Centre for Sustainable Cooling

Thinking Thermally
The opportunity of waste cold

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UNIVERSITY OF BIRMINGHAM | BIRMINGHAM ENERGY INSTITUTE

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SRF The Centre For Sustainable Road Freight

Centre for Sustainable Cooling

The Packaging of LNG

LNG is gas packaged in cold at below -161°C

We transport 350 M tonnes of LNG around the world

Alongside the gas, we also transport 84,000 GWh_{Coolth}

Less than 1% of this is harnessed

- main uses being Air Separation and Electricity Generation

Year	LNG market	Opportunity for emission-free cooling
Today	350 MT	84,000 GWh_{Coolth}
2030	500 MT	120,000 GWh_{Coolth}
2040	700 MT	168,000 GWh_{Coolth}

Source: Shell LNG Outlook 2021

Process	Country
Air separation	China, France, Australia, Japan, South Korea
Electricity generation	Japan
Hydrocarbon liquefaction	Japan
Cryogenic comminution	Japan, South Korea
Liquid CO2/ dry ice	Japan
Refrigeration/cold storage	Japan, South Korea
Seawater desalination	United States
Gas turbine inlet air cooling	India, Japan, Spain

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The Global Cooling Challenge

The world is off-track to meet the 1.5°C objective of the Paris agreement

The world is also off-track to meet the Sustainable Development Goals and adapt to fast increasing climate heat

Cooling is energy intensive and accounts for 10% of global GHG and is the fastest growing GHG contributor

- There needs to be a paradigm shift towards sustainable cooling, providing affordable access to clean cooling for all with minimal climatic impact.
- The challenge is we need to *think thermally*

600 M tonnes a year of food is lost post-harvest, much of it because of lack of cold-chain.

25% of vaccines are lost primarily due to lack of cold-chains

2018 was a record year for global deployment of solar renewable at 104 GW of capacity added; energy demand of global Room Air-Conditioners alone sales was 115 GWs

By 2030 over 50% of the world's population will live in hot climates with increasing exposure to potentially dangerous heat conditions

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Harnessing the waste cold of LNG

Use thermal energy vector to decouple supply and demand by time and location

- ➢ Opens up premium value cooling demands, including in transport (refrigeration / AC)

- ➢ Diversity revenue streams to de-risk capital investment

Impacts

- New high-value revenue
- Avoided new-build electricity generation capacity
- Social / environmental gains
    - Access to cooling – food, health, productivity
    - Reduce emissions and health impacts from cooling
    - Mitigate environmental impacts of LNG

cumulative wins to 2050

4,000 TWh_{coolth} emission-free high-grade cold

>780 M tonnes emission savings

$440 bn of economic value at today's price excluding equipment costs

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The New Approach

chaired by

Professor Richard Williams

OBE, FREng, FRSE, FTSE and FIChemE, FIMMM, CEng, Csci

Principal and Vice-Chancellor, Heriot-Watt University

FPS Flexible Power Systems

Cold Recovery Application Options

IFC LNG Cold Recovery Webinar Series

11th March 2021

Flexible Power Systems

Flexible Power Systems

About us

EV fleet and electrical load management technology developer founded 2018. Our offerings combine engineering, operations management and big data to find more cost-effective low carbon hardware and software solutions spanning multiple energy vectors.

