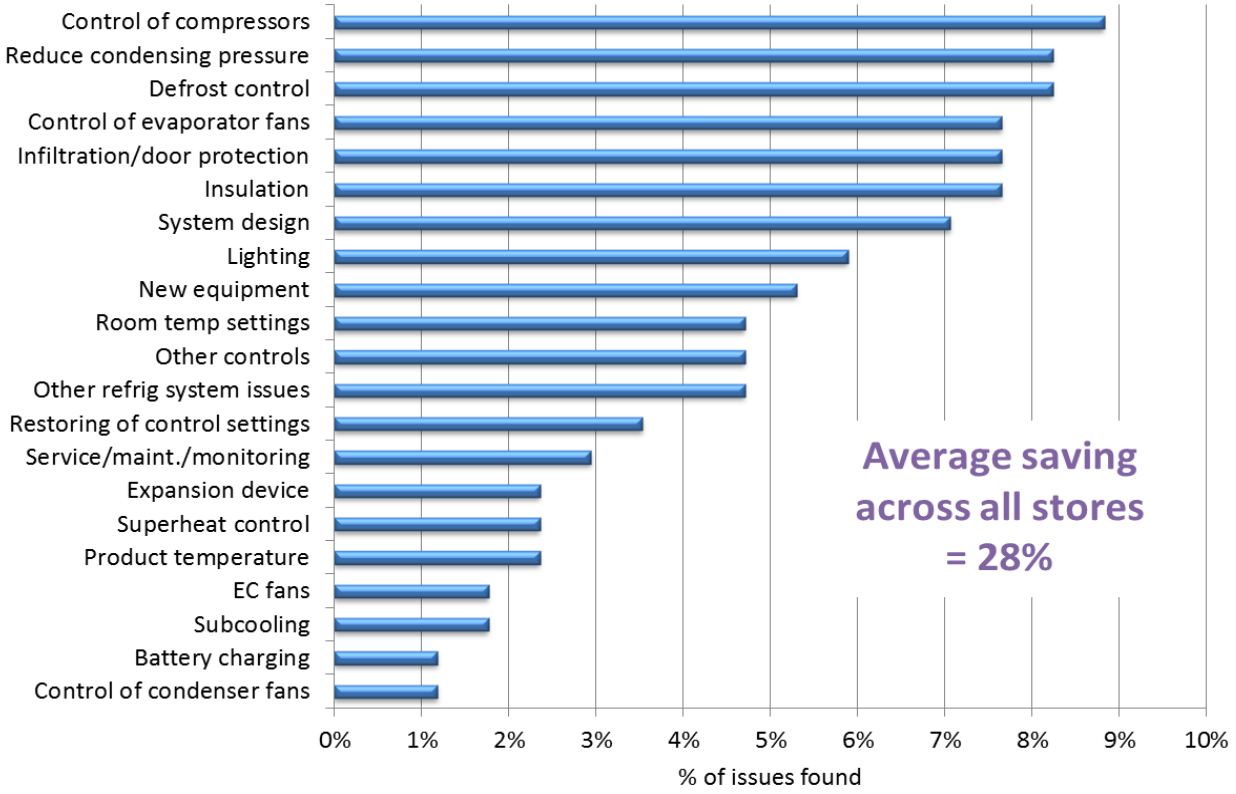

Potential to improve the efficiency of cold stores.

Source: LSBU

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OPPORTUNITIES

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- Estimate the value of the cold technology worldwide (based on potential for UK saving of £1b) is £40-110b. Opportunity for UK business to bring innovative technology to the international market.
- Improvements of GWP of refrigerant gases
- A cold energy systems approach – better planning and integration
- Use of wrong time energy to generate cold and cooling – need for storage.
- UK has a leading cryogenic sector (e.g. Liquid Helium technology)

