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BENCHMARKING OF SUPERMARKET ENERGY CONSUMPTION

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PERFORMANCE INDICATORS FOR ENERGY EFFICIENT SUPERMARKET BUILDINGS

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HPT Annex 44

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OBJECTIVES

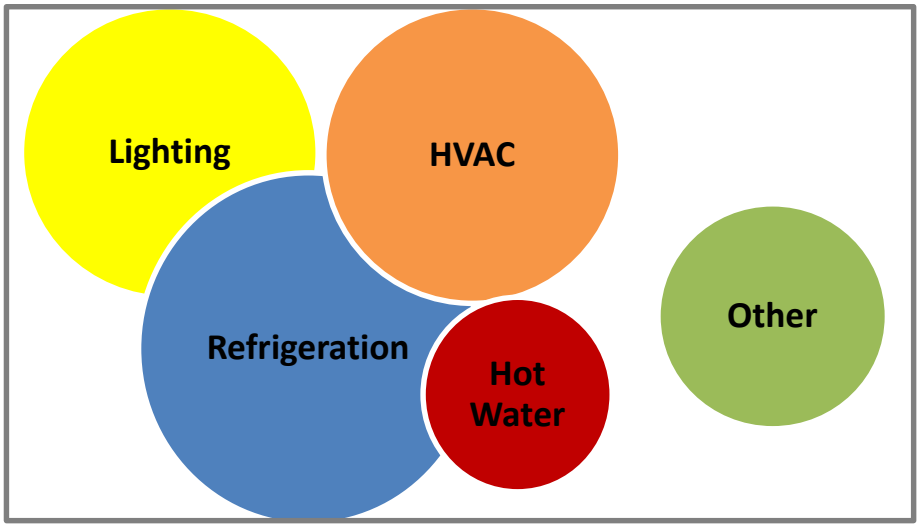
Objectives
- create performance indicators for energy efficient supermarket buildings, so that measurements and monitored data can be converted into knowledge concerning the energy performance.
- create knowledge concerning the energy efficiency of supermarket buildings for decision making, benchmarking and development of energy efficiency strategies.

Is "your" supermarket building energy efficient?

- *Compared to other supermarkets in same chain*
- *Compared to other supermarkets in the same country*
- *Compared internationally.*

SCOPE

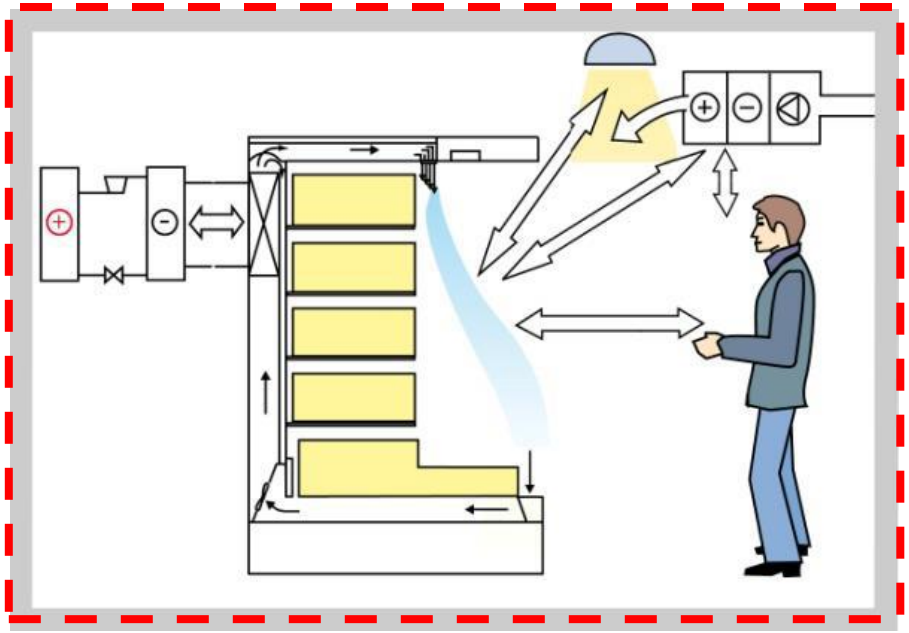
- Supermarkets (ISIC 4711)*
  non-specialized stores, with food, beverages or tobacco predominating
- All energy systems (thermal & electric)



Energy systems	% energy use
Lighting	27 %
HVAC	13 %
Refrigeration	47 %
Hot water	3 %
Others	10 %

Supermarket refrigeration systems are more and more used as heat pumps (heat recovery)

SYSTEM BOUNDARY



(from Lindberg, Axell and Rolfsman 2011, ICR2011)

The system boundary in Annex 44 is the whole supermarket, which includes all energy systems (HVAC, refrigeration, lighting and other uses).

