Integration of the hidden refrigeration capacity as a heat pump in smart energy systems

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This presentation outlines the concepts behind the Danish EUDP-project (64016-0106) 'Super Supermarkets' where rollouts of decentral heat supply provided by supermarkets to district heating systems are planned, designed and executed.
Improve Energy Efficiency
Enable Variable renewables
Reduce Peak demand

The Smart Grid will...

resulting in...

CO2 emission reduction
Improved Energy Security
Minimised grid investment

Food Retail Refrigeration adds Flexibility to the Smart Grid

THE SUPERMARKET as smart appliance
FLEXIBILITY in supermarkets
AGGREGATED Potentials
THERMAL NETWORKS
CASE STUDY on District Heating Connectivity
HIDDEN COMPRESSOR CAPACITY is an opportunity
CONCLUSION
Today Smart Supermarkets are controlled

- Exploiting flexibility is doable without big investments
- The existing retail service structure is perfect to leverage on
Flexibility in supermarkets

1. LOAD SHEDDING FFR (COMPRESSORS)

2. DEFROST PLANNING

3. THERMAL STORAGE
Aggregated flexibility potentials

Supermarkets use up to 2% of all electricity use

Flexibility of multiple supermarkets can be aggregated

Total supermarket aggregation would account for
> 20% of average delivered wind power *
> 50% of average delivered PV power*

*’EU energy in figures’ - 2013 numbers

Wind electr.gen:
DE: 52 TWh (6 GW av.)
EU: 235 TWh (27 GW av.)

CHP electr.gen:
DE: 79 TWh
EU: 382 TWh

PV electr.gen:
DE: 31 TWh (4 GW av.)
EU: 85 TWh (10 GW av.)

DE:
36,000 outlets - 32 mill m²
10 TWh electr.consumption

EU:
222,000 outlets - 154 mill m²
50 TWh electr.consumption

Flexibility potential:
100% in 15 min or 5.7 GW in EU
60% in 25 min or 3.4 GW in EU

Total supermarket aggregation would account for
> 20% of average delivered wind power *
> 50% of average delivered PV power*

*’EU energy in figures’ - 2013 numbers
Thermal networks expand the perception of smart systems and the scope for supermarkets

District heating and cooling networks are perfect for energy storage

Waste heat from refrigeration can be exported

Supermarkets can add flexibility and become storage enablers for heating and cooling
Find a customer for the thermal services
Case study on District Heating connectivity

- Southern Denmark
- Area: 1000 m² from 2010
- Compressors: 5 MT (1 VS), 4 LT
- Cooling Capacity: 160 kW
- Online COP calculation

- Heating:
  - Sanitary water (1.8m³, 65 °C)
  - Space heating/low temp (35 °C)
  - District Heating connection
    - Return line temp. 35-40 °C
    - Flow line temp. 65 °C
Outline of system concept

DH from return line
DH to flow line

Hot tap water reservoir

Space heating water loop

HX BP counter flow

Gas cooler

Medium pressure receiver

MT Compressors

LT Compressors

MT evaporators

LT evaporators

EXV

return line
flow line
Results

THE HEAT LOSS

is 65% of the total heat energy

THE HEAT LOSS

is expected to be 35% when space heating cut in at low ambient temp.

AVERAGE EXPORT OF DH HEAT

is 27 kW at 65 °C. (This can be regarded as an average for the year)

YEARLY DH INCOME

to the supermarket is estimated to be 6000€ (24€ per MWh)
The hidden capacity

- The Cooling capacity has a build-in safety margin due to food safety

- Overall capacity exploitation is low
  - Night load is 20%
  - Day load is 40%
  - Free capacity can be up to 70% in average

- Results can vary dependent on store set up and geographical location

\[ Q_c = K \sum_{k=1}^{n} Q_{c,k} \]
Unused compressor capacity is an opportunity

**DISTRICT HEATING NETWORKS**
can absorb limitless energy

**TYPICALLY ONLY 30%**
of the total compressor capacity is used

**ASSUMING A FACTOR 2**
more energy can be produced with external heat sources

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**CHP heat gen:**
DE: 182 TWh
EU: 806 TWh

**Supermarket heat gen. for DH:**
DE: 6 TWh
EU: 30 TWh

**Supermarket heat gen. for DH extra:**
DE: 14 TWh
EU: 70 TWh

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**Heat pump**

**Supermarket**

**External evaporators**

**Thermal panels**
Free capacity can be used to serve external needs for thermal services

Understand the integration of energy systems

- Smart energy systems
- Flexibility in supermarkets

Identify a customer to the thermal service

- Establish the business case
Establish the business case

The following factors are to be considered:

- Investments
  - Thermal grid connections
  - Heat Exchangers and Controls

- Savings or income
  - In store heat recovery (sanitary water and space heating)
  - Export of thermal services related to normal operation
  - Export of thermal services related to ‘free capacity’
  - Flexibility services (demand response)

NB: Heat remuneration needs to outweigh electricity cost; \( \text{Heat remuneration} > \frac{\text{Electricity cost}}{\text{COP}} \)
Index of cost

Index 100 = 134 k€
NB: depends heavily on energy prices which are country dependent.

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<th>DSF</th>
<th>KW</th>
<th>Min. per event</th>
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Electricity (base) 0,14 € / kWh
Electricity (HP mode) 0,04 € / kWh
Gas 0,55 € / m³
District Heating 0,05 € / kWh
Index of emission savings

- The extra electricity used for HP mode is subtracted the emission saving
- DSF enables renewables and represents indirect emission savings
- Heat recovery can be categorised as energy savings and become subject to incentives in some countries
Supermarkets...
• can play a significant role in smart and integrated energy systems
• are addressable flexibility resources
• require modest investments before they make up a good business case

Heat recovery...
is taken to the next level by connecting DH grids to the supermarket refrigeration system

Extended heat production can be utilised once connected to the DH grids by utilising the free compressor capacity

Thermal and Electrical Flexibility can enforce each other providing a multiplier factor for the business case

Conclusion