Report

Computed Tomography (CT) - Study on the potential for environmental improvement by the aspect of energy efficiency

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PE INTERNATIONAL
EXPERTS IN SUSTAINABILITY

Title of the Study: Computed Tomography (CT) - Study on the potential for environmental improvement by the aspect of energy efficiency

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Nomenclature

CT	Computed Tomography
ErP	Energy related products
h	hours
MFD	multi function devices
RF	radio frequency
SRI	Self-Regulatory Initiative
VA	Voluntary Agreement

1 Introduction

The motivation of this report is to estimate the potential for environmental improvements for Computed Tomography equipment (CT) in particular regarding the energy consumption, by adapting and applying the methodology defined for Magnetic Resonance equipment in 2012. The identified improvement potentials in total and per Company are used by the SRI Steering Committee in the COCIR Self-regulatory Initiative (SRI) for medical imaging equipment to define ecodesign targets for CT. As investigations in earlier phases of the SRI of COCIR showed, the use phase dominates and provides the highest potential for environmental improvements by energy efficiency.

It is in the nature of the product group to be extremely complex and provide manifold functions though the principle is always “providing an image”. However, the diversity is given by aspects such as which image of which part of the body and in which time, frequency, resolution and quality, colored or black and white, fast or slow, dynamic of moving elements or static or even the use of CT technology in combination with other investigation or interventional methods. This leads to the fact, that improvement aspects are not easy to be identified while at the same time ensuring availability of established and new functions, providing physically and technically required performances and new developments.

The document is the result of a continuous accompaniment of COCIR and its members from September 2012 until March 2013. In this time data had been collected and calculations had taken place to proof the applicability of the method. The given calculations are therefore a theoretical potential and serve as support to COCIR to calculate their requested target respectively to provide a proof of ambitiousness in target setting.

The method shows the technical improvement potential and an improvement potential via influencing usage and use behavior. CT is a modern but already mature technology. For those products often technological improvements can be exceeded by system improvements or improvements through smarter usage respectively smart interaction with users. That is inherently already ambitiousness and thus provides ambitious reduction targets. It also serves hints and potentials how individual companies can improve and what it means for the market, if improved devices will be delivered, motivated and initiated from the SRI and its underlying method.

2 Executive Summary

This report is structured into three sections.

The first one introduces to the product group of computed tomography (CT), the scope of the COCIR SRI and its intention of implementing ecodesign, in order to provide a solid information base and to allow understanding the complexity.

The second section provides a description of the method that has been applied in order to quantify the improvement potentials in a meaningful, realistic and comparable way. Only this ensures freedom and leveraging in all developments (innovation through ecodesign), whilst ensuring that the environmental impacts are reduced through best applied energy efficiency.

Finally the third section provides data and information how the method was applied in order to provide the data required by the SRI target setting methodology. The identified technical improvement potential has to be considered as the theoretical maximum improvement that could be achieved under the unrealistic assumption that all the different technological solutions are applied at the same time. As shown in the report, the technical possibilities to reduce the energy use depend on the specific technology of the CT and are highly limited as the technology works already high efficiently.

The study also concludes that due to the technological complexity of CT and the constant trend towards higher performance and functionalities a single efficiency factor is not applicable. It is much more the user behavior that has been identified as one of the main drivers of the energy consumption. A change in the usage of the systems has been agreed to have the biggest energy consumption improvement potential that serves to be ambitious as requested by ErP directive.

The highest improvement potentials are buried in modes, in which in principle several modules do not have to provide functions, i.e. LowPower mode and partly Idle mode. Since CTs are typically used in hospitals with a 24 hours business including many unforeseeable requests and business situations, the influence of the end user with adequate information following article 14 of the ErP directive provides a significant potential that might exceed technical improvements in a quite mature technology. However, the baseline of today is quantifiable for technology only, but not representatively for real case usages considering use behavior – as it is for many other product groups too falling under ErP.

