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Review of energy simulation for hospital design

Potential and future research directions

Vladyslav Shchuchenko[1,2], Bernt Lie[2], Mads Mysen[3], Robert Martinez[1]

1)Norconsult AS

2)Telemark University College

3)SINTEF Building Research Institute

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Low Energy Hospitals Project

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- Low Energy Hospital (LEH) is an R&D Project in collaboration with Norwegian Research Council and private sector partners

- Norconsult, Norways largest consulting engineering firm, is project leader
- SINTEF, Norway's largest research organisation, is provides much research effort.

- Project timeframe from 2010 - 2014 and total budget 24 MNOK (approx. 4 MUSD)
- Project also supports a PhD candidate and will guide several Masters students

- Project partners:
  - Norconsult AS and Norconsult Info Systems AS
  - Helse Sør-Øst - Norway’s largest regional health authority
  - Narud Stokke Wiig - a leading healthcare architect bureau
  - GK-Norway - a large supplier of HVAC equipment in Scandinavia
  - SAAS - designs and delivers complete building automation systems
  - Siemens Healthcare - global supplier of medical equipment
  - Norconsult Information Systems - IT solutions for building sector
  - Oslo University College

Project - Goals

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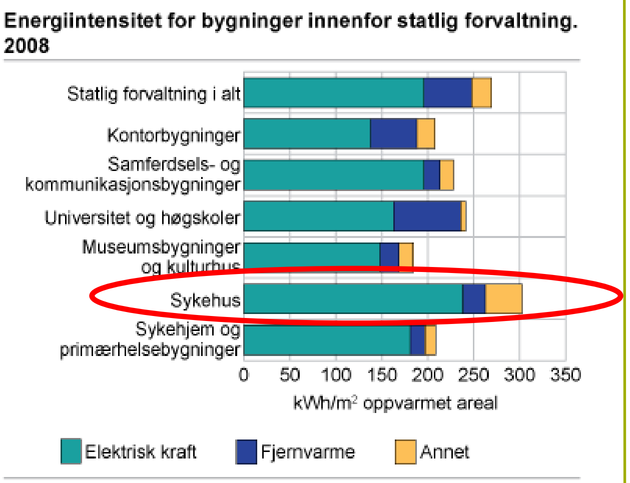
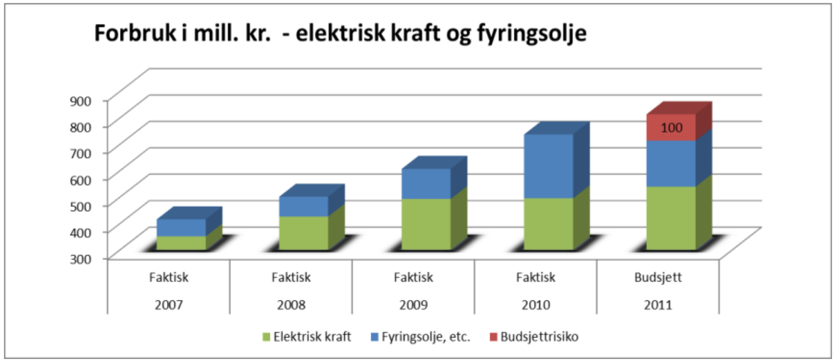
Why hospitals?

- Hospital buildings lead in energy intensity
  - and even higher energy consumption for regional and university hospitals**
  - energy used in acute care hospitals 1,6TWh*
  - Healthcare buildings are responsible for 4.6 % of energy used by non-residential buildings.