Proposed in Annex 44

kWh/(m².year)

- **Total Energy Consumption** (Electricity and Heat/Gas/Oil)
- **Sales Area.**

MONITORING AND MEASUREMENTS

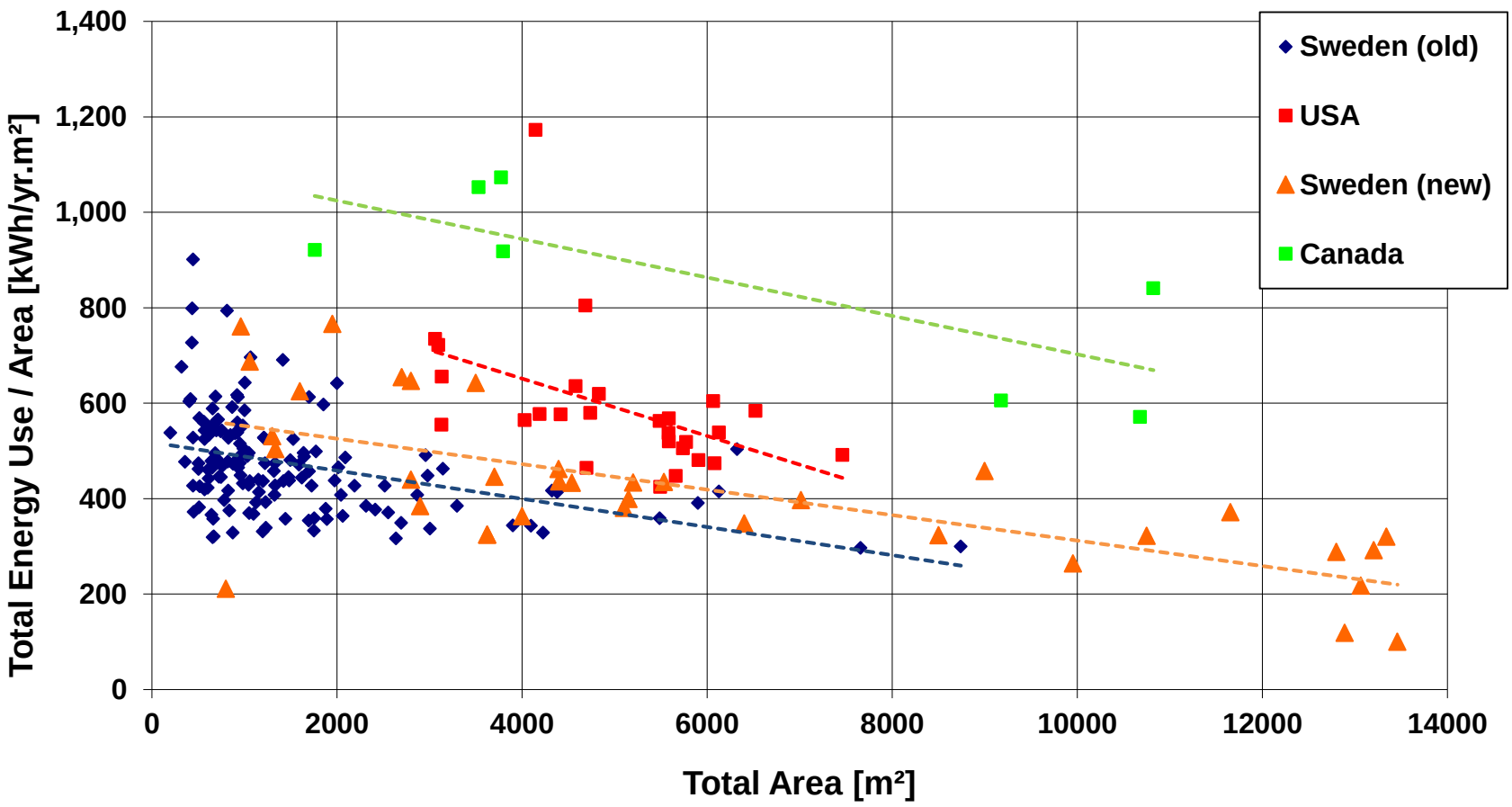
- Primary aim of these systems is control and regulation
- Separate systems i.e. energy meters

Supermarkets require
Efficient handling of alarm monitoring, data structure, HACCP[1] procedures, HACCP policies, refrigeration energy consumption, service calls and refrigeration maintenance management.

[1]Hazard analysis and critical control point here specifically related to safe handling of food

(IEA-HPT Annex 31)

Related (earlier) work.



Related (earlier) work.

(Tassou *et al*. - UK)