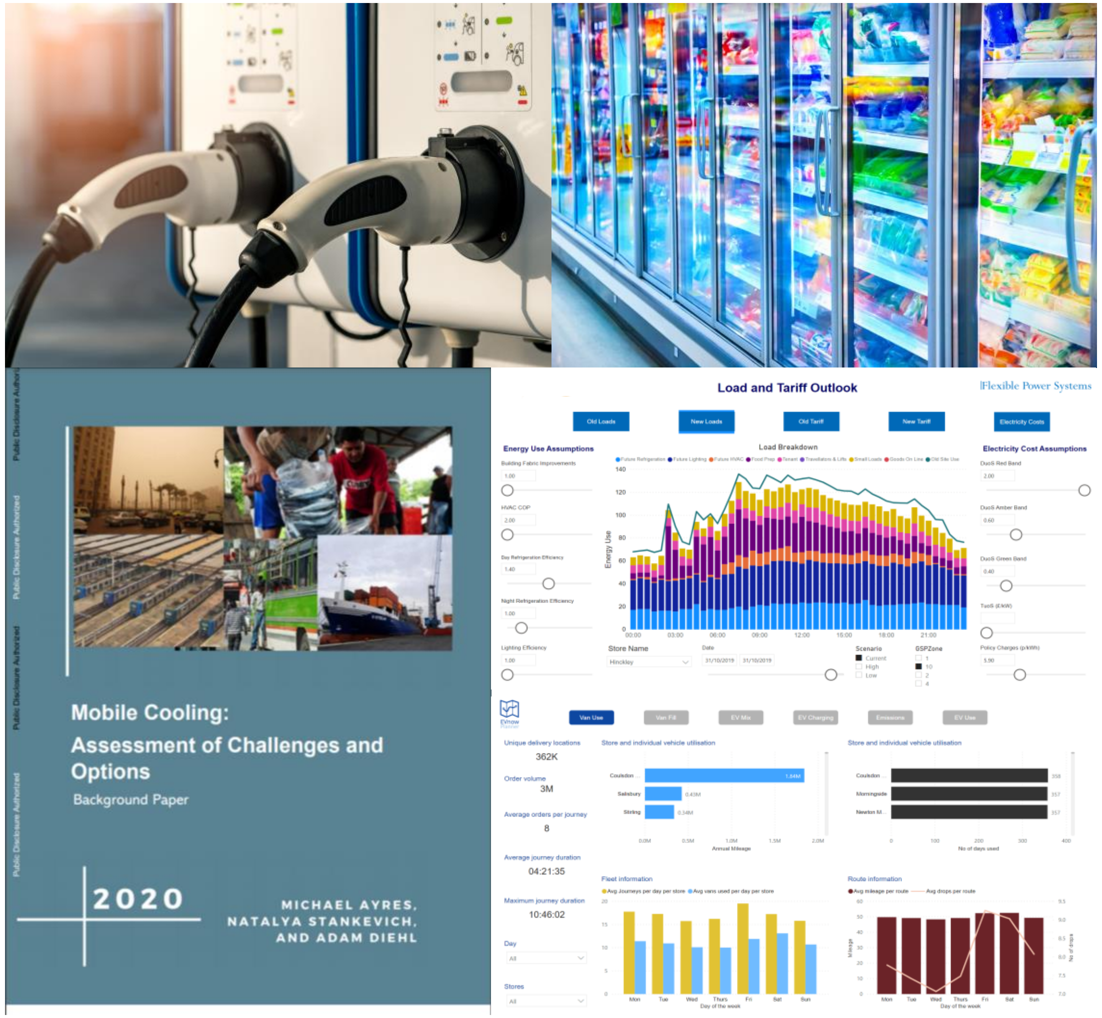
What we do

R&D - running £4m worth of advanced transport and energy storage systems research and development projects ranging from thermal energy storage to wireless EV charging hubs.

Consulting - Advisory, planning and modelling services to intragovernmental organisations, retailers, technology developers and strategy consultancies on EV deployment and cooling technologies.

Our Team

Leadership team have about fifty years' combined experience of advanced energy technology development and deployment across the electricity and transport sectors.



Applications Overview

Application	Indicative Min Process Temperature (°C)	Onsite	Packaged LNG Synergy	Very Low Temperature Vectors	Standard Vectors	Examples Where Implemented Currently
ASU (Nitrogen, Oxygen & Argon)	-196	X				China, France, Japan, South Korea
Liquid Air Energy Storage (LAES)	-196	X				UK*
CO2 Liquefaction (& Dry Ice)	-78.5	X				Japan
Ethylene Production	-104	X				Japan
Power Cycles	-162	X	X			Japan
Sea Water Desalination	-10	X				USA
Gas Turbine/Engine Inlet Cooling	0	X	X		(X)	Japan, Spain
Rubber (& Other Product)Grinding	-196			X		Japan, South Korea
Produce Freezing	-196		X	X	X	Globally*
Evaporative LiN TRU	-196		X	X		US, Europe*
PCM TRU Recharge	-196		X	X	X	N/A
Temp Controlled Warehouse	-40/-80		X		X	Korea
Ice Manufacturing	-21		X		X	
District Cooling	4		X		X	Spain, Singapore
Data Centres	20	X	X		X	