- Energy costs for regional health authority (HSØ) nearing 1 billion kr. and growing 100 mill. kr./year



*ref:: *HSØ 2010, ** Statistics from Rikshospitalet og latest published data for regional/university hospitals from Enova.no*

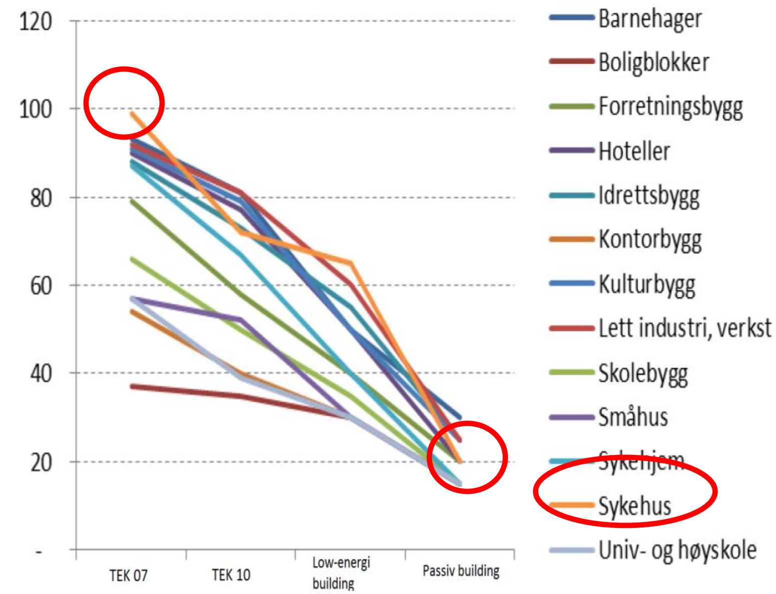
Project - Goals

Why now?

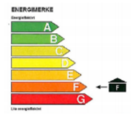
- Energy and environment certification
  - ISO 14001 to be implemented in HSØ.
  - Nordic "Green Hospital" certification
  - Energy classification now, BREEAM coming

- Much stricter building codes
  - Near Null Energy (NNE) buildings in EU fra 2021
  - Hospitals are the category which must reduce the most in energy intensity

- Health authority HSØ goal is to reduce energy use by 58 GWh in 2012.



Ref: Langseth, B. et al. Energibruk i lavenergi- og passivbygg -



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Simulation for design decisions

- Hospitals are very complex, and must satisfy many functional requirements
- Some of these requirements have huge consequences for energy consumption; designs and planners face problem in multidimensional optimization:

- For example: **Should we have more or less window area?**
  - more window area means <u>light</u> for patients wellbeing
  - reduces need for <u>artificial</u> lighting
  - but increases need for <u>cooling</u> in summer
  - increases need for <u>heating</u> on some facades
  - can be opened for natural <u>ventilation</u>
  - has <u>security</u> implications

Ref: Ny Karolinska ,2011

- **Adequate simulation tools which take into account more of the complexity of a contemporary hospital are necessary to show the <u>difference between design alternatives in a lifecycle perspective</u>, which includes energy demand.**

Simulation software - overview

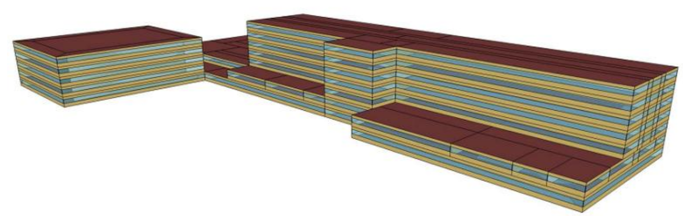
What do we look for in simulation tools? <u>Accuracy</u> and <u>ease of use</u>

- ACCURACY: A single tool cannot cover all aspects needed during the design phase. Some tools focus on the building envelope, while others are more focused on heating and ventilation (HVAC)
  - For example: Simien is ideal for validation against Norwegian building code, but not for design phase
  - EnergyPlus is free and powerful software, but lacks a user friendly interface
- EASE OF USE: The more advanced the software the longer it takes to learn:

Software	Import 3D models	Main features
IDA ICE (Sweden)	Yes, IFC import	CAD; Model can be extended using equation based modelling (Modelica, NMF);
EnergyPlus (USA)	Yes, Google Sketch Up	free software
SIMIEN (Norway)	No	Allows checking energy simulated results against Norwegian standards and building code
Bsim (Denmark)	Yes, application	CAD import, moisture analysis

