UNIVERSITY OF BIRMINGHAM

DOING COLD SMARTER

INNOVATION ROAD MAP

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“Doing Cold Smarter”

Cold is vitally important to modern day life. It underpins the supply of food and medicine, enables the growth of data networks and makes buildings and transportation more comfortable. The lack of cold has massive social and environmental impacts.

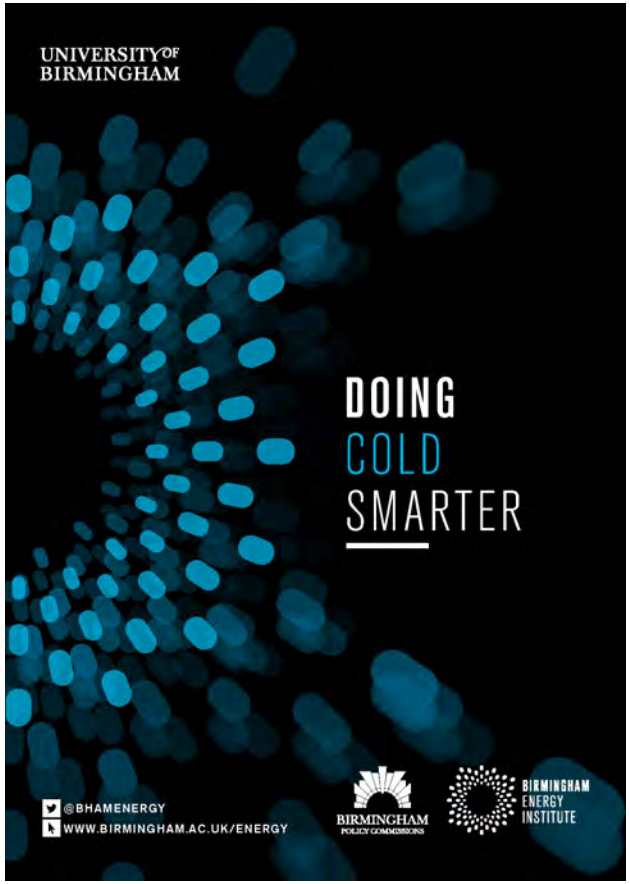
The demand for cooling is expected to boom, and unless we find new ways to make cold sustainable the environmental impact will be ruinous. Yet the UK Government currently spends less than 0.2% of its engineering research budget on cooling.

The ‘greening’ of cold is clearly an urgent global problem – but it may also offer Britain a significant business opportunity.

The University of Birmingham Policy Commission was set up to look at meeting demand for cold from a systems level to recruit vast untapped resources of waste cold, ‘free’ cold, waste heat, renewable heat, and ‘wrong-time’ energy to radically improve the efficiency of cooling, and reduce its environmental impact and cost. It also produced a high-level technology roadmap to guide next steps and longer term progress with the support of stakeholders from innovators to end-users.

Developing policy and action on clean cold will help deliver:

- reduced carbon emissions and better air quality;
- energy resilience;
- global food security;
- economic growth, in-country jobs and skills.



