STRICTER SPECIFICATION OF THE ENERGY PERFORMANCE OF HEALTHCARE EQUIPMENT CAN REDUCE HOSPITAL ENERGY CONSUMPTION

Medical Equipment and Trends in Energy Consumption in Modern Hospitals

Trond Thorgeir HARSEM,
Norconsult AS
NORWAY

1. Background

Energy performance of hospital medical equipment is under scrutiny now due to the need to control healthcare costs, especially in Norway which has one of the highest healthcare costs in the world. Another good reason to examine energy consumption is to reduce overall climate-gas emissions in the health care sector through lower energy intensity. Stricter requirements under the new EU ecodesign directive are also bringing equipment energy consumption into focus, although most medical equipment has not yet been phased in under the directive so far.

Parallell advancements in medicine, computation, and digital imaging are merging to create new and even more useful medical equipment. This equipment has become an indispensable part of most clinical functions and has been embraced by both public and private hospitals.

2. Methodology

Data for power levels were collected from medical imaging equipment using high-resolution measurement. Cooling load data was gathered from hospital energy management systems. Activity (patient) treatment data was collected from hospital records and supplemented with usage of data provided by hospital administrators. Statistical data was gathered from national bureaus and supplemented with data from previous national and EU studies on hospital energy consumption. This data was synthesised into a spreadsheet energy model for calculation of equipment energy.

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3. Medical equipment

How much of the equipment energy consumption is attributable to large medical imaging equipment, and how much is due to the multitude of smaller medical devices scattered about a modern hospital?

1. Large medical imaging equipment category (MIE)

The first category of medical imaging equipment (MIE) includes equipment such as Magnet Resonance tomography imaging (MRI), Positron emission tomography (PET), Computer Tomography (CT), X-ray and fluoroscopes for diagnosis. These are large, expensive items housed in special rooms, usually with hookups for water cooling to supplement air cooling. These draw very large amounts of power during ongoing procedure, but in addition they have high standby power levels.Since these devices are few in number, even large university hospitals in Norway will have only between 10-15 of such devices, they constitute no major portion of the total energy consumption.

The majority of these devices are in use only during day time, approximately 10-14 hours per day, With few exceptions (MR), these devices can be entirely powered off outside of standby hours, but tend to have long startup times.

2. Smaller medical equipment category (SME)

The second category of smaller medical equipment (SME) is a much longer and more varied list including monitors, analyzers and many therapeutic devices. These are smaller air-cooled equipment distributed in many rooms throughout the hospital. These devices have short startup times and draw much less power, but many of of these units are in use throughout the day. SME devices constitute a large number in a large hospital. An ultrasound apparatus is strictly speaking an imaging device, but shares many of the characteristics of SME and is therefore grouped under this category.

4. Medical equipment Energy consumption

1. Sources of energy consumption

Hospitals have many large internal energy loads, which mean that most of the waste heat from medical equipment does not benefit the building and must be removed by ventilation or local cooling systems. This cooling utility energy must therefore be added to the direct electrical energy consumed by medical equipment to estimate the true energy and climate footprint. The following relationships are used when examining yearly energy consumption of all medical equipment:

Equipment measuring energy (kWh) = measuring power (kW) X usage(hrs) X no. of devices

Equipment standby energy (kWh) = standby power (kW) X usage(hrs) X no. of devices

Equipment total energy (kWh) = treatment energy (kWh) + standby energy (kWh)

Equipment energy (cooling) = Equipment total energy (kWh) X (1- heat recycled %)

Total energy (kWh) = Equipment total energy (kWh) + Equipment energy (cooling)

Nearly all electrical energy input to medical equipment generates a "waste" heat which must be removed by the surrounding room air or by closed ice water cooling systems (for larger MIE). The percentage of waste heat which may be recycled for building or domestic hot water heating depends on the design of the heating- and cooling system and also on the location of the particular medical equipment. Water cooled devices have higher recycling rate, as condenser heat from the ice-water chiller can be easily routed to other applications.

Waste heat removed by air-cooling is more difficult to control and recycle. Best practice for ventilation air heat recycling in most building types is with rotating heat wheels, which allow up to 85% heat recovery. This technology, however, allows some leakage of exhaust air and moisture into the incoming air stream and therefore cannot be applied in many areas of a hospital where there is a contamination risk. For such areas one must use other methods with lower recycling rates, from 50% to 70% depending on the application.