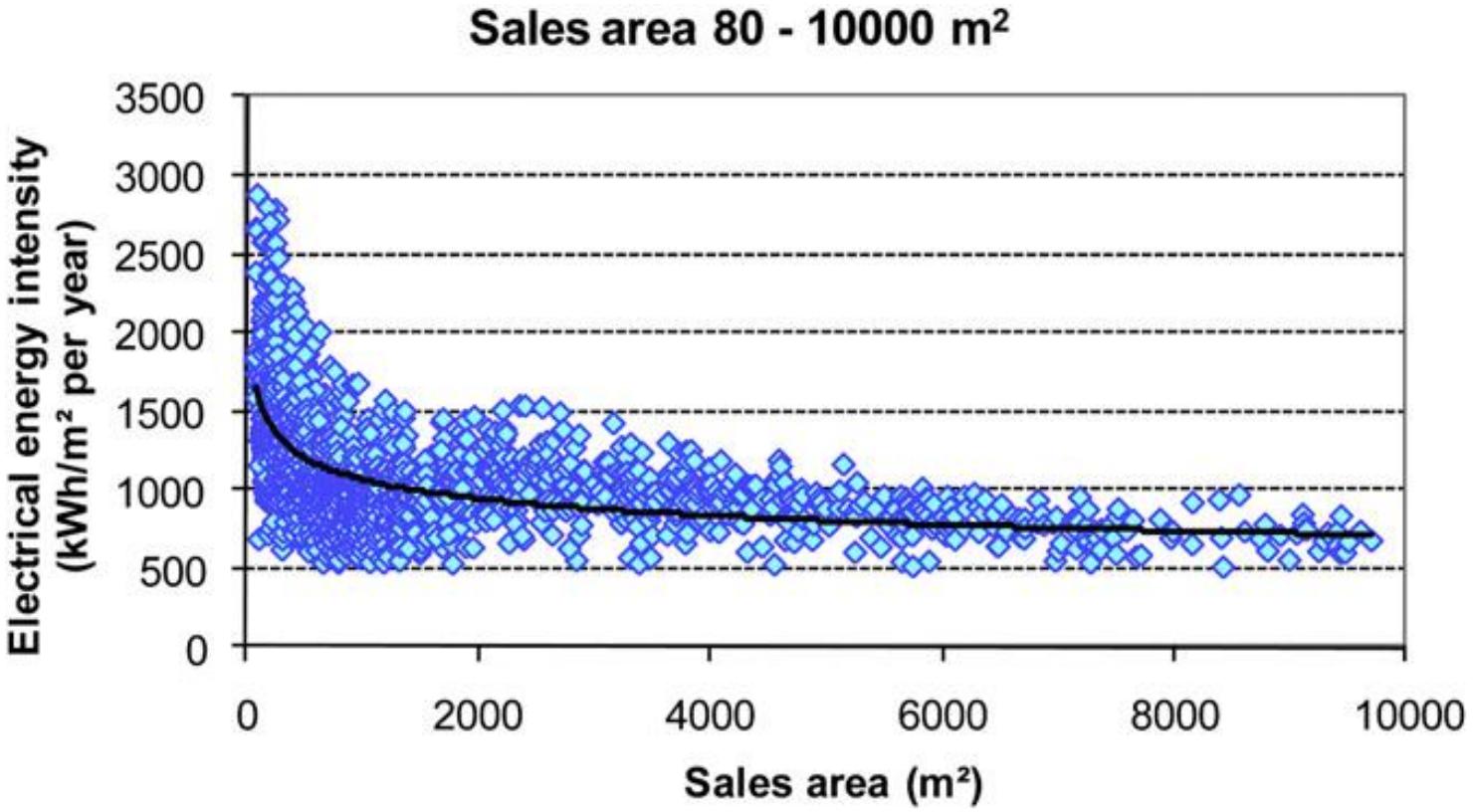
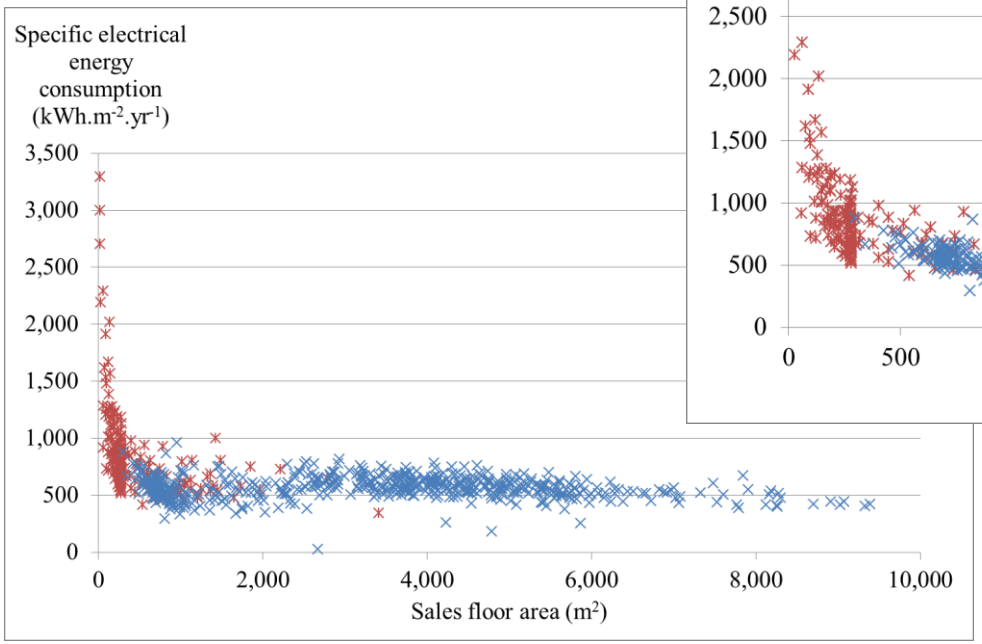
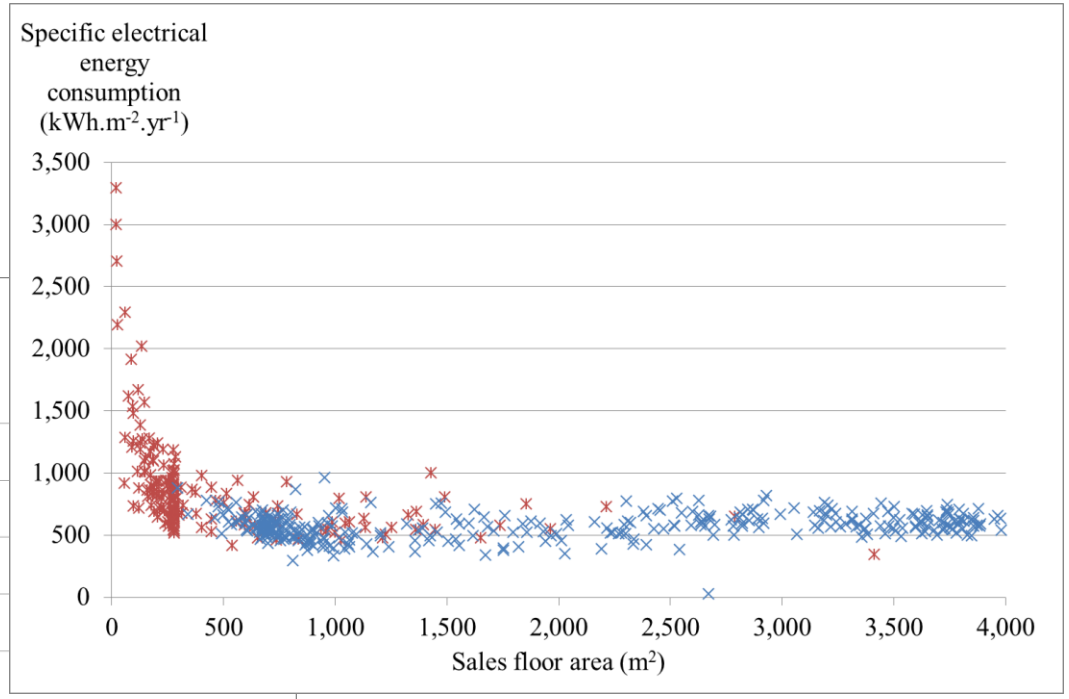