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OPPORTUNITIES

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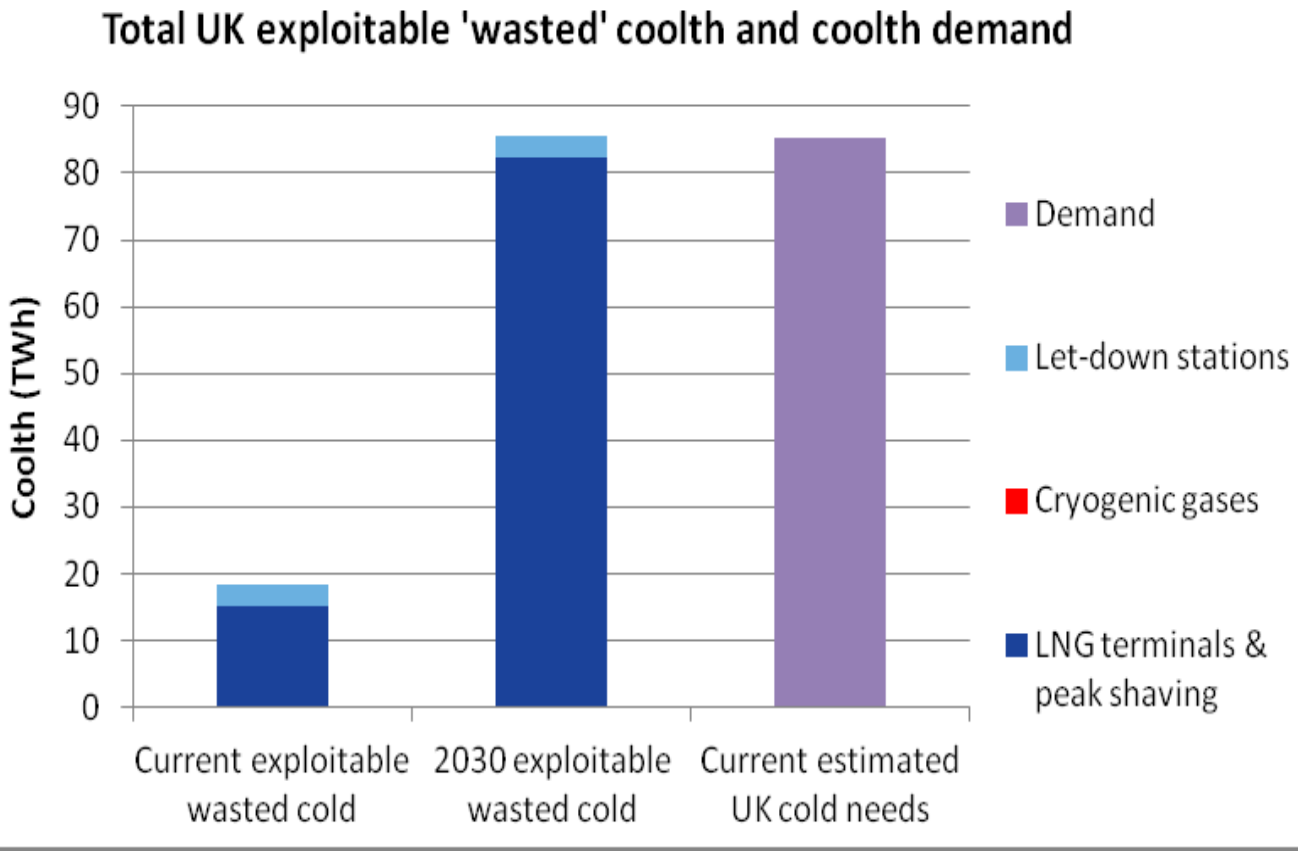


DOING COLD SMARTER:
IN THE DEVELOPING WORLD

Improved cold chains will allow for the creation of new export markets for perishable products from thedeveloping world.

LNG Import

Fresh produce Import /Export

'Waste Cold' from imported LNG shipments captured and turned into Liquid Air to power cold economy. Regasification plant captures the cold which would otherwise be wasted.

LNG is moved by rail to remote locations to provide power.

Refrigerated rail reefers provide long distance transport of perishable food stuffs bridging the gap between local farmers and International food markets.