2. Available data on energy consumption

Most hospitals collect electrical energy consumption data at the switchboard or building level, making it impossible to disaggregate energy due to individual medical equipment from other electrical loads such as lighting and fans. Typical energy management practice and building codes also do not distinguish between medical and other equipment such as IT and copy machines; all energy consumption is lumped under the category "technical equipment" in most energy budgets. These practices have hidden the true cost of energy for medical equipment from hospitals designers and administrators. The following points can only provide some indicators of this consumption from the existing literature, as proper benchmarks are sorely lacking for this area. The next section shows actual equipment power and energy measurements.

- Indirect evidence of the extra energy demand caused by medical equipment is the gap in specific energy consumption (kWh/m^2) between well-equipped university hospitals and less well-equipped but busy central hospitals. This gap of about 50 kWh/m^2 represents 12% extra yearly whole-building energy consumption. (Ref.1, SSB 2009)

- Actual energy consumption from a Norwegian university hospital is shown in table 5-1. These show that all equipment (medical equipment, IT and other types) consumes 47 kWh/m^2. The energy consumption data for this energy category in a typical office building is 35 kWh/m2. The difference of 12 kWh/m^2 may be attributed to hospital-specific equipment. (Data from Ref.2, Bjerknes, 2010)

- Studies from the USA suggest that between 20 and 25% of a given facility's overall (electrical) load is due to medical equipment. (Ref. 3 Healthcare Design 9/28/2009)

- According to the Green Guide to Healthcare (USA), a LEED-based certification tool, imaging process loads are 86 W/m^2 compared to 11 W/m^2 plug loads of SME found in other areas.

- Studies from the UK show that medical equipment uses 17 kWh/m^2 out of a total electrical supply of 155 kWh/m^2, which amounts to 12%. (Ref. 4, using DETR data from 1999)

AHL St.Olavs	kWh/m²	%
1a. Space heating	35,0	12 %
1b. Ventilasjon heating	12,0	4 %
2. Domestic hot water	30,0	11 %
3a.Fans	45,0	16 %
3b. Pumps	0,0	0 %
4. Lighting	49,0	17 %
5. All equipment	47,0	17 %
6a. Room cooling	0,0	0 %
6b. Vent.& process cooling	65,0	23 %
SUM	283	100 %

Table 5-1 Yearly energy consumption from St.Olavs Hospital: Heart & Lung center

5. Results from power measurement of medical equipment

1. Annual energy consumption for large medical imaging equipment

Data on energy consuming by medical imaging equipment from another large university hospital in table 7-4 shows direct annual electrical energy consumption of about 520 000 kWh/year. Indirect cooling utility consumption means that total energy is approximately 625 000 kWh/year assuming 80% recycling of waste heat. The hospital area is 120 000 m² which puts total specific energy consumption for medical imaging at about 5,2 kWh/m².

Using available data from the previous section suggest that large digital imaging equipment accounts for less than half of the total energy consumption of medical and hospital-specific equipment.

2. Annual energy consumption for smaller medical and hospital-specific equipment

Smaller medical equipment (SME) : console-based ultrasound apparatus have typical yearly energy consumption of about 1 600 kWh, but there are typically more than 20 such units in a central hospital, giving a total yearly consumption which is comparable to a typical CT device. Patient monitors, laboratory analyzers, chromatographs, centrifuges, incubators, dialysis devices, localized patient heating devices etc. have various power levels and usage patterns drawing an estimated average of about 0,3 kW each for an estimated 5 000 hrs/year, but with only a 50% recycling of waste heat. Based only on these very rough estimates, the contribution of SME to yearly energy consumption is about 500 000 kWh/year, which gives a specific energy intensity of 4,2 kWh/m² in this particular case. An additional 250 000 kWh/year (3,1 kWh/m²) is therefore attributed to hospital-specific, but non-medical electrical equipment loads such as central sterilization, laundry, and a full-service kitchen. Note that these latter loads also have large steam and process loads which are accounted for elsewhere.

3. Power signatures of large medical imaging equipment

The data presented in this study was collected from two different university hospitals in Oslo area. Here we present four of the MIE`s and their power levels over a defined period of time using high-resolution measurements; namely the PET scan, MR scan, angiography as well as CT scan (Figure 6.1 and 6.2).
In general, the logging plots demonstrate a high standby power level, especially for the MR scan. It has a maximum power of 40 to 45 kW during the procedure, and in standby mode the power is approximately 17 kW. During night-time when the MR equipment it turned down to the lowest possible level it is still using almost 20% of maximum power, in our example 9 kW.