Simulation software - cases

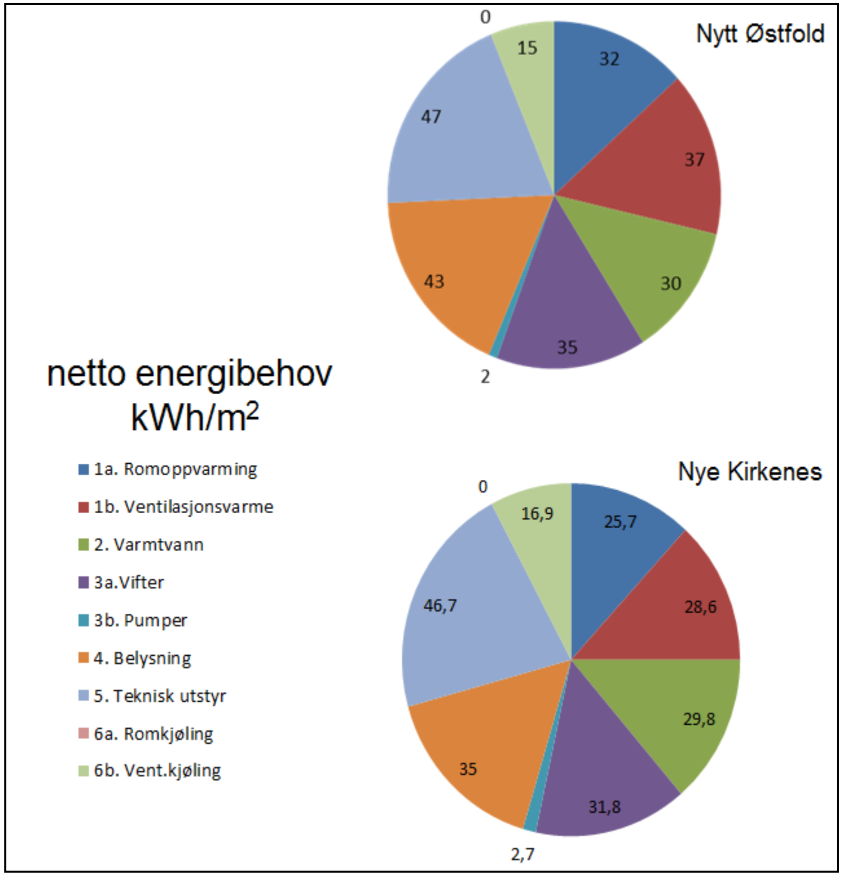
Case	Software
New Østfold Hospital, Kalnes (Norway)	IDA ICE 4.0
New emergency centre, Ullevål, Oslo (Norway)	Simien, IDA ICE
U.S. hospitals ("50% energy savings report"[1])	EnergyPlus
New Kirkenes hospital	Simien
Tehuset Hospital, Borås (Sweden)	IDA ICE 4.0



Simulation software - cases

What do we simulate?

- Local heating
- Ventilation heating
- Domestic hot water
- Fan energy (electrical)
- Pump energy (electrical)
- Lighting (electrical)
- Equipment energy electrical)
- Local cooling (thermal)
- Ventilation cooling (thermal)



Source: Martinez et al. R&D-project LowEnergyHospital, Report phase 1, 2011

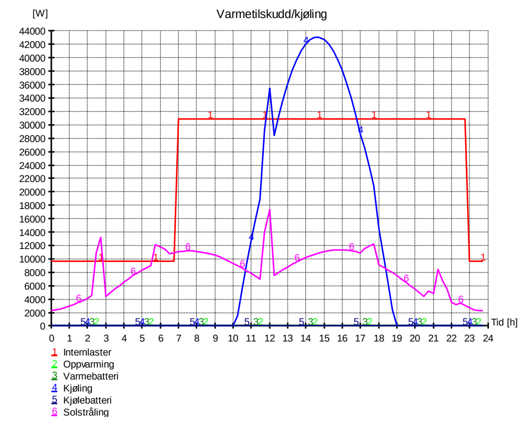
Simulation accuracy - usage patterns

Must be able to model usage patterns

- Most energy models and tools do not realistically model hospital usage
- Usage of lighting, equipment etc. has energy consequences
- Simple models use too low values, or assume 24hr operation, or both.
- Accuracy of results for indoor summer temperature & cooling energy is reduced.