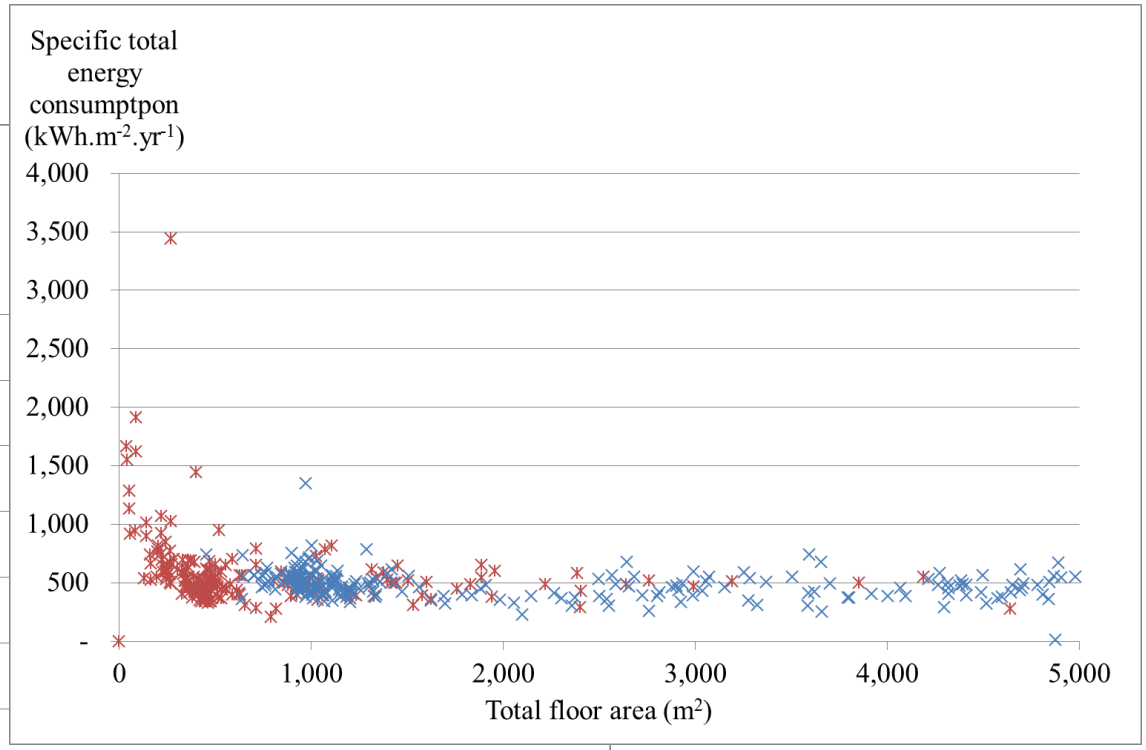
illustration of the decrease in energy intensity as the supermarket size increases (with permission, from Tassou, 2010).