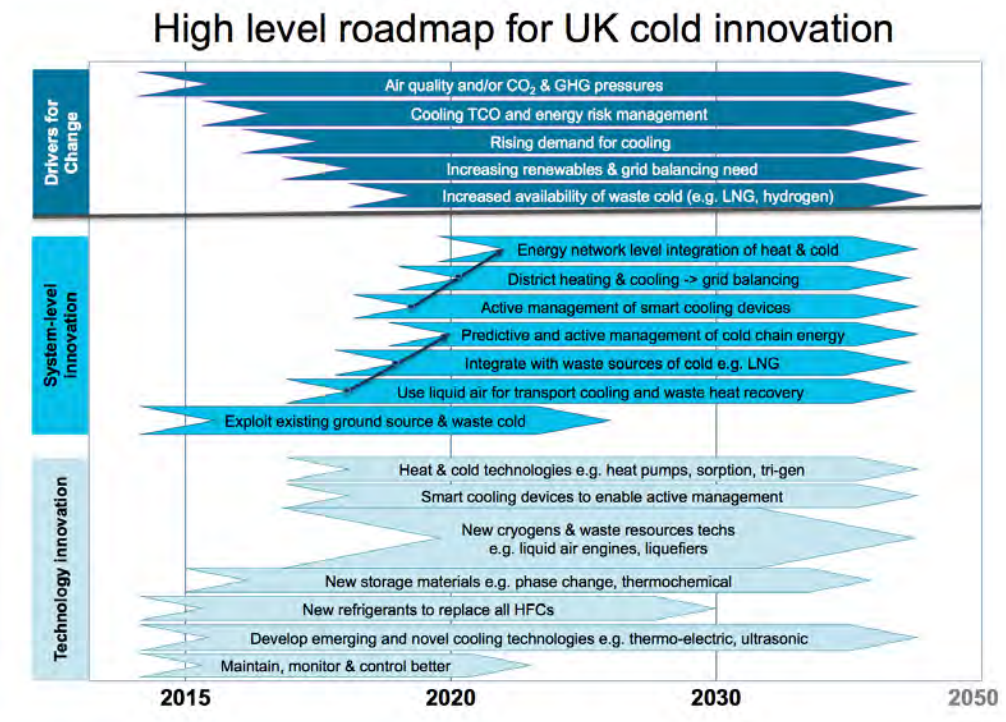
Birmingham Policy Commission

“Consensus Road Map”

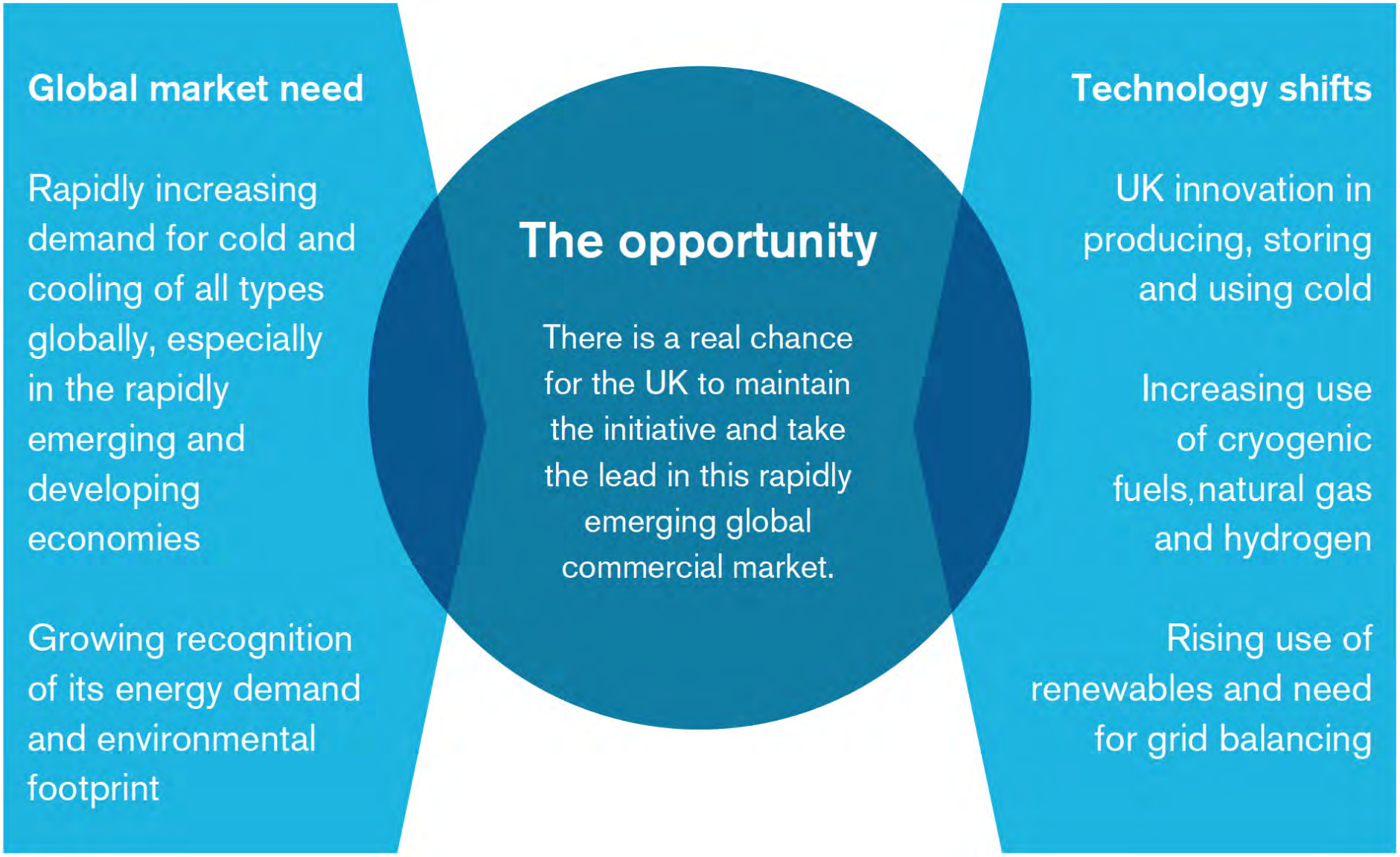
The roadmap for cold is intended to describe what is required to develop a vibrant British clean cold industry that will not only dramatically improve the environmental performance of cooling in this country, but also establish and maintain a lead in a new global market potentially worth £ hundreds of billions.