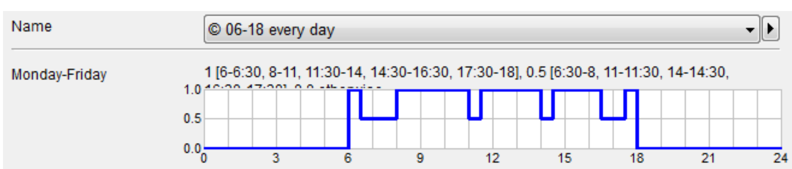
	Hospital 1						
	net area	% share og total	h/day	Days/week	Hours per year	% use per year	Weighted use
	(1000*m2)						
Use ordinary hours	32,2	47 %	9	5	2340	27 %	12 %
Use extended hours	2,0	3 %	12	6	3744	43 %	1 %
Use except night	10,7	16 %	16	7	5824	66 %	10 %
Use 24/7	24,1	35 %	24	7	8760	100 %	35 %
In total	69,0						**59 %**
	Hospital 2						
Use ordinary hours	39,7	46 %	9	5	2340	27 %	12 %
Use extended hours	1,8	2 %	12	6	3744	43 %	1 %
Use except night	26,2	30 %	16	7	5824	66 %	20 %
Use 24/7	19,3	22 %	24	7	8760	100 %	22 %
In total	87,0						**55 %**

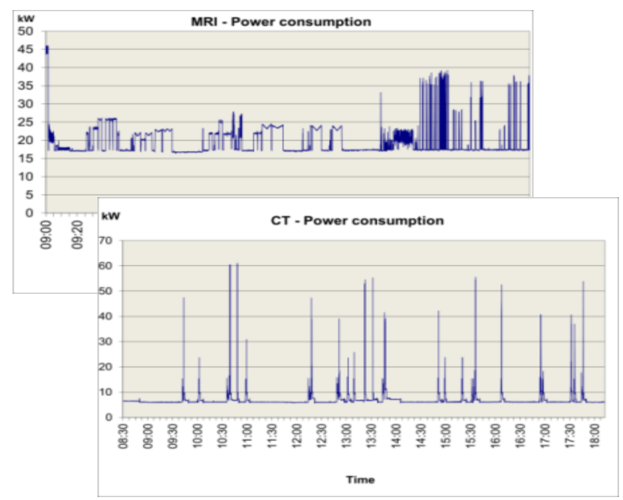
Source: Martinez et al. R&D-project LowEnergyHospital, 2011



Simulation accuracy - usage patterns

- Modelling tools have usually been used mainly for technical systems and building envelope (i.e. walls, floor, roof)
- Internal loads and building activities are usually oversimplified and not modeled at all
- But for hospitals, correct modelling of these loads and activities is essential for a successful design
- How to energy model an activity? An *activity* consist of :
  - location (in which zone, where in the hospital does activity occur)
  - power level, kW (for medical equipment we must distinguish between stand-by and full power)
  - number of units or persons
  - schedule





- This approach to activity modelling for energy is also being used to model and optimize patient flows within the hospital