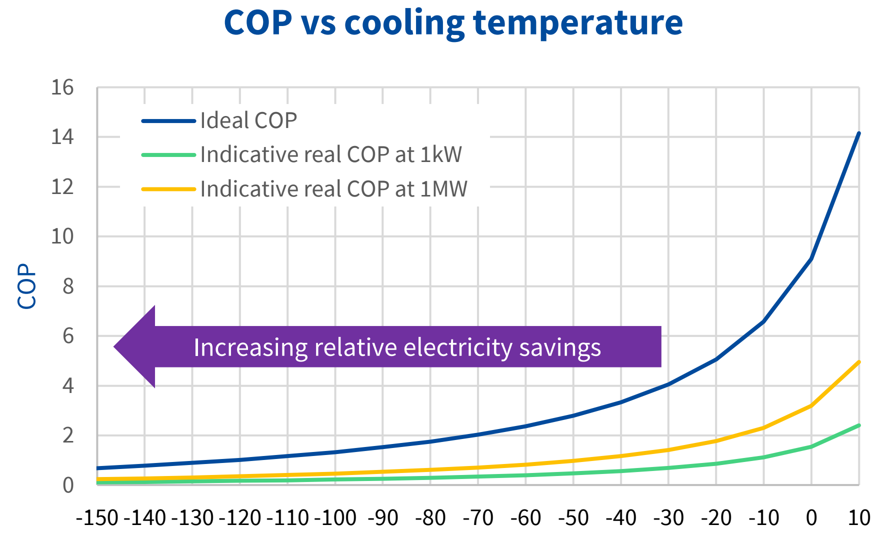
* Application demonstrated without terminal coupling

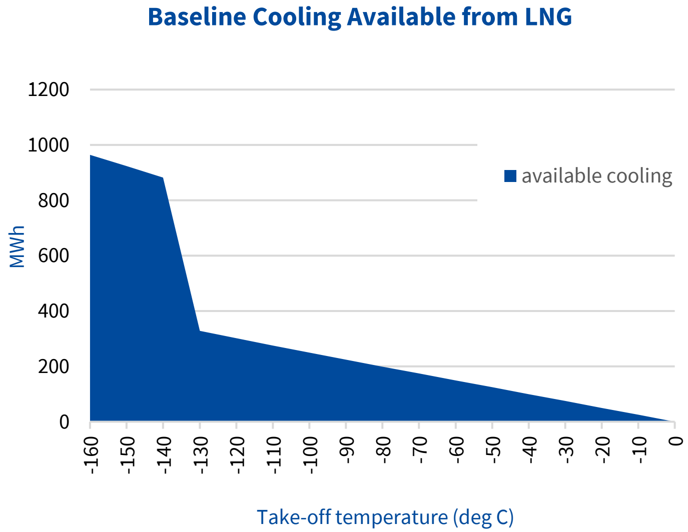
Application Choices

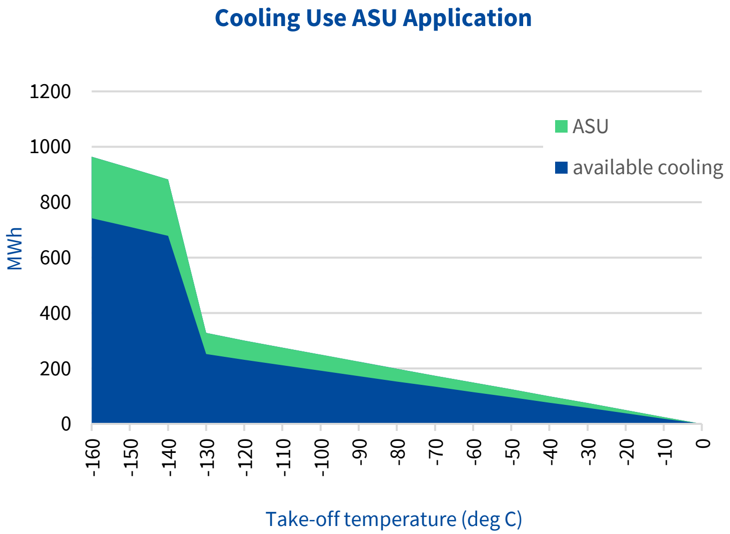
Emission and cost benefits will be highest when lower temperature cooling is displaced because of variations in plant efficiency.