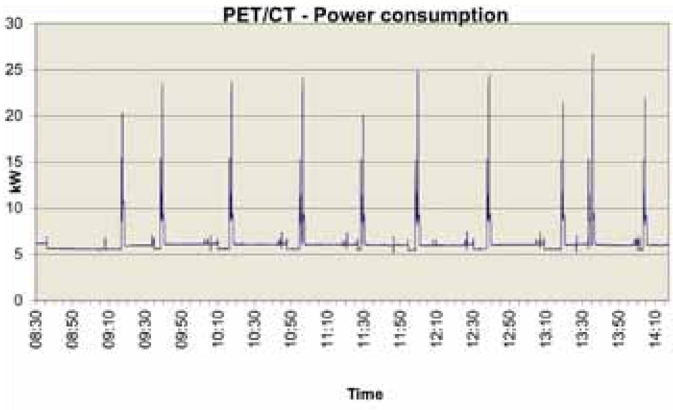

Figure 6.1: PET/CT Electrical power as a function of time

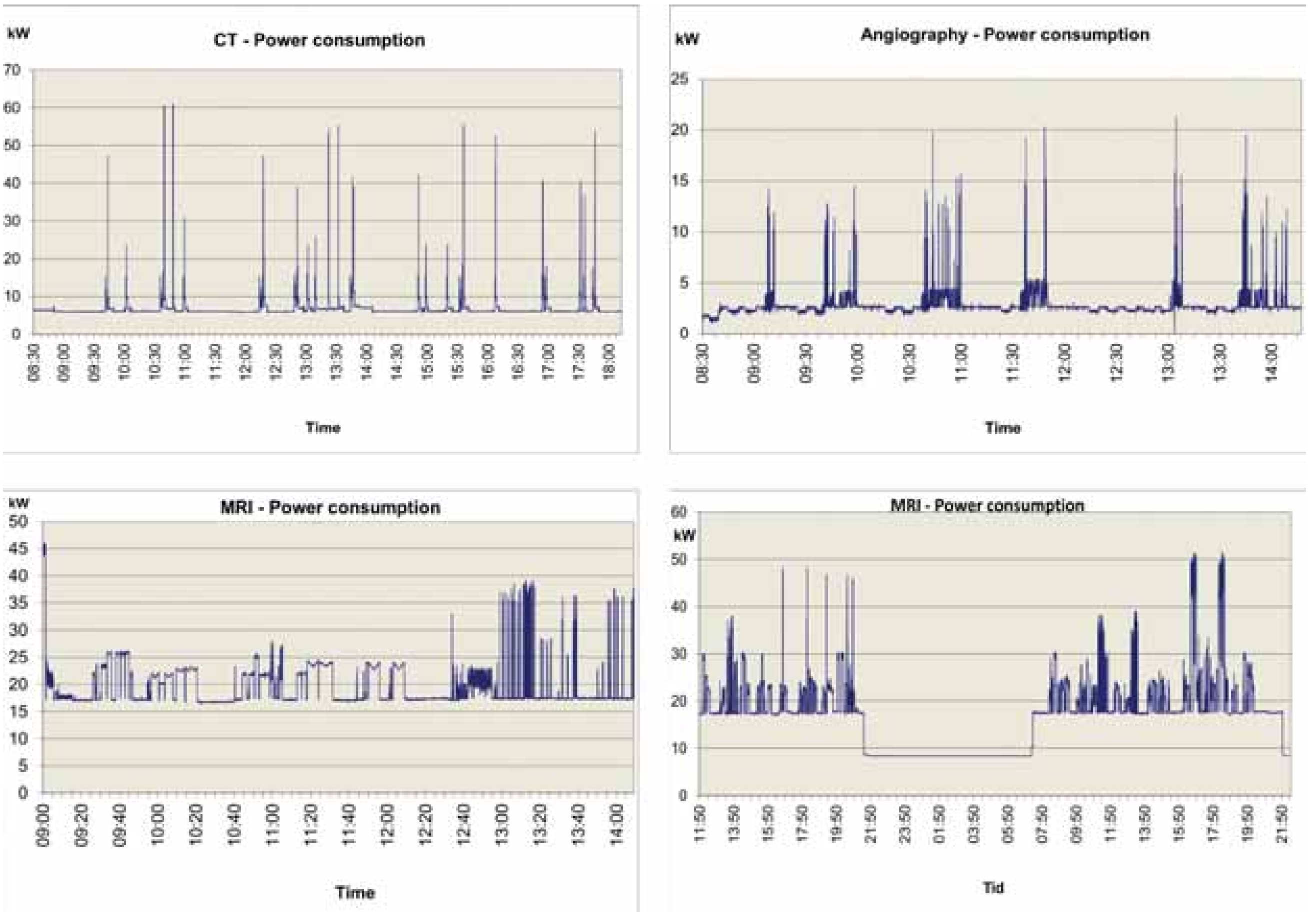

Figure 6.2 a-d: Presentation of electrical power as a function of time for - a) CT Scan, b) Angiography, c) MRI plot during daytime, d) MRI plot during 24 hours

6. Conlusions and recommendations

1. Relative energy consumption of medical equipment categories

Our findings show that large medical imaging equipment accounts for not more than half of the energy consumption related to all medical equipment in acute hospitals, and a much smaller percentage when all hospital types are considered. The relatively lower share of energy consumption for large medical imaging equipment is due to the fewer number of devices, more limited duty schedules, and higher heat recycling rates due to water cooling systems.

