WPs 2.1, 2.2, 2.3, 2.4, 2.5

Graeme Maidment
i-STUTE cooling based projects

WP2.1. and WP2.2 Supermarket refrigeration

WP2.3. Data centres

WP2.4. Transport refrigeration

WP2.5. Integrated heating and cooling
WPs 2.1, 2.2
Retail refrigeration

Judith Evans, Alan Foster
Retail refrigeration

- Roadmap
- Joint publications
- Prototype cabinet
- Deliverables
WP 2.1 and 2.2 Retail refrigeration

Road map
Updated after industry consultation

Input from:
1. IOR
2. CIBSE
3. ASDA
4. CEBES
WP 2.1 and 2.2 Retail refrigeration

Baseline store

- Medium sized ASDA store (6290 m²)
- Intermediate age
- Savings applied directly to store

Meeting with ASDA to discuss how they use outputs
Agreement to also model a new large store to determine whether savings similar
Presentation

- Graphs:
  - Direct
  - Indirect
- Bubble maps
Cabinets - current

Payback time (years)

Uptake time (years)

- Air deflectors/guides
- Anti-fogging glass - min
- Anti-fogging glass - max
- Cabinet lighting occupancy sensors - min
- Cabinet lighting occupancy sensors - max
- Defrost controls (on demand) - min
- Defrost controls (on demand) - max
- Doors on cabinets - min
- Doors on cabinets - max
- Glazing (improved LT, doors added to MT) - min
- Glazing (improved LT, doors added to MT) - max
- Improved axial fans
- Night blinds and covers
- Risers and weir plates - min
- Risers and weir plates - max
- Strip curtains - min
- Strip curtains - max

100 tonnes CO$_2$
Refrigeration - current

Payback time (years)

Uptake time (years)

- Refrigerants – lower GWP HFC
- Refrigerants – HFO
- 100 tonnes CO$_{2e}$

- Floating head pressure control - min
- Floating head pressure control - max
- DC (EC) condenser fans
- Inverter Drives and MECs - min
- Inverter Drives and MECs - max
- Liquid pressure amplification - min
- Liquid pressure amplification - max
- Refrigerants - HFC retrofit HFO
- Refrigerants - lower GWP HFC - min
- Refrigerants - lower GWP HFC - max
- Suction-liquid heat exchangers
- Suction pressure control
Conclusions from Road map

• Large potential savings
• Many have:
  – Short application time
  – Short payback time
• Savings not necessarily cumulative
• Cabinets (retrofit or new) – mainly indirect
• Retrofit refrigeration systems – indirect + direct
• New refrigeration systems – mainly direct
• Great potential to reduce emissions being explored with ASDA
WP 2.1 and 2.2 Retail refrigeration

IOR presentations:

- Presentation on road map
- Joint presentation with CSEF on joint modelling


WP 2.1 and 2.2 Retail refrigeration

Other presentations:

- Presentation at ICCC in New Zealand
- Publication of road map document as IIR document (will be peer reviewed by IIR members)

Prototype cabinet

- George Barker open fronted multi-deck
- Typically used in ASDA stores
- Adapt using selected technologies
- Select from road map (link technologies), not always additive effect
- Test and validate


**WP2.1 and 2.2** Retail refrigeration

**Original intentions:** 40-70% of energy in supermarkets used for refrigeration, UK retail refrigeration ~ 9-10 TWh/year ~7.3 Mt CO2 (~26% direct, ~74% indirect);

**Timescale:** Year 1 to Year 5

**Achievements to date:** 1) Typical supermarket has been modelled. Significant savings were found to be achievable: Cabinet Indirect emissions 49.5%; Refrigeration Indirect 32.9% Direct 80.4%; 2) ASDA trialling options. 3) Prototype cabinet being developed. 4) 9 publications to date including 2 with CSEF. 5) A new project submitted with CSEF and CEI. 6) Inputting to IEA Annex 44.

**Outputs to date:** 9 papers: Two IIR International Congress of Refrigeration Yokohama, One IIR International Conference on Sustainability and the Cold Chain London, One book, One book chapter, One Journal, Two Proc Inst Ref with CSEF.

**Has the effort been justified?** 1) ASDA utilising results in a trial and a new cabinet being developed with potential roll out across the Wallmart Corporation. 2) Peer reviewed paper on technological options in development (IJR). 3) Joint project submitted with Brunel and UCL on benchmarking supermarkets with Link to Annex 44 Involves large UK supermarket, Smaller freezer centre supermarket and LSBU in discussions with additional 1 large and 1 medium sized supermarket chain

**Synergies with other WPs:** WP2.4 & WP1.3, WP1.4,

**Recommendations:** a) Continue

**Targets / deliverables for 3rd annual report or elsewhere:** Roadmap published.
I-STUTE Project  
- WP2.3 Data Centre Cooling, Waste Heat Recovery and Reuse

Gareth Davies 
Centre for Air Conditioning and Refrigeration 
London South Bank University

Supporting slides for Advisory Board Meeting  Warwick University, 6th April 2016
Data Centre Cooling?