Liquid air used

- to provide refrigerated transport for crops to markets (in country or for export);
- for keeping heat-sensitive medicines cool
- to provide power when no wind/sun, alongside sources of waste heat
- for local domestic/business cooling and refrigeration

Delivering healthcare in partsof the developing world with poor access to energy requires the Development of cold chains for the transportation and preservation of vaccines and medicines which are very temperature sensitive.

Additionally, cryogenic liquids are transported by rail to provide cold and power where there is great demand.

Ice packs

Ice packs provide a low-tech way of storing small amounts of cold energy for onward transportation of vaccines to remote areas. In time, novel cold energy storage materials may provide greater energy densities for cold storage than ice.

Refrigeration

In remote areas without electricity, solar photovoltaic panels are used to generate electricity. The electricity is intermittent. Some electricity is stored in batteries for powering lighting and small electrical devices. The cooling energy needed is stored in the form of "ice". Fridges work as 'batteries' storing the off-grid energy in the form of cold.

The integration of advanced phase change materials can improve the performance of simple street vending stalls ensuring perishable food stays fresher for longer.

Work on developing crop breeds that are resistant to higher temperatures can help in reducing the need for cooling.

Back houses provide refrigerated storage and processing of perishable produce. Construction of back houses in rural areas provides the bridge between local farmers and markets for food. 3% of food loss in the developing world occurs because of the lack of refrigeration.

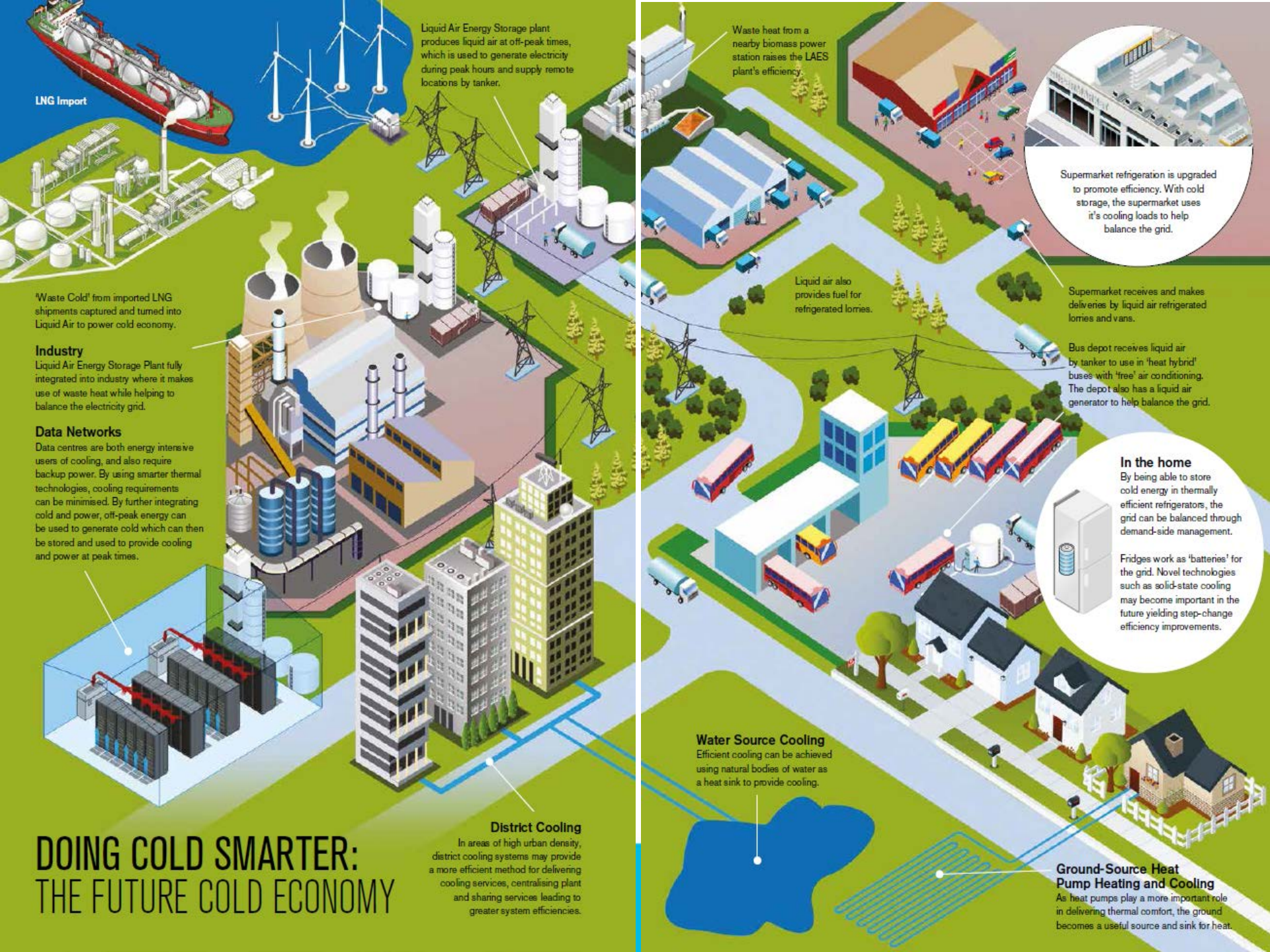
Back houses are a crucial intermediate stage in the cold chain infrastructure to prevent post harvest food loss.