It is a high-level industry roadmap, developed by the Commission and external experts. It is technology agnostic and resolutely practical: it does not fix its eyes solely on what might be achieved from blue-sky technologies in 15 years, but is equally occupied with the significant short-term gains from improved maintenance of existing equipment – and all the steps in between.

The aims of the roadmap are to reduce consumption of non-renewable natural resources, pollutant emissions, greenhouse gases (CO_2, refrigerants) and the total cost of ownership for equipment operators, but at the same time generate economic value to UK plc through improved productivity and exports, and social benefits for emerging economies through the creation of clean cold chains.



Why Clean Cold?



Why Clean Cold?

- Refrigeration and air conditioning is estimated to cause between 7% and 10% of global CO_2 emissions – two to three times more than is attributed to aviation and shipping combined.
- Global demand for air conditioning alone is forecast to grow 33-fold by the end of the century, when it would consume the equivalent of half our worldwide electricity generation in 2010.
- If nothing is done, within fifteen years cooling will require an additional 139GW – more than the generating capacity of Canada – and raise greenhouse gas emissions by over 1.5 billion tonnes of CO_2 per year, three times the current energy emissions of Britain.
- It is estimated that around 23% of perishable food is lost through a lack of refrigeration in developing countries.
- Analysis suggests that the number of transport refrigeration units on the road could reach more than 15 million by 2025. That's more than four times the number in operation today.
- If nothing is done, 15 million transport refrigeration units will emit the same amount of pollution as would be created by more than 800 million diesel cars.

Clean cold consensus roadmap

A shared roadmap for cold aimed at

Reducing

- consumption of non-renewable natural resources
- pollutant emissions
- greenhouse gases (CO_2, refrigerants)
- total cost of ownership for operators

Delivering

- economic value to UK plc (UK productivity and exports)
- societal benefits for emerging economies (cold chains)

The key steps to doing cold smarter

Evidence to the Commission suggested a four-stage approach to doing cold smarter, culminating in the Cold Economy:

1. **Reduce cold load/cooling work required:** e.g. better building design, vaccines that survive at higher temperatures;

2. **Reduce the energy required for cooling:** i.e. increase the efficiency of cooling technologies – eg. cold stores could raise efficiency by an average of 30% using off the shelf solutions only – and reduce the global warming potential (GWP) of refrigerant gases;

3. **System level thinking/Cold Economy:**
   a. Harness waste resources: 'wrong-time' renewables; waste cold (LNG); waste heat, or renewable heat from biomass or ground source heat pumps; system integration across the buildings and transport;
   b. Cold energy storage to warehouse and shift wrong-time energy to replace peak electricity demand and diesel consumption in built environment and transport applications.