- Original project
- Data centre road map
- Data centre waste heat recovery
- Thames water
- Waste heat recovery and reuse from other applications
Data centre cooling

- Data centre cooling methods reviewed and evaluated
- Developed roadmap for future data centres
- Roadmap to be published - June 2016

Remote air cooling

Local air cooling

Direct liquid + air cooling

Total immersion liquid cooling

London South Bank University
Options for energy and carbon saving in data centre cooling

- **Air side direct free cooling**
  - Free air cooling:
    - both airside and water side, and direct and indirect
    - also evaporative (adiabatic) cooling
  - Air containment:
    - cold aisle or hot aisle containment, or use of chimneys above racks

- **Rack based liquid cooling**
  - Liquid cooling:
    - direct contact liquid cooling for processors only, or for whole IT server board. Water, dielectric or refrigerant used
    - immersion cooling. Tank based or rack based. Use dielectric or refrigerant
  - The above cooling methods can achieve the required operating conditions, but result in reduced energy usage and carbon emissions compared to legacy data centres
Recovery and reuse of waste heat from data centres

- Can recover heat from air return
- Need to increase temperature using heat pump for most reuse applications
- Data centres in central London represent a large heat resource
- Could use waste heat recovered from data centres in district heating networks
- A significant proportion of heat demand could be met for many London districts
Use of mains water for cooling data centres and LU tunnels

- Cooling using London’s mains water network
- Could add up 5°C in temperature ≡ 500 MW cooling for 8 months of year
- Synergy between mains water heating requirements of TW and cooling needs of data centres, LU and others
- Possible configuration for mains water cooling system for underground railway tunnels
District heating network

- Investigate recovery of waste heat from LU tunnels and its use as a heat source for Islington Council (IC) district heating network (DHN)

- Innovate UK project involving LU, IC and LSBU

- Temperature of recovered heat will be raised to required level for input to DHN using heat pumps

- Potential energy carbon and cost savings available will be evaluated

- General approach could be extended to other waste heat sources e.g. data centres
**WP2.3 Data centres (DC)**

**Original intentions:** DC: 2-3% UK electricity & growing. ~50% due to cooling. Review and evaluate potential new technologies for reducing energy use and carbon footprint.

**Timescale:** Year 1 to Year 4

**Achievements to date:** (1) seminal publication on DC cooling & heat reuse; (2) opportunity for waste heat recovery to mains water identified; (3) MICAH (metropolitan integrated cooling and heating) cooling underground & heat reuse in district heating (4) gov’t report on DC energy use


**Has the effort been justified?** Potential CO$_2$e savings: (1) UK DC, use of energy efficient cooling technologies & waste heat recovery, 0.67 Mt CO$_2$e 2015 rising to 4.15 Mt 2025 (2) Identified savings of 500 MW cooling & waste heat reuse from Thames Water (TW) water mains, 0.74 Mt CO$_2$e 2015. Waste heat sources: DC, London Underground (LU) and others. (3) Preheating of mains water for domestic and commercial hot water, 0.2 Mt CO$_2$e (4) Heat recovery to district heating network (DHN) from DC and LU, 0.9 Mt CO$_2$e 2015 rising to 4.4 Mt 2025. Project MICAH with LU and Islington Council (IC) evaluating DHN. Other benefits: (5) Revenue savings for end users e.g. DC, LU, TW and IC (6) Less mains leakage for TW (7) DHN addresses fuel poverty (8) Reduced disruption for road maintenance. Above applications expected to start becoming mainstream from 2017 - live trials currently being planned.

**Synergies with other WPs:** WP2.5 & WP1.3, WP1.4, WP3.1, WP3.2, WP4.1

**Recommendations:** a) Continue

**Targets / deliverables for 3rd annual report or elsewhere:** Roadmap for future data centre technologies, route/options for scale up identified
WP 2.4 : Refrigerated Road Transport

Christina Francis-Rowe
Email: francc17@lsbu.ac.uk

6th April, 2016
WP2.4 refrigerated road transport (RRT)

Background

Deliverables

• Develop a model to investigate real contribution of direct and indirect emissions

• Optimising system performance
**Project Schedule**

- **Conducted Prelim Study & Leak Analysis**
  - Data Analysis I

- **Developed:**
  - a) Leakage Tool
  - b) Steady State Model

- **Collect Data & Analyse**

- **Develop Transient Model**

**Today**

- Validated & Optimised Model
- Results of Data Collection & Analysis
- Transient Model
- End of Project