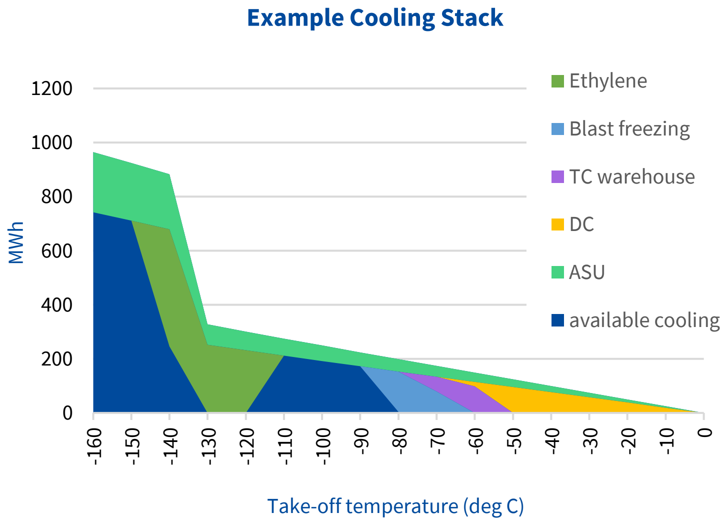
Many of these applications use different ranges of waste cold and so there exists the possibility of stacking applications to make efficient use of available cold resources.

The charts below show an example stack of applications. The optimal stack will depend on local demand and market conditions.









Energy Vectors

Typically an LNG import terminal will be servicing the needs of the local gas infrastructure and so its location or send out rates may not match with when services related to cold recovery applications are required. As a result energy vectors to move the cooling in time or location can improve value.

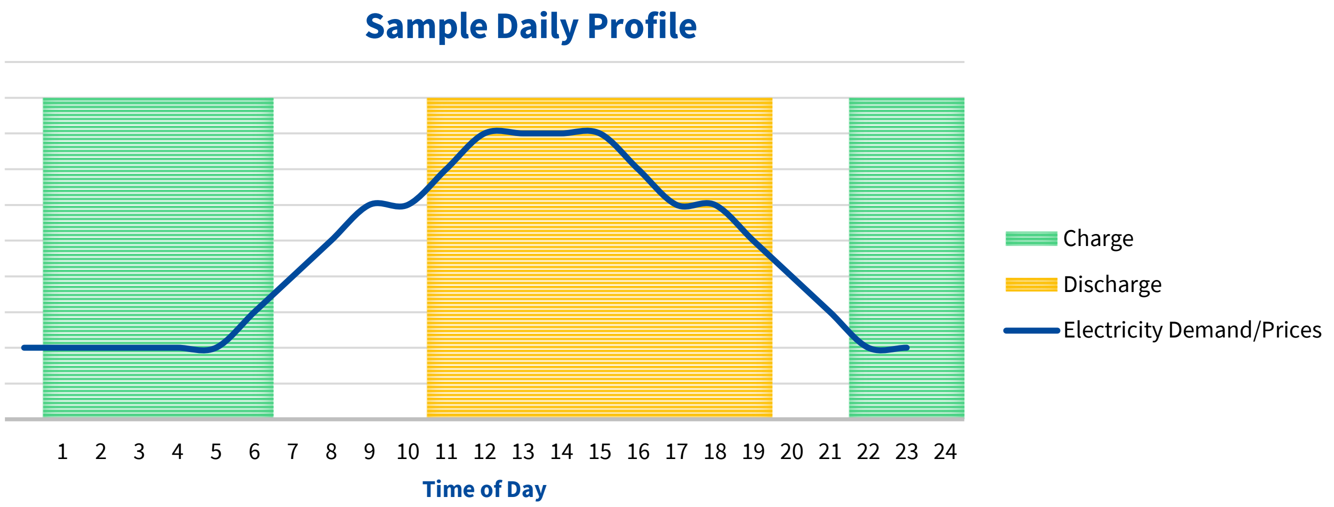
Vector	Indicative Temperature Range	Indicative Pipeline Feasible Distance	Tanker Feasible Distance	Storage or Transport of Cold?
Water Glycol	-12°C	~20km	N/A	Transport
Slurries	0°C	<5km	N/A	Both
CO2	-60°C	~20km	~200km	Transport
LNG	-162°C	<5km	~200km	Both
LiN	-196°C	<5km	~200km	Both