4. Having thus minimised energy demand, **convert remaining cooling loads to sustainable energy sources.**

The primary focus of the roadmap is steps two and three, since the other elements are broadly understood, whereas nobody has previously investigated the system-level efficiency of cooling, and early work suggests the gains from these two steps are potentially huge. Additionally much of the cold demand is going to come from new 'smart' cities yet to be built, and we have the chance to develop cold into properly planned and integrated energy systems.

The roadmap takes an integrated system approach to cold

Making cold
- Harness waste/unused resources e.g.:
  - 'wrong-time' renewable energy (e.g. wind)
  - waste cold (e.g. LNG)
  - ambient heat & cold (e.g. ground source)

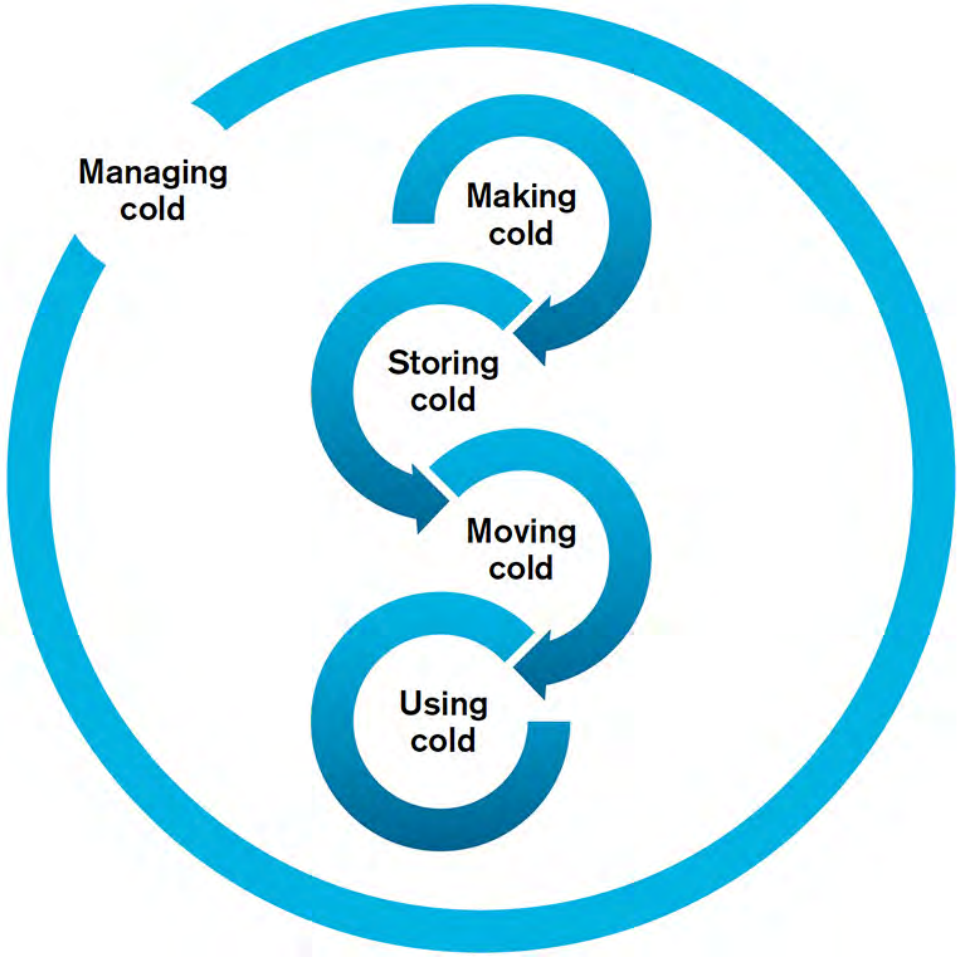
Storing cold
- Thermal energy storage to warehouse