**Timeline:***

- **2013**
  - Project Started
- **2014**
  - Prelim Study & Data Analysis Completed
- **2015**
  - Steady State Model Completed
- **2016**
  - PhD Thesis
  - Industry Report
  - Validated & Optimised Model
  - Results of Data Collection & Analysis
- **2017**
  - Transient Model
  - End of Project
# Measure Actual RRT Data

<table>
<thead>
<tr>
<th>Item No.</th>
<th>RRT Truck Part</th>
<th>Data Collection Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Refrigerated/insulated box</td>
<td>Euroscan X2-6 series Temperature Recorder</td>
</tr>
<tr>
<td>2</td>
<td>Refrigeration unit</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Transport vehicle</td>
<td>FleetBoard Telematics System</td>
</tr>
</tbody>
</table>

*Selected instruments comply with vehicle certificate agency automotive type approval for electromagnetic compatibility (VCA-EMC)*
## Data Results – Journey Report

(17/12/2015 15:00 h – 18/12/2015 14:55 h)

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Data Results</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Real journey time</td>
<td>22 hours 46 minutes</td>
<td>Euroscan</td>
</tr>
<tr>
<td>2</td>
<td>Actual driving time</td>
<td>10 hours 12 minutes</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Pausing and other times</td>
<td>12 hours and 33 minutes</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Door openings/ closing events</td>
<td>Total = 16 x</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Side Door = 7 x</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rear Door = 16 x</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Distance travelled</td>
<td>189.7 km</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Fuel consumed</td>
<td>24.1 litres</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Total carbon emissions (i.e. for both the RRT system and the vehicle motive work)</td>
<td>63.4 kgCO₂</td>
<td>FleetBoard</td>
</tr>
</tbody>
</table>
Euroscan Combined Data Results –
For refrigerated compartment and fridge unit

[Graph showing temperature changes over time with various lines and markers, indicating different conditions and times.]

1: Alarms  2: Door Open  3: At POI  4: Driving

17/12/2015  18/12/2015
WP 2.4 Deliverables

- Developed a steady state model and leakage analysis tool
- Presented the results at the 24th ICR 2015 in Yokohama Japan
- Journal Paper IJR being corrected.
- Conducted a preliminary survey on home delivery RRT truck
- Characterized the basic operational performance of an urban home delivery RRT truck
WPs 2.5
Integrated Cooling, Heating and Storage

Akos Revesz
Background

• To investigate the interactions of underground railway tunnels and ground heat exchangers
• To investigate the potential indirect use of waste heat from the tunnels to heat buildings above ground.

Deliverables

• Development of a model
• Case study materials
2. Project time line with the key milestones

**Up to date:**

- Preliminary 2D model was developed
- 3D railway model was developed
- 3D ground heat exchanger models were developed
3. Key achievements

• 2D analysis of railway and ground source heat pump interactions.
• The up to date work has been presented on the 24th IIR Congress on Refrigeration, in August 2015 in Yokohama, Japan.
• A journal paper was published in October 2015.
• 3D railway and ground heat exchanger models were developed.
• An abstract was submitted to ASHARE Winter Conference 2017.
• A research photo has won second place in the EPSRC science photo competition’ people category.
4. Results

2D modeling work...

Analysis
2D simulation results of different parallel running tunnels
3D modeling work...

The running tunnel

Different borehole array configurations

Immediate next steps:

Parametric studies with the 3D models
**WP. 2.5. Integrated cooling, heating and storage**

**Originally intentions and timescale** Investigate the interactions of underground railways (URs) and GSHPs. Understand how energy generated by urban railway systems could contribute to sustainable city planning. Timescale: 36 months

**Achievements to date** To address the original intentions, two and three-dimensional numerical investigations were set out. In addition to that site visits and measurements were conducted at a disused London Underground station.

**Outputs to date**

|------------------|--------------------------------------------------------------------------------|

**Has the effort been justified?** The initial work of this project clearly demonstrated that interactions occur. Simulation results showed that the GHE temperature at a specific measurement point was increased by 10 degC when the proximity between the tunnel and GHE was reduced to 3m. Implementation could have the following benefits:

- Potential CO₂ savings by running more efficient heating systems: The heating CoP of a GSHP system improves by approximately 3% / °C Revenue savings for end users by running more efficient/smaller size heating system: London Underground (LU), GSHP developers/operators.
- Heat recovery from LU to district heating networks: Projected a potential of 4.4 Mt from LU and other waste heat sources by 2025. District heating addresses fuel poverty.

**Synergies with other WPs** WP2.3

**Recommendations - is it worth continuing?** Continue

**Targets / deliverables for 3rd annual report or elsewhere** RES5 report
Questions