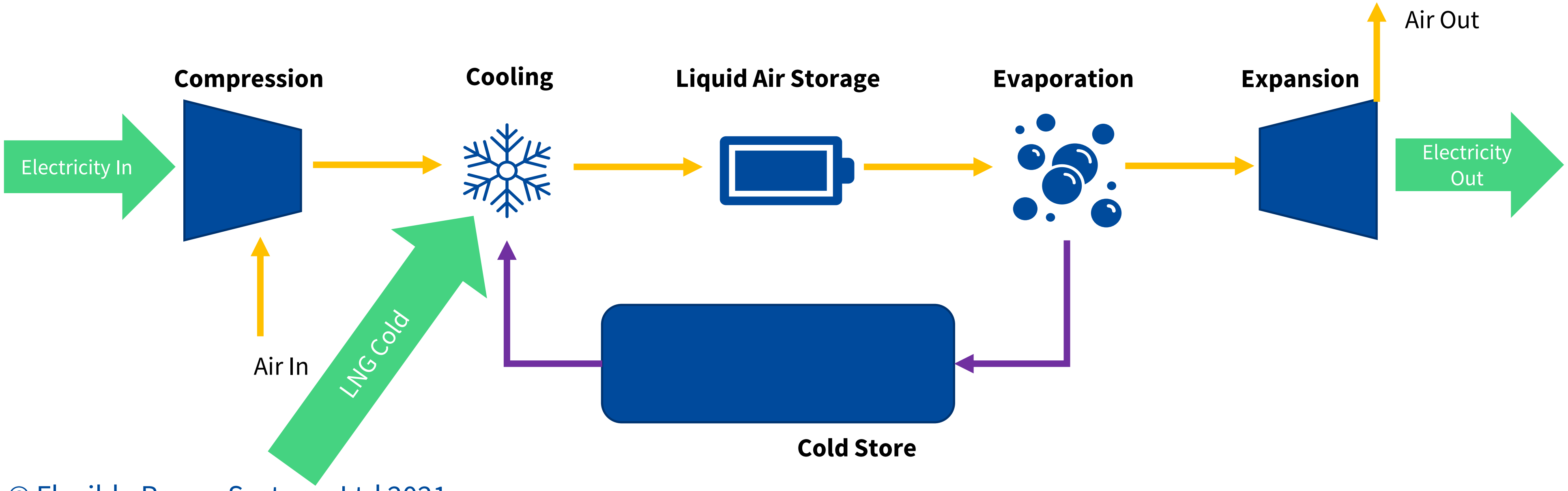
Electricity Systems Integration - LAES

Flexible Power Systems

Several of the applications offer the potential for integration with the electricity system through offering storage or generation capacity expansions.

The potential to enhance LAES cycle efficiency could be very attractive in markets with emerging supply/demand mismatches caused by a combination of variable renewable energy generation and local demand profiles.





Flexible Power Systems (FPS)

FPS is a technology company that helps companies reduce their transport emissions. We combine data analytics with technical and operational expertise to deliver unique solutions to our customers.