Simulation accuracy - results vs. reality

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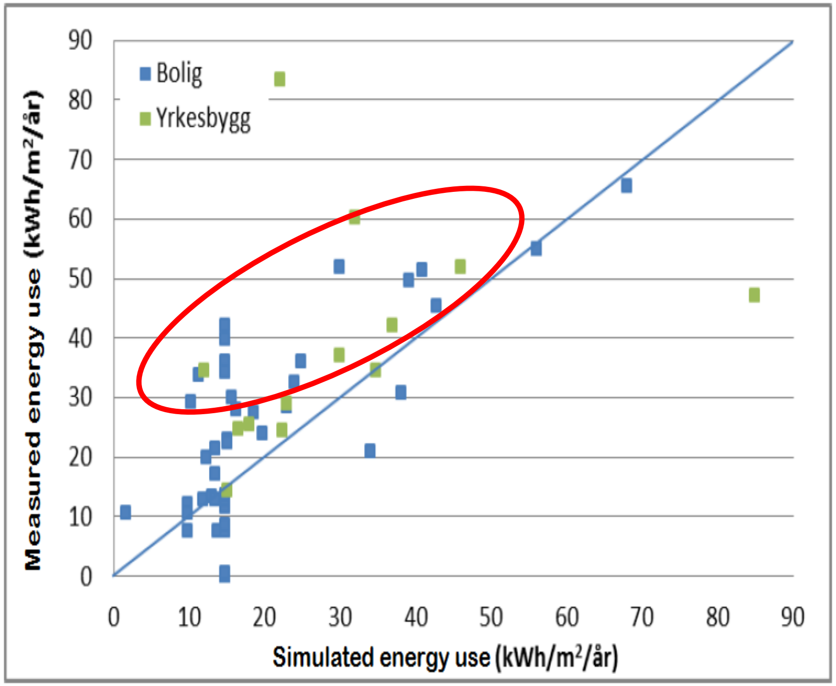
So simulation models underestimate real energy consumption?

- Buildings are built with mistakes (e.g. unexpected thermal bridges)
- Simplifications in the software model
- Weather conditions differ in reality from that used in simulation software
- Differences in occupant behaviour
- Different individual climate requirements
- Non-optimal operation of heating and cooling plants



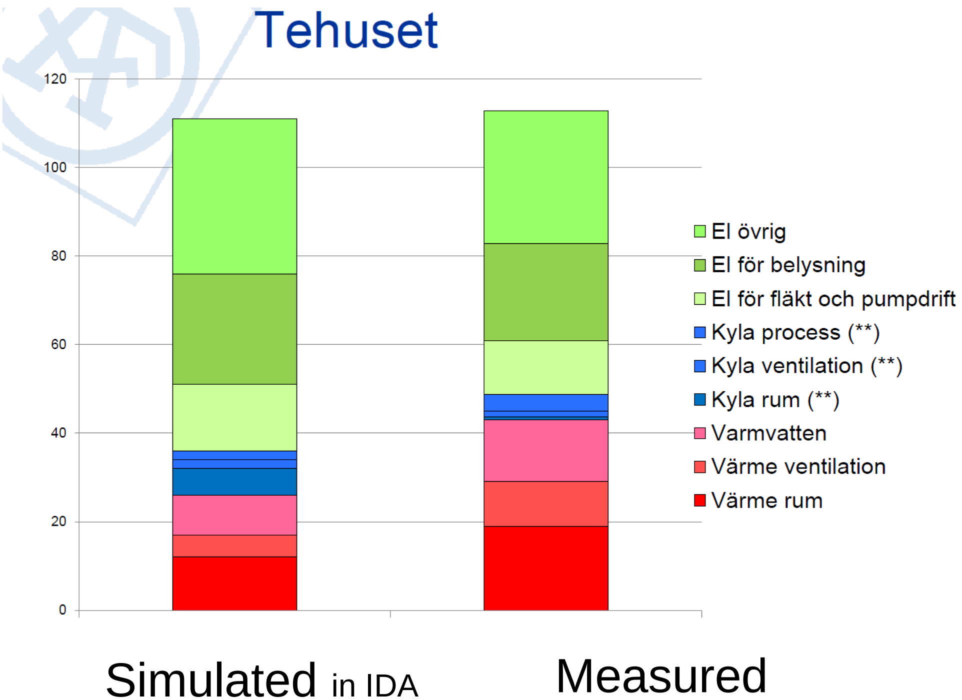
Source: Langseth, B. et al. Energibruk i lavenergi- og passivbygg - 2011

Remark: Measured data is not heating-days corrected so even higher deviation may be expected

Simulation accuracy

Excellent agreement between simulation result and reality can sometimes happen

- For example, new hospital building (20 000 m^2) "Tehuset", Södra Älvsborg, Sweden
- Done by a simulation expert in close collaboration with hospital designers