Power plant integrates Liquid Air Energy Storage for grid stability and backup

Distributed communication infrastructure requires both cold and power. Advanced phase-change materials can help reduce the cooling load in warm climates.

Cold Chains

The development of cold chains creates opportunities for farmers in the developing world to move up the value chain, producing higher value outputs from their agriculture. Using cold to preserve food means that rather than selling whole carcasses, farmers can sell frozen high-value meat products like frozen chicken breast meat.



DOING COLD SMARTER:
THE FUTURE COLD ECONOMY

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CHALLENGES

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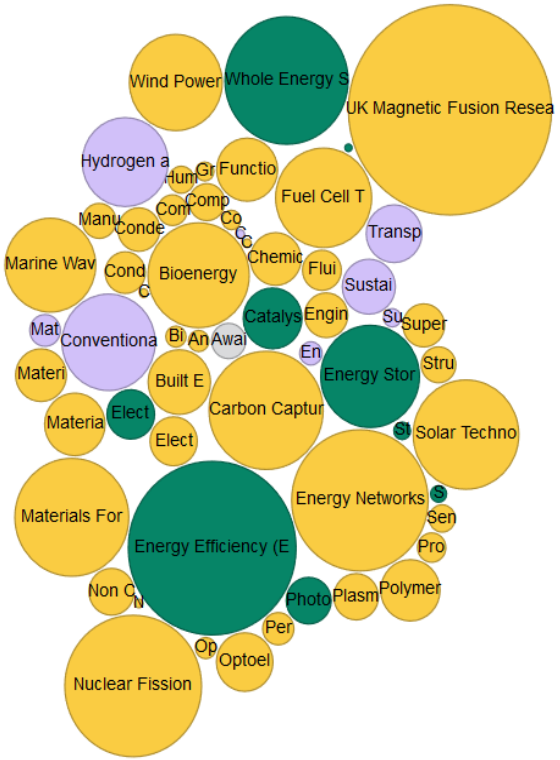
THE UK CONTEXT:

- Research base: 70% for R&D comes from EPSRC, of the total EPSRC fund 0.2% goes to cooling.
- InnovateUK funding ~0.1% of funded projects
- If UK to take advantage of international markets then need to have an innovation pipeline.



Key

Grow | Maintain | Reduce | Under Review

Circles are sized according to EPSRC investment. All values represent the current grant portfolio.

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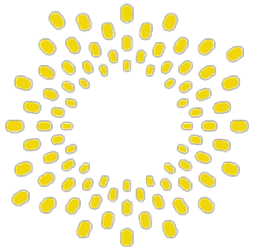
RECOMMENDATIONS



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- Raising awareness
  - Establish a lead Government department
  - Appoint an institutional Champion
  - Review National Policy Statements
  - Develop a concordat
- TINA for cold and cooling
- Systems level model for UK cold
- Support Demonstration projects
- Measurement and management of clean cold
- Interventions: R&D investment and plan, Skills, Financing and Business models

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INTERVENTIONS

Camfridge's solid-state cooling solution for domestic refrigerators. Image courtesy Camfridge

Interventions:

2015

How can we do things better?