2. Recommendations for further research and for suppliers

Further research is recommended for suppliers of large imaging devices to reduce scan times, lower standby power level, introduce hibernate functionality, shorten start-up times, and expanded use of water cooling instead of air cooling. Suppliers of smaller medical equipment should implement energy-saving measures for the IT components in their devices, especially power-save modes for screens. Functions which can be handled by networked IT devices such as printing should be decoupled from the medical equipment.

3. Recommendations for hospital administrators, planners and health estate agencies

Green procurement practices and energy certifications such as BREEAM and LEED should be more demanding of the energy performance, especially on standby, of medical equipment. Hospital administrators and health estate agencies should consider energy monitoring and management programmes for medical equipment, and strategies for energy economy. These include energy alarms and reminder functions, and timed electrical power circuits for non-critical equipment. Hospital planners and architects should consider grouping of medical equipment wherever possible to allow more effective, enclosed air-cooling design.

High power consumption of medical equipment incurs hidden investment costs which are typically not accounted for in lifecycle analysis. Larger dimensions for transformers, uninterruptible power supply and other components of the in-house electrical network are additional costs which can be eliminated with lower-power specifications. This aspect is not elaborated upon in this paper, but should be kept in mind when facing investment decisions.

4. Energy in a wider perspective

In a wider perspective, even high-power medical equipment can give a net energy benefit if early diagnosis reduces the length and complexity of a patient's later treatment. Digital systems which replace older analog devices save water previously used in film processing and hence lifecycle energy. Telemedicine technology in particular shows promise for reducing transport energy costs. These aspects are difficult to quantify but should also be considered when evaluating lifecycle costs of medical equipment.

Equipment type	Treatment kW	Standby kW	Usage pattern		Treatment	Usage	Standby energy	Treatment energy	Total energy
Name	**kW**	**kW**		**hours/day**	**hours/day**	**days/year**	**kWh/year**	**kWh/year**	**kWh/year**
Radiography, thorax	1,4	0	0800-1600 5/7 week	8	1	260	0	364	364
Fluoroscopy	7,5	6	0800-1600 5/7 week	8	2	260	12 480	3 900	16 380
Fluoroscopy (acute)	7,5	6	24 hours	24	6	365	52 560	16 425	68 985
Radiography (acute)	1,5	0	24 hours	24	4	365	0	2 190	2 190
Radiography	1,5		0800-1600 5/7 week	8	1,5	260	0	585	585
Mammography	1	0	0800-1600 5/7 week	8	1	260	0	260	260
Mammography	1	0	0800-1600 5/7 week	8	1	260	0	260	260
CT	6,2	5,5	0800-1600 5/7 week	24	2,5	260	34 320	4 030	38 350
CT - acute	8,8	8	24 hours	24	2,5	365	70 080	8 030	78 110
CT - acute	16,7	0	24 hours	24	4	365	0	24 382	24 382
Angiography (intervention)	9	3,8	0800-1600 5/7 week	24	3	260	23 712	7 020	30 732
Angiography (intervention)	9	3,8	0800-1600 5/7 week	8	2	260	7 904	4 680	12 584
MR	52	5	0800-2200 5/7 week	14	7	260	18 200	94 640	112 840
MR	52	5	0800-2200 5/7 week	14	7	260	18 200	94 640	112 840
Gammacamera	2	0	0800-1600 5/7 week	24	4	260	0	2 080	2 080
Gammacamera	4	0	0800-1600 5/7 week	24	4	260	0	4 160	4 160
Special camera	14,3	0	0800-1600 5/7 week	24	4	260	0	14 872	14 872
Operation, major	9	3,8	sporadic	8	1	90	2 736	810	3 546
SUM							240 192	283 328	523 520

Table 7.4 Energy consumption data from Akershus University Hospital, 2010 for digital imaging equipment (not including ultrasound)

8. References

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7. *Mads André Larsen, Effektbelastning i sykehus: Operasjon- intensiv- neonatal- og Sengeavdeling, NTNU, 2001*

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