Picture source: Rasmus Cagner ÅF Infrastructure AB

Case : Ullevål emergency centre

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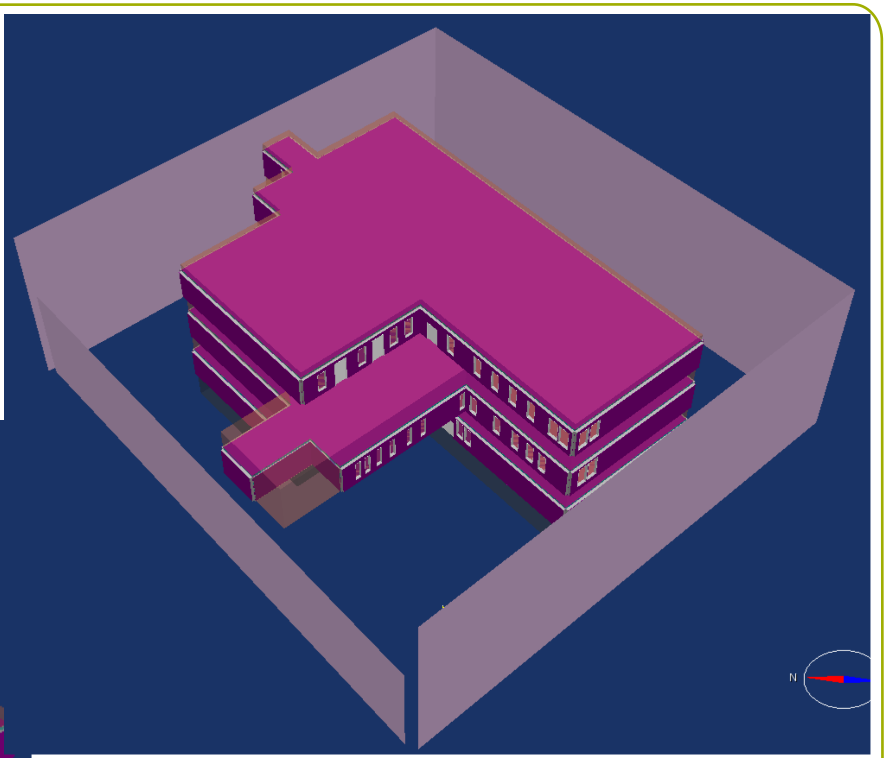
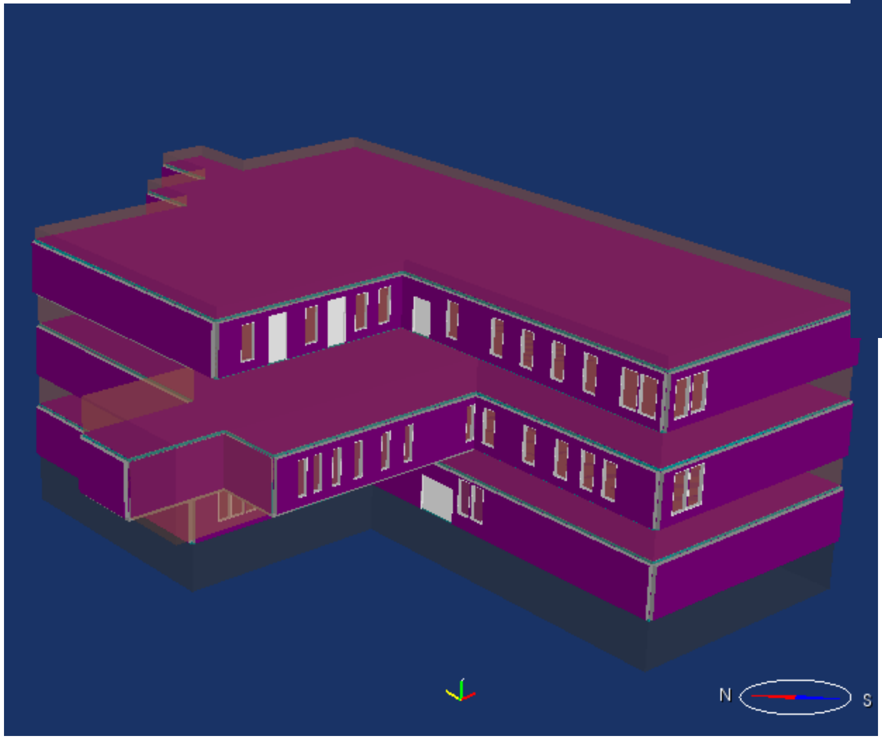
- Shading from surroundings has a significant impact on model results