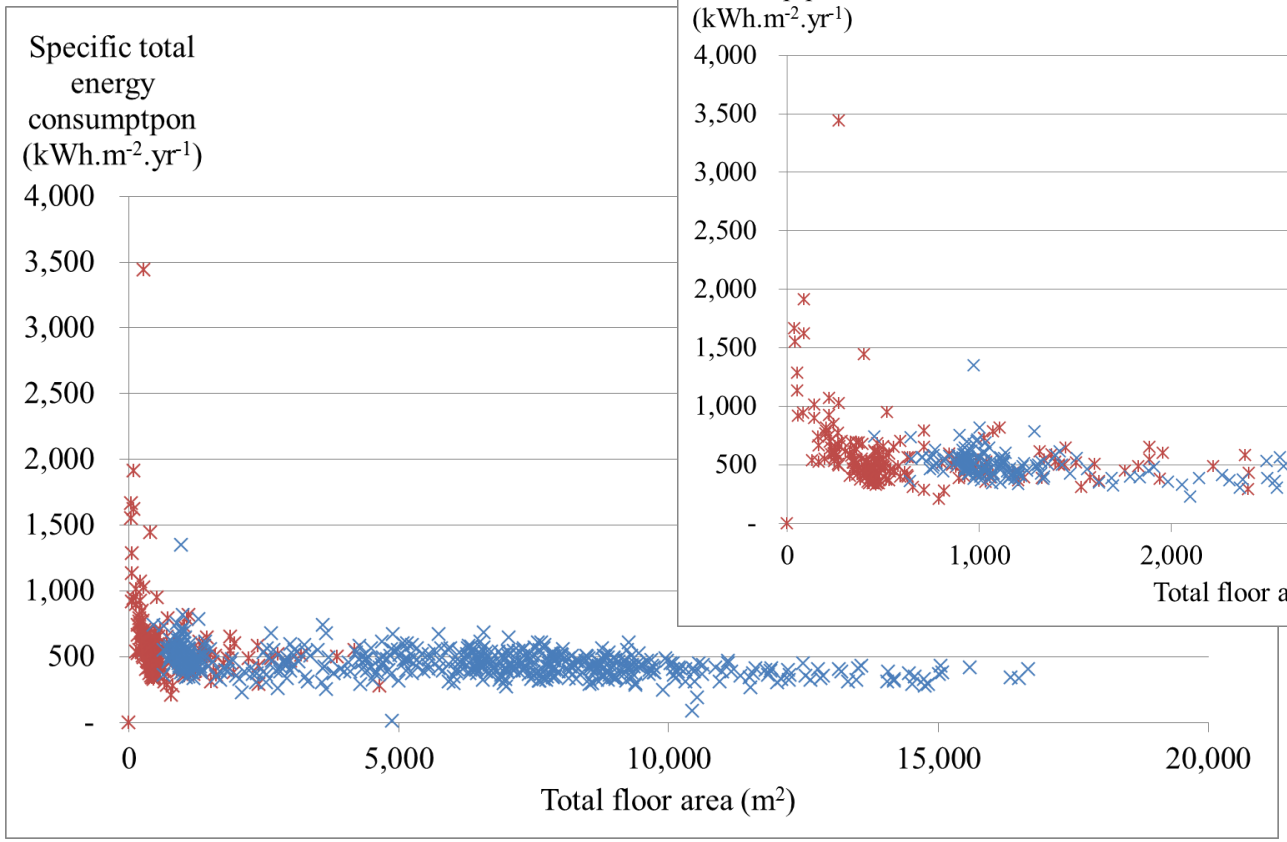
New study **Electrical energy consumption vs Sales area** (Foster *et al.* - UK)





Total energy *vs* Total area (Foster *et al.*)





Comparison

Store location and date	Energy intensity (kWh/m2)	Basis of SEC	Floor area applicable for
Store A (2015)	566	EE /SFA	3306
Store B (2016)	886	EE /SFA	435
Store B (2016)	1870 to 600	EE /SFA	20 to 300
Store B (2016)	700 to 470	EE /SFA	300 to 3400
Store B (2016)	1350 to 675	EE /SFA	80 to 300 (no filling stations)
Store B (2016)	2400 to 675	EE /SFA	20 to 200 (filling stations
Store A (2015)	450	TE /TFA	5845
Store B (2016)	601	TE /TFA	681

Issues arising from (earlier) work

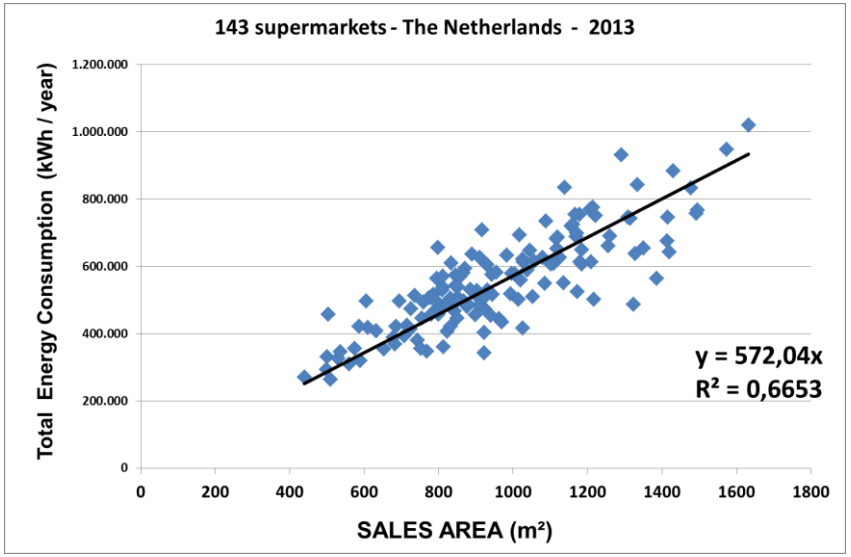
Comparison basis:

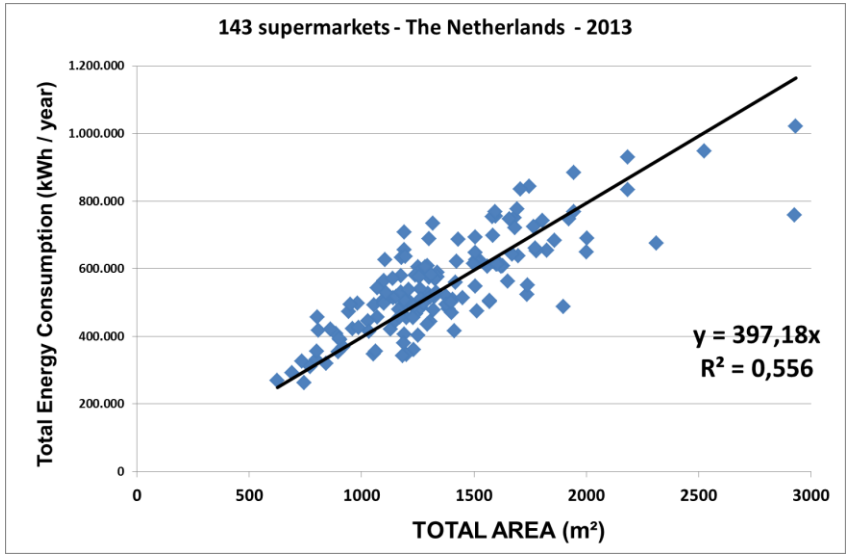
- Supermarket Size:
  - * First source (Annex 31) uses TOTAL Supermarket Area
  - * Second source (Tassou) uses Supermarket SALES Area
- Energy consumption:
  - * First source (Annex 31) uses TOTAL energy consumption / m^2.year
  - * Second source (Tassou) uses ELECRICAL energy consumption / m^2.year
- What is the preferential choice?
- How do data from these sources relate?

- $SEC_{EE/SFA}$

Analysis of Dutch data.

- SALES area relates better to energy consumption than TOTAL area, therefore SALES Area must be considered.

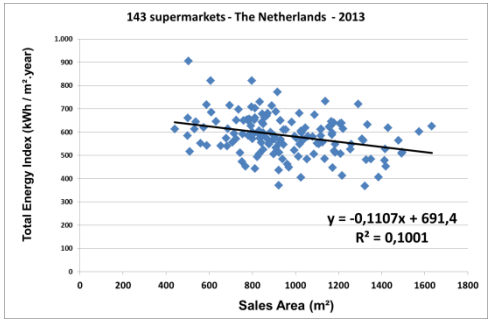


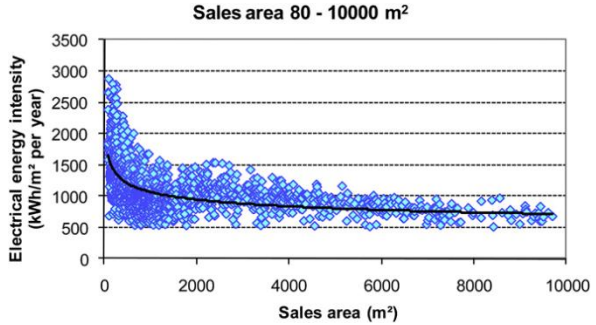


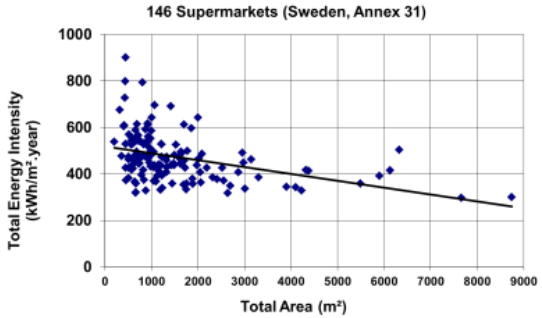
(Average TOTAL Area / SALES Area = 1,4)

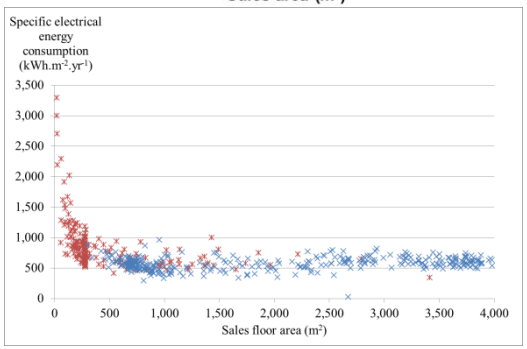
Energy intensity: total energy use / sales area

- NL 2013: Average Energy Intensity = 585 kWh/m².year (@ 957 m²)
- NL 2014: Average Energy intensity = 539 kWh/m².year (@ 970 m²)
- Energy intensity decreases with increasing supermarket size.
  (- 2 % for each 100 m² sales area increase)