A drinks fridge employing Surechill's novel cold storage system. Image courtesy Surechill

Interventions

- Development of cold and cooling as a product; move from technology focus
- Create appropriate incentives and regulatory framework
- Introduction of market mechanisms that allow new technologies to break through
- → Small and large scale demonstration facilities for proof of principle and validation
- → Manufacturing environment to accelerate price competitive technologies to market
- → Explotation of state-of-the-art manufacturing processes and data
- Develop a service culture and infrastructure related to cold technologies
- → Development of R&D capability on a scale which matches potential of cold
- → Develop@ UK skills base linked to state-of-the-art cold systems

A retail refrigeration unit employing Simply Air refrigeration. Image courtesy Simply Air.

2030

A number of servers mounted in a rack cooled with Iceotope technology. Image courtesy Iceotope.

TECHNOLOGY ROADMAP

	Here now 0-3 YEARS	Short term 3-5 YEARS	Medium term 5-10 YEARS	Long term 10 YEARS +
Making Cold	Use of existing geological and ambient cooling sources Co-locating loads near waste cold sources, e.g. data centres / LNG More efficient cooling techs and systems, including district cooling Research & deploy new coolants Develop emerging cooling techs e.g. thermoelectric cooling	Use of new cooling sources/vectors e.g. LNG/liquid air Integrate cooling & heating systems, including other thermal cycles e.g. heat pumps Further develop new refrigerants and related codes & standards Develop currently novel cooling techs e.g. sorption systems	Develop small-scale air liquefaction R&D of solid state refrigerants R&D of novel cooling techs e.g. magneto and electro-caloric	R&D of very novel cooling techs e.g. wind direct drive liquefaction, ultrasonic, hydraulic Elimination of all HFC coolants
Storing cold	Use full range of currently available options e.g. water, ice, glycols, thermal piles	Apply developing technologies and opportunities e.g. phase change materials, composite heat/cold systems	Develop next generation technologies and opportunities e.g. inter-seasonal thermal storage, denser materials	R&D of disruptive technologies e.g. thermochemical storage, tunable phase change materials
Moving cold	Use full range of currently available options e.g. water, ice, glycols	Improved technologies for cold transport e.g. containerized LNG and liquid air	Harnessing waste cold of cryogenic fuels	R&D of novel materials for packaged cold high energy density, cost and weight
Using cold	Maintain and repair existing equipment to improve performance. Apply efficiency measures to reduce losses e.g. doors on chiller cabinets	Apply cryogenic “cold and power” engines Develop supply chain for cryogenic ancillaries Develop low cost systems for low utilization uses Apply super-chilling and tri-gen	Wider application of cold & power systems, Systems integration in automotive – e.g. air conditioning and aux power Develop white goods suitable for integration into district heating and cooling scheme.	Harnessing the waste cold from liquid hydrogen infrastructure. Exploit advanced cold technologies (e.g. Magnetic, Peltier).
Managing cold	Improve measurement, data processing and control at cooling device and fleet level	Active management of devices for cold production. Smart fridges – grid sensing / interaction. Better processes for cold chain optimization. Weather & climate linked cooling.	Fully integrated cold and energy chains, minimizing losses and environmental impacts; optimize system components	Long term management of cold