Moving cold
- New energy vectors and material to shift cold

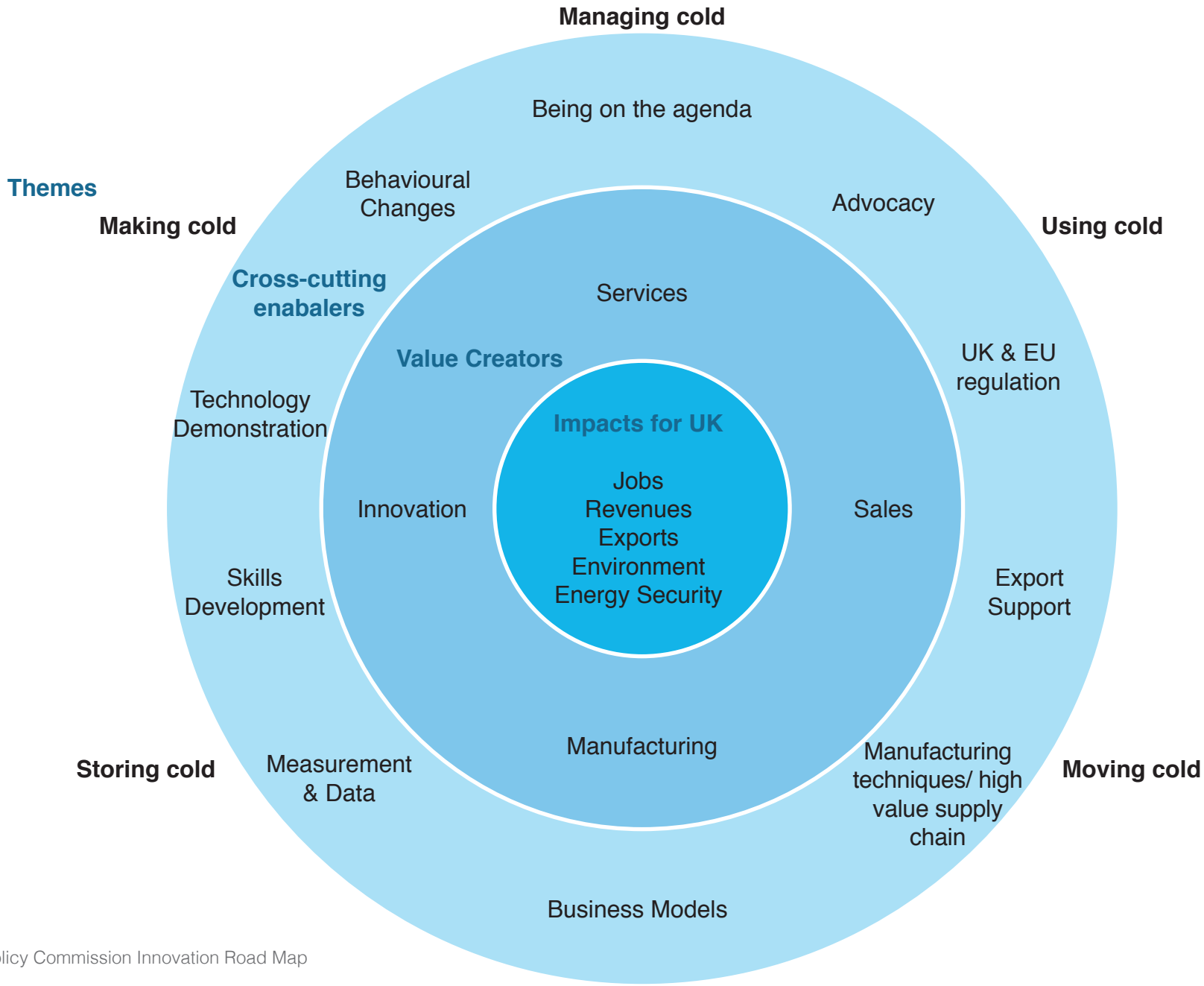
Using cold
- Reduce cold loads
- Increase efficiency and reduce GWP of conventional technologies
- New technologies to harness novel thermal stores and energy vectors