Thus the proof of ambitiousness is given, but a meaningful target is not quantified by a single number representing the target than by scenarios showing the order of magnitude that is possible to reach once the baseline is set via for example market investigations. Depending on the scenario the improvement potential ranges somewhere between ca. 10% and ca. 31%, which is most ambitious for such modern but also mature technology as CT is.

3 Overview COCIR and PE INTERNATIONAL

COCIR is the voice of the European Radiological, Electromedical and Healthcare IT Industry. COCIR is a non-profit trade association, founded in 1959, representing the medical technology industry in Europe. COCIR’s members play a driving role in developing the future of healthcare in Europe and worldwide.

COCIR's aim is to represent the interests and activities of its members at European level, and to communicate with policymakers on economic, regulatory and technical issues related to healthcare. COCIR also cooperates with international organizations on issues of common interest.

COCIR seeks to promote the development of harmonized international standards and regulatory control respecting the quality and effectiveness of medical devices and healthcare IT systems, without compromising the safety of patients and users. COCIR's key objectives include promoting free worldwide trade of medical devices and maintaining the competitiveness of the European imaging, electromedical and healthcare IT industry.

PE INTERNATIONAL provides companies with cutting-edge tools, in-depth knowledge and an unparalleled spectrum of experience in making both corporate operations and products more sustainable. Applied methods include implementing management systems, developing sustainability indicators, life cycle assessment (LCA), carbon footprint, design for environment (DfE) and environmental product declarations (EPD), technology benchmarking, or eco-efficiency analysis, emissions management, clean development mechanism projects and strategic CSR consulting. PE INTERNATIONAL uses its broad range of expertise to jointly find solutions with our clients to meet their varied needs in the above areas of sustainability. We run workshops, provide training, manage full projects and offer standard and customized software solutions complete with data bases. By ensuring a thorough understanding of the client’s needs, we can focus our services on what matters. We take pride in our efficiency and effectiveness and we ensure that our clients will reap the benefit of a cost effective investment in their sustainability needs.

PE INTERNATIONAL already assisted COCIR in the target setting process for MRI that was also part of the Self-Regulatory Initiative for imaging medical devices of COCIR member companies. Thus, the successful cooperation has been prolonged to the target setting for CT devices.

4 COCIR SRI

The Self-Regulatory Initiative (SRI) for medical imaging device is a voluntary agreement between COCIR Member Companies which complies with relevant criteria specified in the Ecodesign Directive (2009/125/EC).

Participating Companies commit to improve the environmental performances of medical imaging equipment through a transparent and open process with the involvement of the European Commission and stakeholders.

The most significant environmental aspects are identified and quantified. Specific methodologies are developed to measure them and to evaluate the improvement potentials. Reduction targets are set and improvements are tracked and yearly communicated to the European Commission and to stakeholders.

The initiative and a first pilot project on Ultrasound equipment was firstly presented to the European Commission and the Consultation Forum in 2009. The comments received during and after the meeting were used to refine the proposal that has been submitted for official endorsement to the European Commission and was officially acknowledged in December 2012.

4.1 The SRI Methodology for Target Setting for CT

The SRI adopts the “fleet approach” regarding to ecodesign targets. Targets are defined as the average performance of all models placed on the market in the year under consideration, not as specific threshold levels on product performances.

The SRI defines a methodology for setting targets on the identified environmental aspects, which requires the knowledge of the performances of all the models on the market and an estimation of the potential for improvement for the selected aspect.

The result of the methodology is a reduction percentage used as target over a period equal to the innovation cycle of the modality (3 to 7 years).

The target is evaluated by the SRI Steering Committee to determine if it is achievable and reasonable in a cost-benefit perspective. After discussion with the European Commission and interested stakeholders, the target is adopted and published on the annual Status Report.

4.2 Goal and Scope of the Project

Main goal of this project is the evaluation of the expected product improvement potentials in terms of energy consumption in order to provide the data required by the SRI methodology for the definition of a reduction target for the product group of CTs.