3D view with shading from surrounding buildings





3D view without shading

Case : Ullevål emergency centre

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Simien

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	46616 kWh	18,0 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	415628 kWh	160,4 kWh/m²
2 Varmtvann (tappevann)	0 kWh	0,0 kWh/m²
3a Vifter	150507 kWh	58,1 kWh/m²
3b Pumper	11580 kWh	4,5 kWh/m²
4 Belysning	181547 kWh	70,1 kWh/m²
5 Teknisk utstyr	313764 kWh	121,1 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	52612 kWh	20,3 kWh/m²
Totalt netto energibehov, sum 1-6	1172253 kWh	452,4 kWh/m²

IDA ICE

	Delivered energy	
	kWh	**kWh/m²**
Lighting, facility	181723	70.1
Cooling	66271	25.6
HVAC aux	84615	32.6
Total, Facility electric	332609	128.3
Heating	287750	111.0
Domestic hot water	0	0.0
Total, Facility fuel*	287750	111.0
Total	620359	239.2
Equipment, tenant	382732	147.6
Total, Tenant electric	382732	147.6
Grand total	1003091	386.8

*heating value

Conclusions

- Simulations are an effective method for comparison of different design alternatives, and should be encouraged in early phase design decision-making
- Simulations are less reliable as a source of absolute energy performance: absolute values of simulation may deviate significantly from measured data

- IDA ICE seems one of the most appropriate for energy simulations in hospitals, due to possibilities of including own models using Modelica or Neutral Model Format. In addition, IFC (BIM) import available at IDA ICE eases a zone defining procedure.

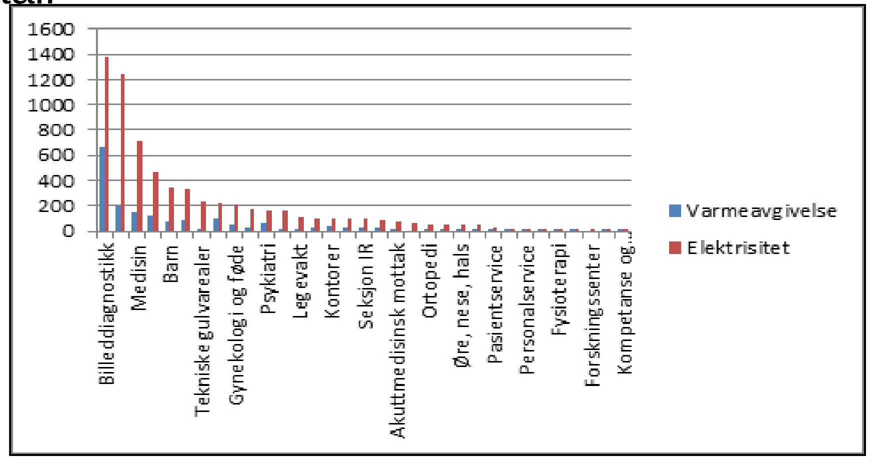
- Further research is needed in order to simulate advanced energy saving technologies

Further research

New areas for energy simulation models will improve accuracy:

- simulation and control of <u>energy storing/production</u> cycles in order to satisfy variable energy demand in hospitals
- simulation of energy-optimal design of <u>heat pump thermal plants</u> and energy distribution systems in hospitals
- more precise modelling of <u>internal loads</u>, based on empirical data for actual equipment throughout a real hospital:

Electrical power and heating effect by hospital equipment category, Ahus, 2011



- **In future we may hope for an integrated model of ALL hospital functions : technical and clinical.**

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