Managing cold
- Data monitoring
- Intelligent controls
- System level management

System approach to cold



How does UK capture value?



Where is the roadmap relevant?

Energy Systems: grid buffering and stabilisation, district heating cooling, system level waste heat/cold recovery, storage and movement of cold

Food: packing, processing, manufacturing

Cold Chain: transport refrigeration, depots, retail & medical, domestic refrigeration

Built Environment: building energy, local scale energy buffering & power generation, air conditioning, data centre cooling, warehouse refrigeration

Transport: propulsion, waste heat recovery, interaction with ICE & electrochemical systems, LiAir, LN2, LH2 LNG or NH3 as a fuel, provision of a/c from cold

Industrial process: industrial gases and processes, LNG and LH2 import and distribution, industrial-scale chilling & freezing processes

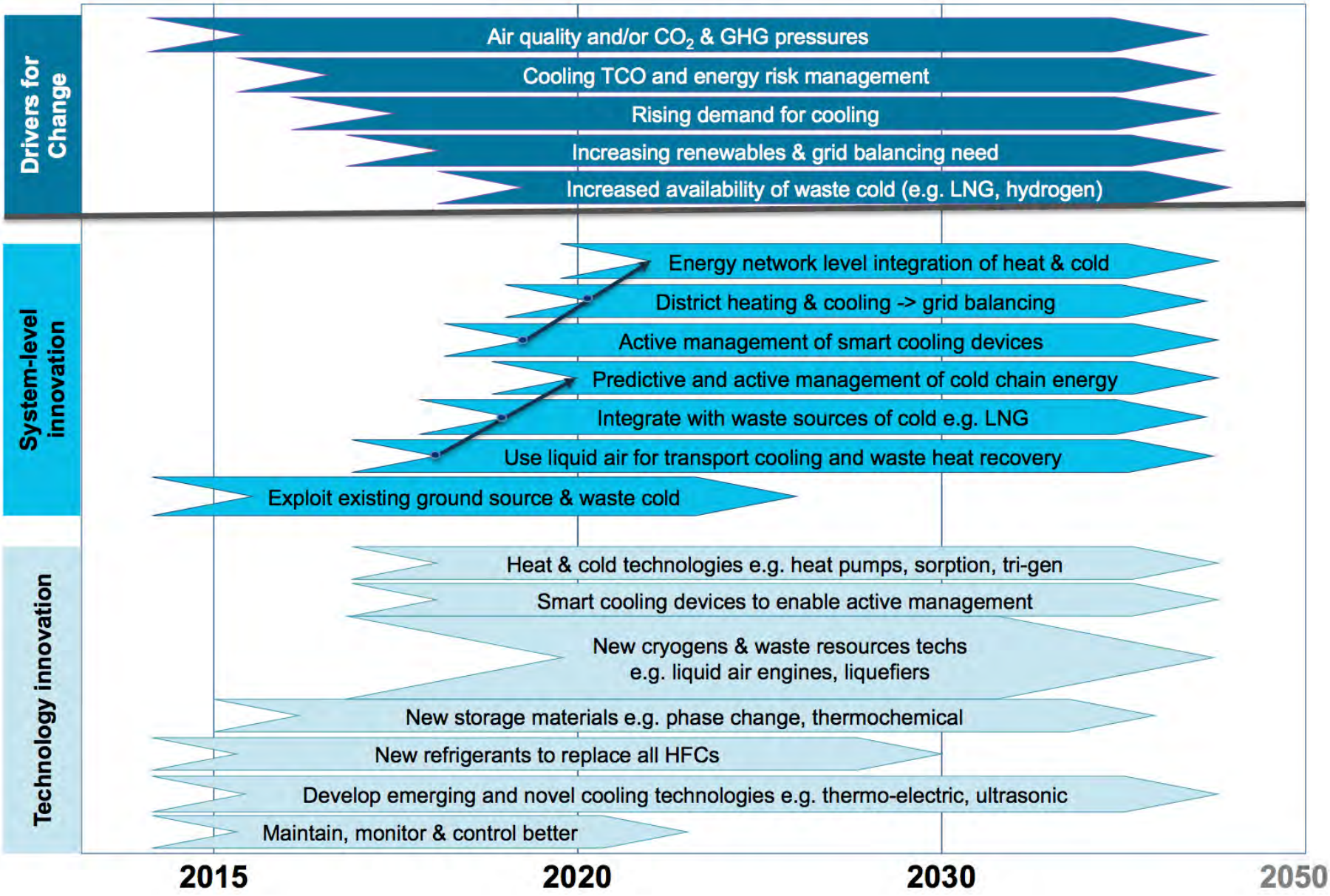
Advanced: superconductors, nanotechnology, other fundamental or advanced concepts