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The Cold Economy and opportunities to combine LNG with other cooling applications

11th March 2021

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* Image credit: SJ-NTU Corporate Lab

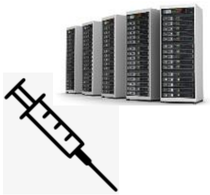
[1] Prof. Toby Peters – University of Birmingham

- Cold Economy introduce by the University of Birmingham in early 2010s
- NTU leading the effort on Cold Economy for Singapore / South-East Asia

❖ Why a Cold Economy study for Singapore / SE Asia?

Tropical climate getting warmer

CDD expected to increase by 12% in 2040
⇒ Higher cooling load



Particular cold energy consumers constantly growing

e.g. Data centres (380 MW - 12% growth) and Cold storage (e.g. vaccines)

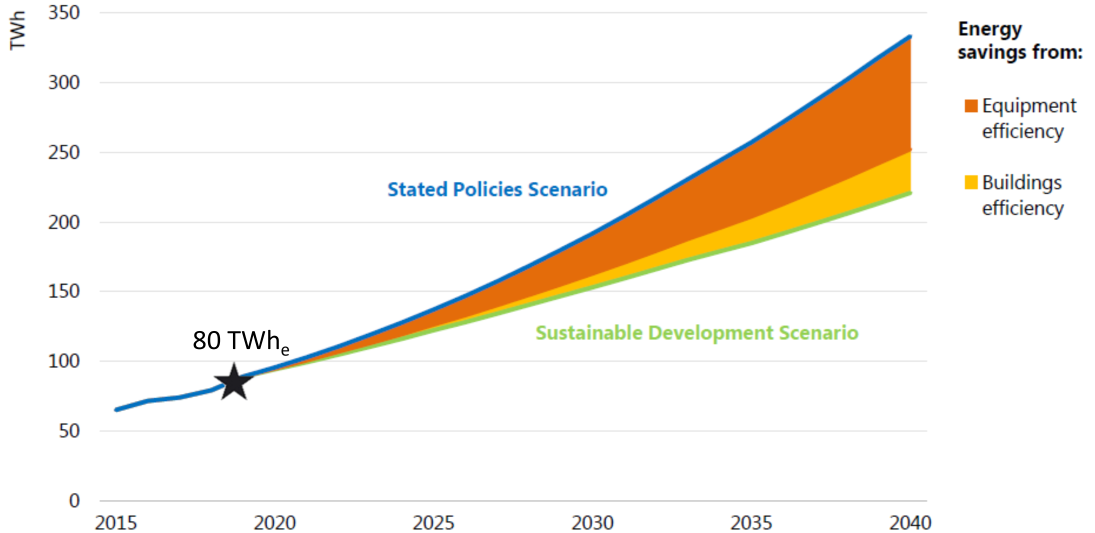
Towards a Mega City

Population expected to increase by 11% in 2040 ⇒ Higher cold demand

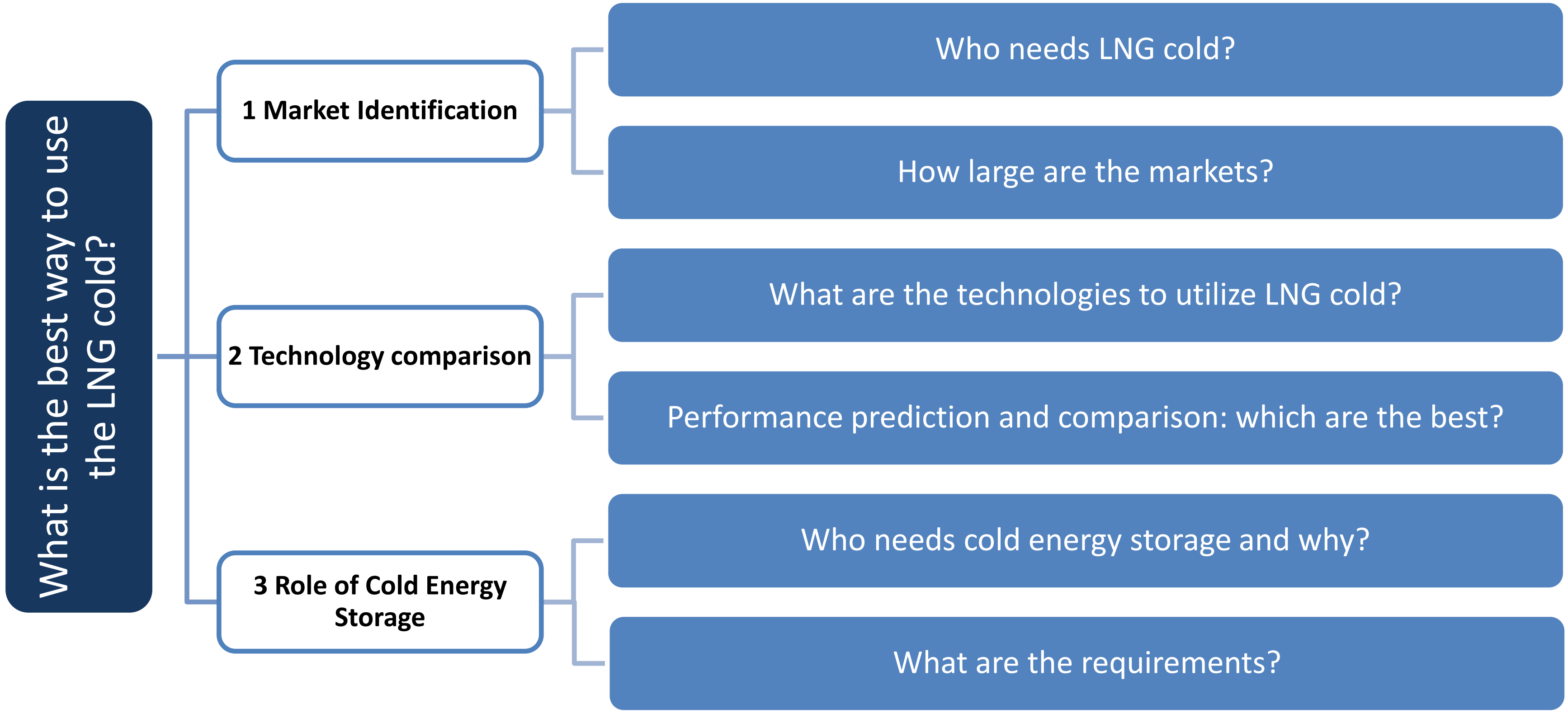
Possibility of storing high-grade cold

About 736 GWh_{cold} is wasted per year during LNG regasification
⇒ Sustainable development scenario

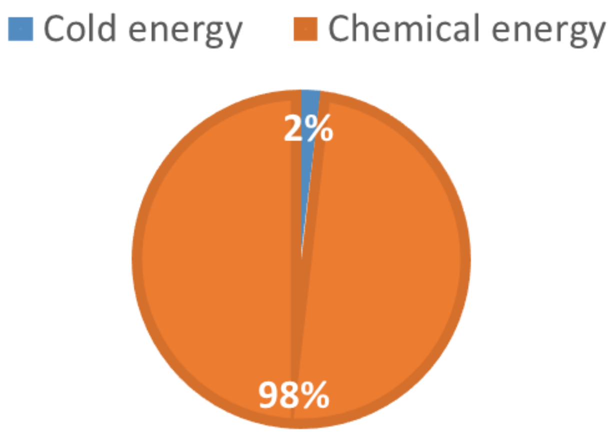
Electricity demand for cooling in Southeast Asia
(Source: IEA 2019)