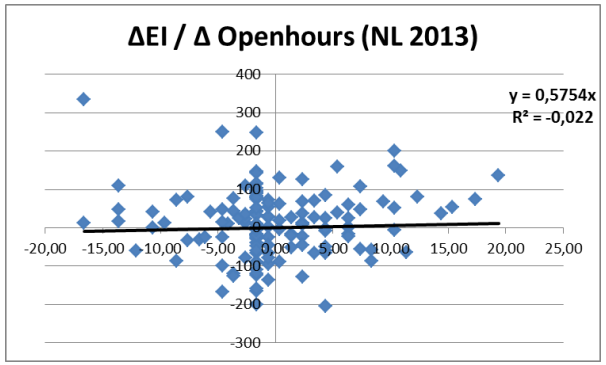


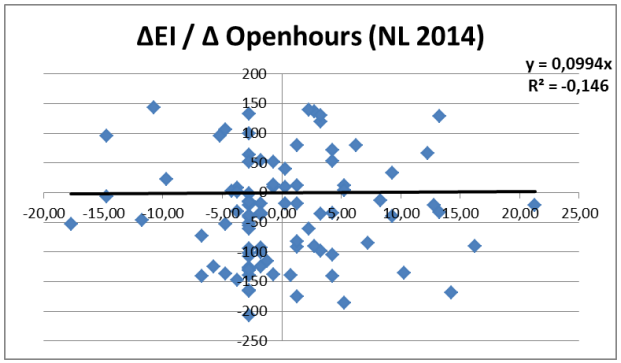




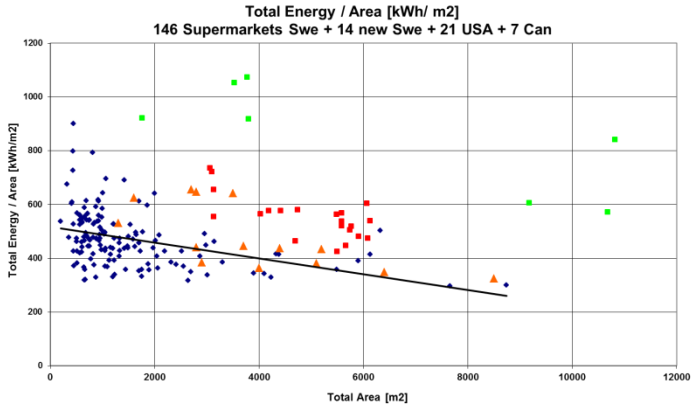
Energy intensity: opening hours dependency

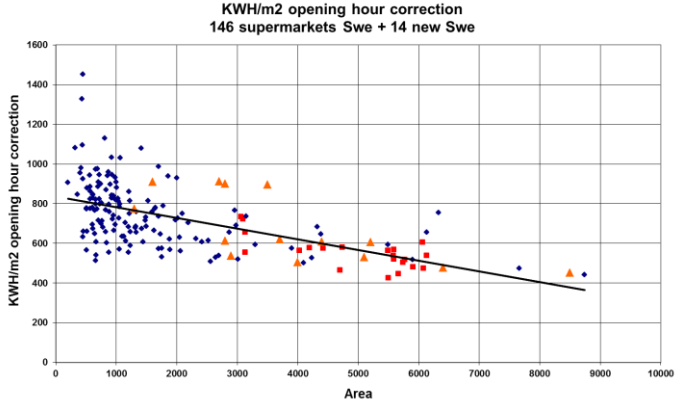
- Minimal dependency in Dutch data sets 2013 and 2014





- Essential correction factor in Annex 31 data Sweden & USA





Under further investigation

RESULTS

Annex 44
Supermarket size as primary performance indicator

Discussions to include non – conventional indicators, to fully explain observed energy use and efficiency in practice, i.e.

- the maintenance and dynamics of the systems
- sales volume or customer density
- the indoor temperature & humidity
- the cleaning and loading procedures
- the training of personnel

Results 1(4)
Supermarket comparison

Data from Denmark, Sweden, The Netherlands:

- Total energy consumption below 400 kWh/m^2/year - energy efficient supermarkets with referred data to total supermarket area.
- 400 kWh/m^2/year – the average energy intensity.

Average total area 1 360 m^2 and 73 openings hours per week.

- No relation between total energy consumptions (heat & electricity) and the geographic region
- Developments, i.e. refrigeration systems and lighting, increased energy efficiency ranging 1-10% per year.

Results 2(4)

UK Data

- SEC different conclusions with different data sets
- SEC reduces with increasing area
  - Very small stores very large SEC

Results 3(4)
Reduction in SEC with time

- Sullivan and Gouldson (2013)
- Six UK supermarket chains
- 2.5 to 5.5% reduction p.a. relative to 2007
- Up to 10 years, 2 to 3% reduction
- Savings often outstripped by business growth

Results 4(4)
Reduction in SEC with time

- New data - 1 UK store
- 2013 to 2017 - 3.3% reduction p.a.
- Over 5 years
  - 32% reduction in lighting
  - 20% reduction in refrigeration
  - 8% reduction in HVAC

Future work and for discussion

- Other secondary performance indicators?