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EXISTING CAPABILITY

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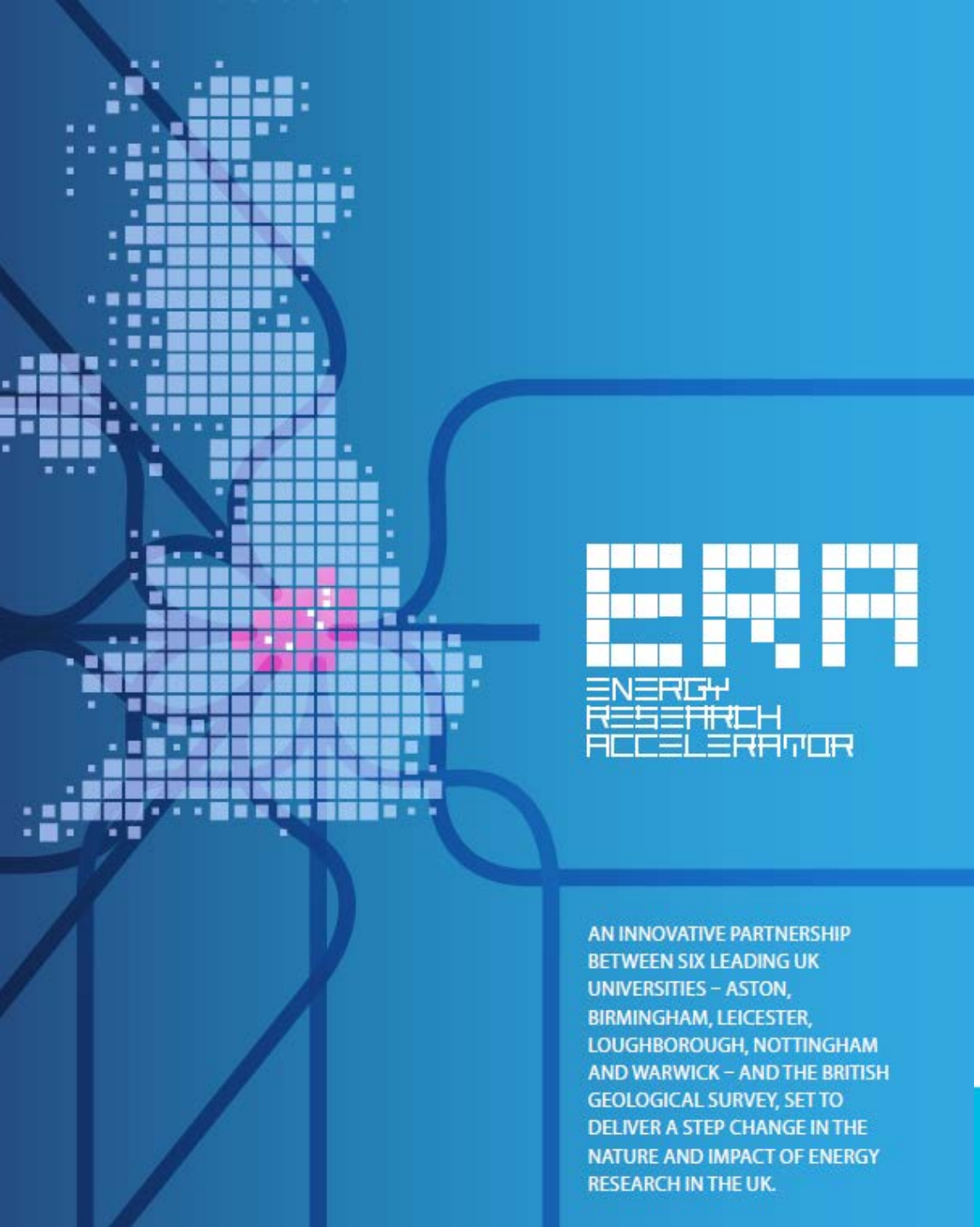
CryoHub: a €7 million European grant for pan-European consortium of researchers led by Professor Judith Evans, LSBU to investigate integrating cryogenic energy storage (CES) with refrigerated warehouses and food processing plants.

Birmingham Centre for Cryogenic Energy Storage: a £12 million project led by Professor Yulong Ding of the University of Birmingham, including £7 million for bespoke cold/thermal and cryogenic energy storage '8 Great Technologies' initiative.

i-STUTE: an interdisciplinary centre for Storage, Transformation and Upgrading of Thermal Energy. i-STUTE, funded through the research councils Energy programme.