In particular PE INTERNATIONAL has been required to provide the following information as a result of the study:

1. Definition of a realistic Business as usual scenario for year 2018 based on the current and expected trend in the CT technology and market
2. Estimation of the maximum potential for improvement for CT based on best available technologies and technologies now under development (best not yet available technologies)

3. Realistic estimation of the potential for improvement per company required by COCIR SRI for the target setting process

To achieve this goal, companies participating to the SRI provide information on various aspects, i.e. state of the art technology, functions, structure of the product under consideration (modules), typical use (function and modes), known and established developments and development cycles (BAU and BAT), new developments (BnAT), consumption of energy per modules and mode (partly calculated, partly measured), technical improvements and improvement potentials, sales per product type and intended future sales as well as general information to understand status and trends regarding to the product under consideration and its market. PE INTERNATIONAL evaluates data and information, which are partly highly confidential, and delivers the main results to COCIR.

Provided data in this report are always understood per market and never per individual company. However in order to follow the approach of the SRI also confidential and/or company individual data and information are provided to COCIR to ensure proper calculation of targets and protection of company individual rights.

Challenges of this project in regard to measurement and data collection are the difficulties to measure energy consumption per module and mode and its transfer into real world use scenarios, specifically regarding to LowPower mode and its application from users, since for the latter there is by today rather qualitative information than solid references or sources of information.

5 Methodology for Defining the Potential for Improvement

This chapter introduces CT equipment to provide a better understanding of the products and their related functions. This is a key element to realise the provided method as a logical solution to motivate for environmental improvements whilst allowing all freedom in design and in developing new options and functions with the goal. It is important to bear in mind that the medical industry is committed to develop lifesaving equipment to provide better diagnostic tools and better healthcare to patients. Therefore, any solution that would reduce environmental impacts while reducing performances at the same time cannot be adopted. Moreover any restriction to innovation capability could have negative consequence on healthcare that must be avoided.

The functional unit is the reference ensuring the comparability of power consumption of different products and their developments over time. As identified in the CT energy measurement methodology, the functional unit is a typical daily usage in hospital environment.

5.1 Description of Product Group CT

5.1.1 The Functional Unit

The functional unit is the reference ensuring the comparability of power consumption of different products and their developments over time. As identified in the CT energy measurement methodology, the functional unit is a typical daily usage in hospital environment.

Computed tomography is a medical imaging procedure that utilizes computer-processed X-rays to produce tomographic images or 'slices' of specific areas of the body. CT is used in medicine as a diagnostic tool and as a guide for interventional procedures. Sometimes contrast materials such as intravenous iodinated contrast are used. This is useful to highlight structures such as blood vessels that otherwise would be difficult to delineate from their surroundings. Using contrast material can also help to obtain functional information about tissues.

X-ray slice data is generated using an X-ray source that rotates around the object; X-ray sensors are positioned on the opposite side of the circle from the X-ray source.

Newer machines with faster computer systems and newer software strategies can process not only individual cross sections but continuously changing cross sections as the gantry, with the object to be imaged slowly and smoothly slid through the X-ray circle. These are called helical or spiral CT machines. Their computer systems integrate the data of the moving individual slices to generate three dimensional volumetric information (3D-CT scan), in turn viewable from multiple different perspectives on attached CT workstation monitors. This type of data acquisition requires enormous processing power, as the data are arriving in a continuous stream and must be processed in real-time.

Detectors

The earliest sensors were scintillation detectors, with photomultiplier tubes excited by (typically) cesium iodide crystals. Cesium iodide was replaced during the 1980s by ion chambers containing high-pressure Xenon gas. These systems were in turn replaced by scintillation systems based on photodiodes instead of photomultipliers and modern scintillation materials with more desirable characteristics.

To be able to obtain a good quality image, detectors have to reach a specific temperature (steady state) from the off state. This process could take different times according to the specific CT and detector technology.