In relation to indoor conditions, Annex 44 propose:

	Dry bulb temperature °C	Relative humidity %	Water content (g H_2O / kg dry air)
Proposed reference condition	20	50	7,3
ISO Standard test condition	25	60	16,7

- Other indicators/ calculations in relation to other parameters that influence

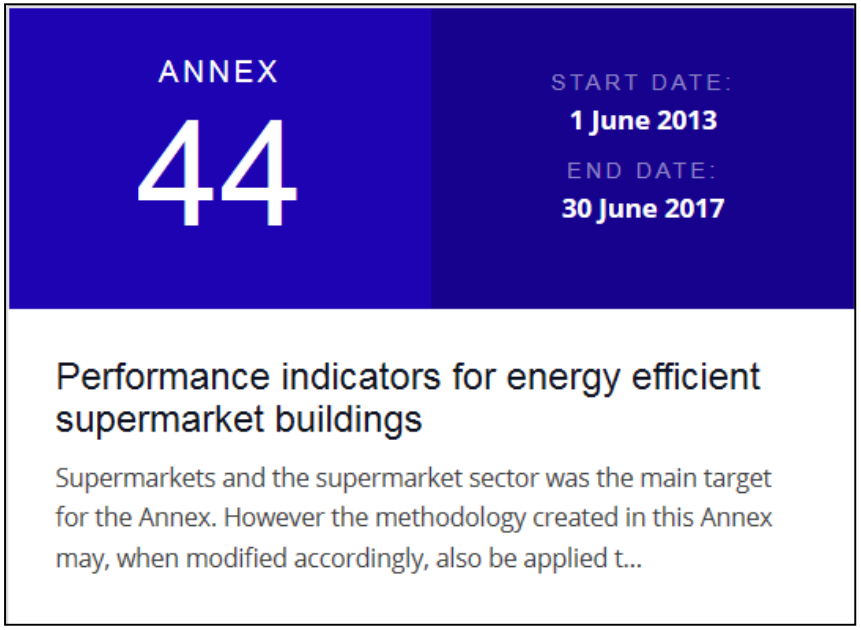
✓ energy consumption?
✓ costs?
✓ heat recovery?
✓ parking area?

- How to display the indicators, different detailed levels depending on interest.

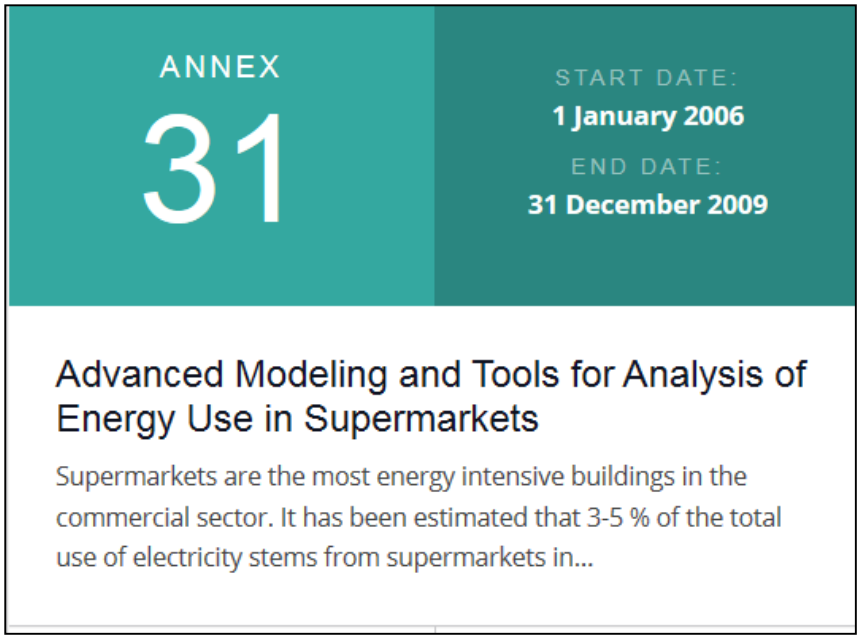
HOW TO START OR JOIN AN ANNEX

Any party working in any of the programme's member countries can participate in annexes. **HPT welcomes ideas and topics for new international collaborations!**

http://heatpumpingtechnologies.org



Read more Visit annex



Read more Visit annex

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THANKS!

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Indicators for the refrigeration system (time period =1 year)

	Goodness factors: Specific electrical energy (kWh/m^3 and year)		
	Refrigeration	Chilled food	Frozen food
	$w_{reftot} = \frac{W_{e,reftot}}{V_{reftot}}$ (1)	$w_{ref} = \frac{W_{e,ref}}{V_{ref}}$ (2)	$w_{fr} = \frac{W_{e,fr}}{Vfr}$ (3)
	kWh/(m^3 and year)	**kWh/(m^3 and year)**	**kWh/(m^3 and year)**
Supermarket A	613	499	698
Supermarket B	259	169	601
Supermarket C	1137	783	1950

Axell and Lindberg, 2005

$$W_{e,reftot} = W_{e,dry-coolers} + W_{e,ref} + W_{e,fr}$$

Indicators for the refrigeration system factors related to the buildings area

Supermarket	Goodness factors	
	Total Electrical Supply / (Total area)	Total Electrical Supply / (Total sales area)
	$w_{tot} = \frac{W_{e,tot}}{A_{tot}}$ 1	$w_{sale} = \frac{W_{e,tot}}{A_{sale}}$ 2
	kWh/(m²and year)	kWh/(m² and year)
A	425	995
B	348	434
C	665	943

Data on supermarkets

	Supermarket		
	A	B	C
Total area, A_{tot}, (m²)	8 981	3 300	949
Sales area, A_{sale}, (m²)	3 839	2 650	670
Air volume, sales area, V_{sale}, (m³)	16 000	10 843	2 093
Air volume; chilled food; cabinets and rooms, V_{ch}, (m³)	1267	1339	123
Air volume; frozen food; cabinets and rooms, V_{fr}, (m³)	373	187	31

TOTAL YEARLY ENERGY CONSUMPTION (ELECTRICITY +HEATING) VS TOTAL AREA