National Centre for Sustainable Energy use in Food chains (CSEF): research into energy, resource use and sustainability of the food chain, le[illegible] Tassou from Brunel University, and one of six centres funded by[illegible] (RCUK) to address 'End Use Energy Demand Reduction' in the[illegible]

CATAPULT Energy Systems



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The Energy Research Accelerator brings together the Universities of Aston, Birmingham, Leicester, Loughborough, Nottingham and Warwick and the BGS to form a **£250M** research hub which will deliver on UK expertise and leadership to give the UK competitive advantage in energy R&D.

The University of Nottingham | UNIVERSITY OF BIRMINGHAM | WARWICK THE UNIVERSITY OF WARWICK | Loughborough University | Aston University Birmingham | University of Leicester | British Geological Survey

T-ERA ENERGY RESEARCH ACCELERATOR

To lead the development and integration of a range of thermal (heating and cooling) energy technologies and the global cold economy.

Phase I

- Advanced Thermal Manufacturing Centre
- Seed development of advanced thermal research design capacity and biorefining capability through EBRi/5-BIO

I-ERA ENERGY RESEARCH ACCELERATOR

To deliver integrated energy solutions addressing major energy use markets - buildings and transport - through manufacturing.

Phase I

- National Low Carbon Mobility Centre
- Battery chemistry, scale up and characterisation capability

G-ERA ENERGY RESEARCH ACCELERATOR

To unlock the potential of our indigenous and international energy resources by accelerating innovation in unconventional fossil fuels, carbon capture, geological energy storage and smarter energy use.

Phase I

- Borehole Array stage I
- Community Energy Demonstrator
- Research Acceleration and Demonstration Centre

Phase 2

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Fundamental R&D

Demonstration and validation

Manufacturing and productionisation

Universities

CATAPULT
Energy Systems

CATAPULT
High Value Manufacturing

T-ERA ENERGY RESEARCH ACCELERATOR

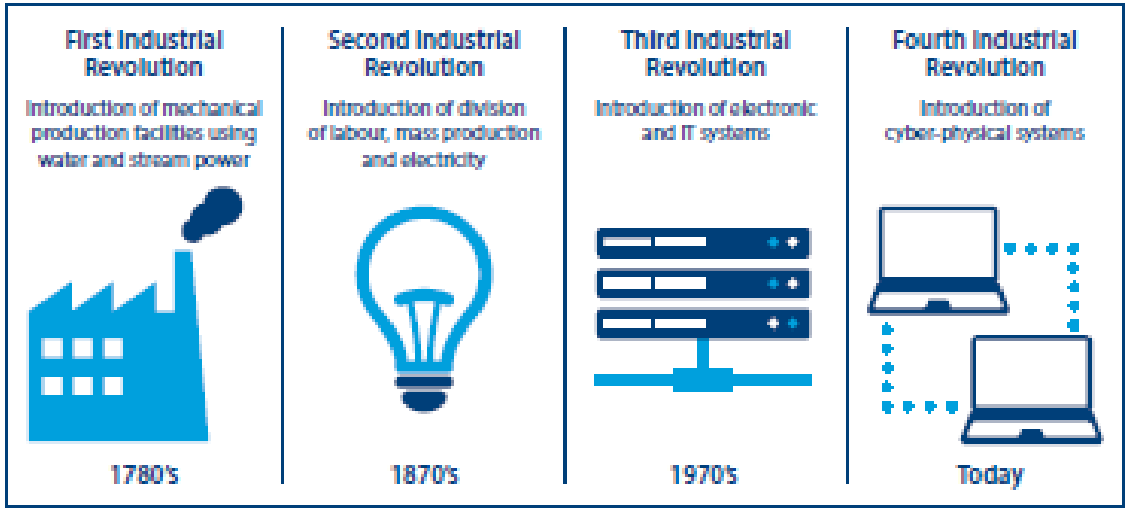
I International
T Thermal
E Energy
M Manufacturing
A Accelerator

In collaboration with:

mtc Manufacturing Technology Centre

New Approaches:

- Industry 4.0
- Factory in a Box
- Smart Manufacturing



Scaling up and accelerating the introduction of new thermal technologies.

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Thank you for your time

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