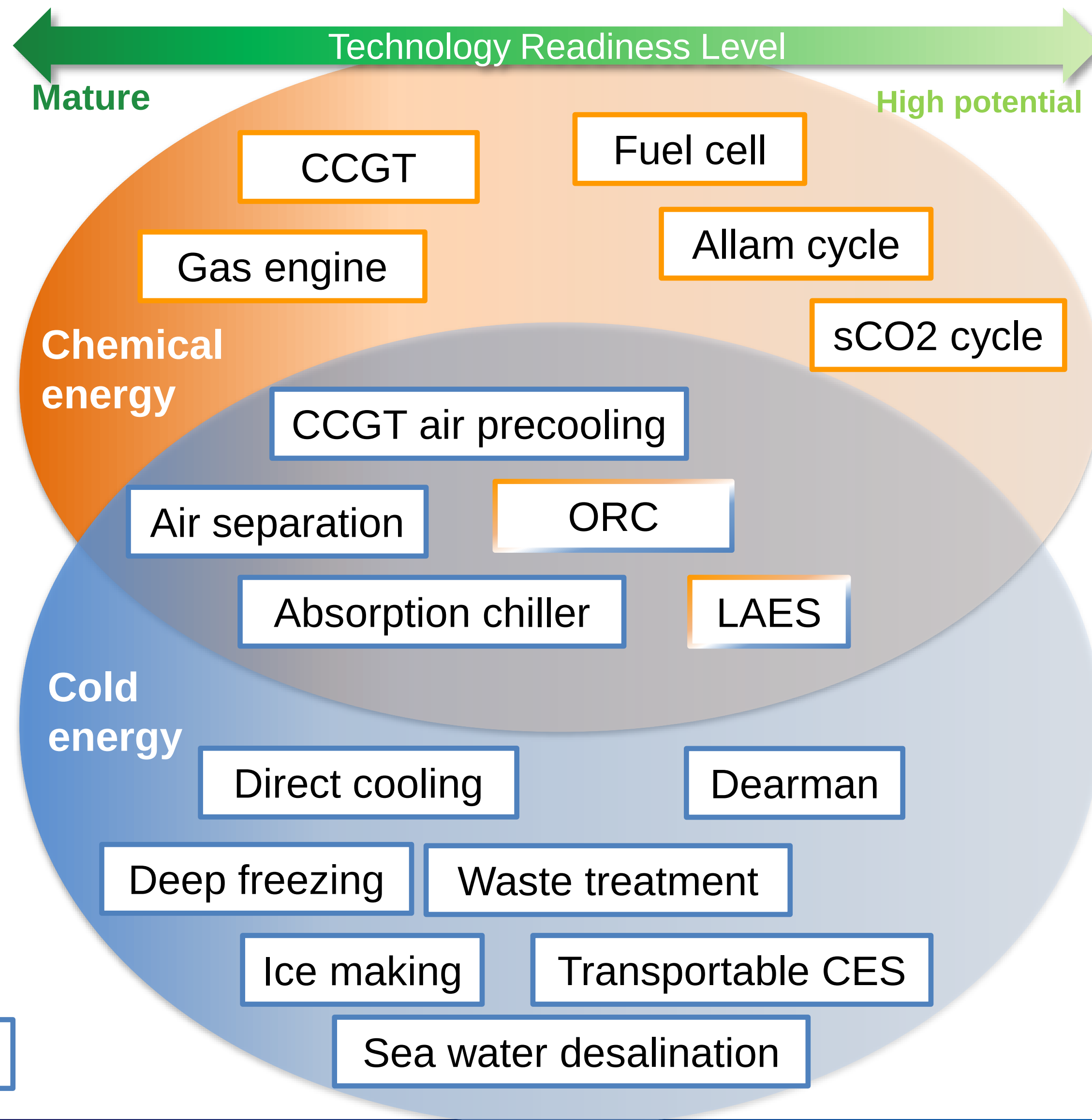


❖ Structure of LNG cold energy potential assessment



❖ How to use LNG?





Legend

Power generation

Cold production and/or utilization

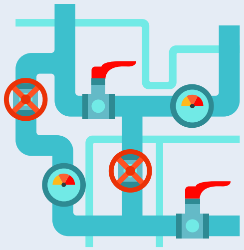
❖ Role of Cold Energy Storage- LNG-based Cold Economy

Part 1

LNG terminal

Generation of cold energy

Part 2



Transportation

Delivery of cold energy

Part 3

End users

Utilization of cold energy

→ **Cold Energy Storage (CES)** is **essential** and can significantly enhance the **performance** of each part of the LNG-based cold economy

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Thank you

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