Summary features of roadmap

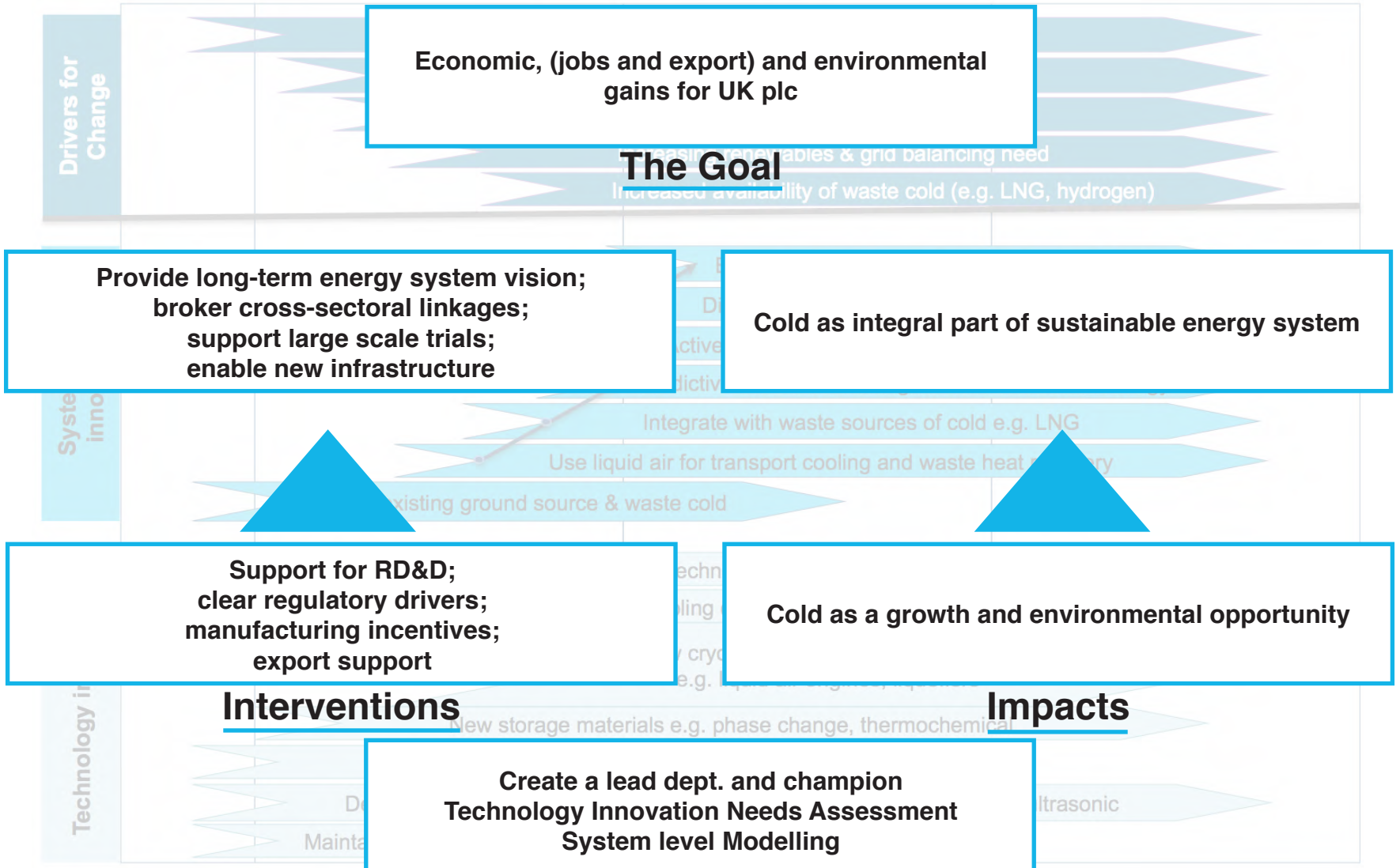
Details in report

	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 optimisation. Weather & climate linked cooling	Fully integrated cold and energy chains, minimizing losses and environmental impacts; optimize system components	Long-term management of cold

High level roadmap for UK cold innovation



Interventions and Impacts



Economic, (jobs and export) and environmental gains for UK plc

The Goal

Provide long-term energy system vision;
broker cross-sectoral linkages;
support large scale trials;
enable new infrastructure

Cold as integral part of sustainable energy system

Support for RD&D;
clear regulatory drivers;
manufacturing incentives;
export support

Cold as a growth and environmental opportunity

Interventions

Impacts

Create a lead dept. and champion
Technology Innovation Needs Assessment
System level Modelling

Where it all starts

Potential roadmap stakeholders

Energy Sector: grid, power generation, liquid air and hot/ cold-storage players

Urban planners: district cooling networks, heat island effect, integration of services and utilities

Energy Users: liquefaction, users with cold processes, industrial parks, city authorities

Cold dependent businesses: agriculture and food industry (post harvest food loss community), medical, data centres

Vehicle manufacturers: technology developers especially urban trucks & buses, refrigerated transport, light urban vehicles, goods handling, marine and mining

Equipment manufacturers: commercial and domestic refrigeration manufacturers – built environment, transport and mobile refrigeration plant and the providers of power in emission-sensitive environments

Transport & Logistics operators: including cold-chain, buses, urban delivery and haulage

Component suppliers: including heat exchangers, refrigeration compressors, electrical systems, ICEs, fuel cells and other future technologies with waste heat / cooling need

Industrial gas suppliers: embracing liquefaction and distribution of LN2, LiAir, LH2, LNG

Superconductor innovators: magnets, electrical conductors, motors

Policymakers: in energy, energy storage, transport, air quality & environment

Finance community: venture capital, asset finance, novel financing models, shared risk

For further information

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The full policy report, Doing Cold Smarter, is available for download from the Policy Commission website, via www.birmingham.ac.uk/research/activity/energy/policy/cold/doing-cold-smarter.aspx

Birmingham energy Institute

The Birmingham Energy Institute is the focal point for the University of Birmingham and its national and international partners, to create change in the way we deliver, consume and think about energy. The Institute harnesses expertise from the fundamental sciences and engineering through to business and economics to deliver co-ordinated research, education and the development of global partnerships.

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