Reconstruction engines

Once the scan data has been acquired, the data must be processed using a form of tomographic reconstruction, which produces a series of cross-sectional images.

In terms of mathematics, the raw data acquired by the scanner consists of multiple "projections" of the object being scanned. These projections are effectively the Radon transformation of the structure of the object. Reconstruction essentially involves solving the inverse Radon transformation.

Recently, manufacturers have developed iterative physical model-based maximum likelihood expectation maximization techniques. These techniques are advantageous because they use an internal model of the scanner's physical properties and of the physical laws of X-ray interactions. Earlier methods, such as filtered back projection, assume a perfect scanner and highly simplified physics, which leads to a number of artifacts, high noise and impaired image resolution. Iterative techniques provide images with improved resolution, reduced noise and fewer artifacts, as well as the ability to greatly reduce the radiation dose in certain circumstances. The disadvantage is a very high computational requirement, but advances in computer technology and high-performance computing techniques, such as use of highly parallel GPU algorithms, now allow practical use.

5.1.2 Modules

As described in the functional unit section above, computed tomography (CT) uses computer-processed x-rays to produce tomographic images of different areas of the body. The basic hardware components of all CT systems are the tube and generator chain, that produces the x-ray, the detector, that recognises the residually arriving x-rays on opposite of the tube, the gantry motor, that turns the system around the body or object to be investigated in order to receive a 360° information and the cooling system. A computer controls the CT scanning operation and processes the information towards becoming images.

Due to the high complexity of the system, the definition of the most important modules is needed to simplify by separation into single functions (out of the entire product functionality) and to figure out the modules with the highest energy consumption.

The most important energy consuming modules of the entire CT system have been identified to be:

- Tube and generator chain
- Detector
- Power distribution unit and other power supplies
- Computation, Controls
- Cooling
- Patient table
- Gantry motor

5.1.3 Application

The CT works mainly in 4 different modes. Either it's Off, LowPower, Idle or Scan mode. The Idle mode can take place within an examination in between the scans as well as between examinations, e.g. when examinations or patients change, as shown in

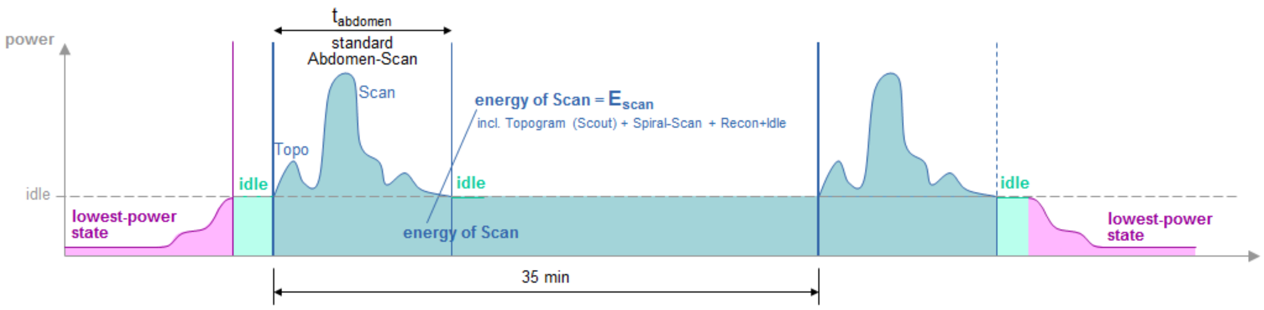

Figure 1. Furthermore, the system runs in Idle mode after and before switching from Off or LowPower at the beginning and end of the working hours. The different modes result in a diverse activity of the modules. Therefore the impact on energy consumption differs between the modules and modes. Some of the modules are almost inactive during LowPower, if the system runs down. Due to this fact, energy consumption should be measured by mode and module in order to derive an accurate estimation that would lead to an ambitious target.

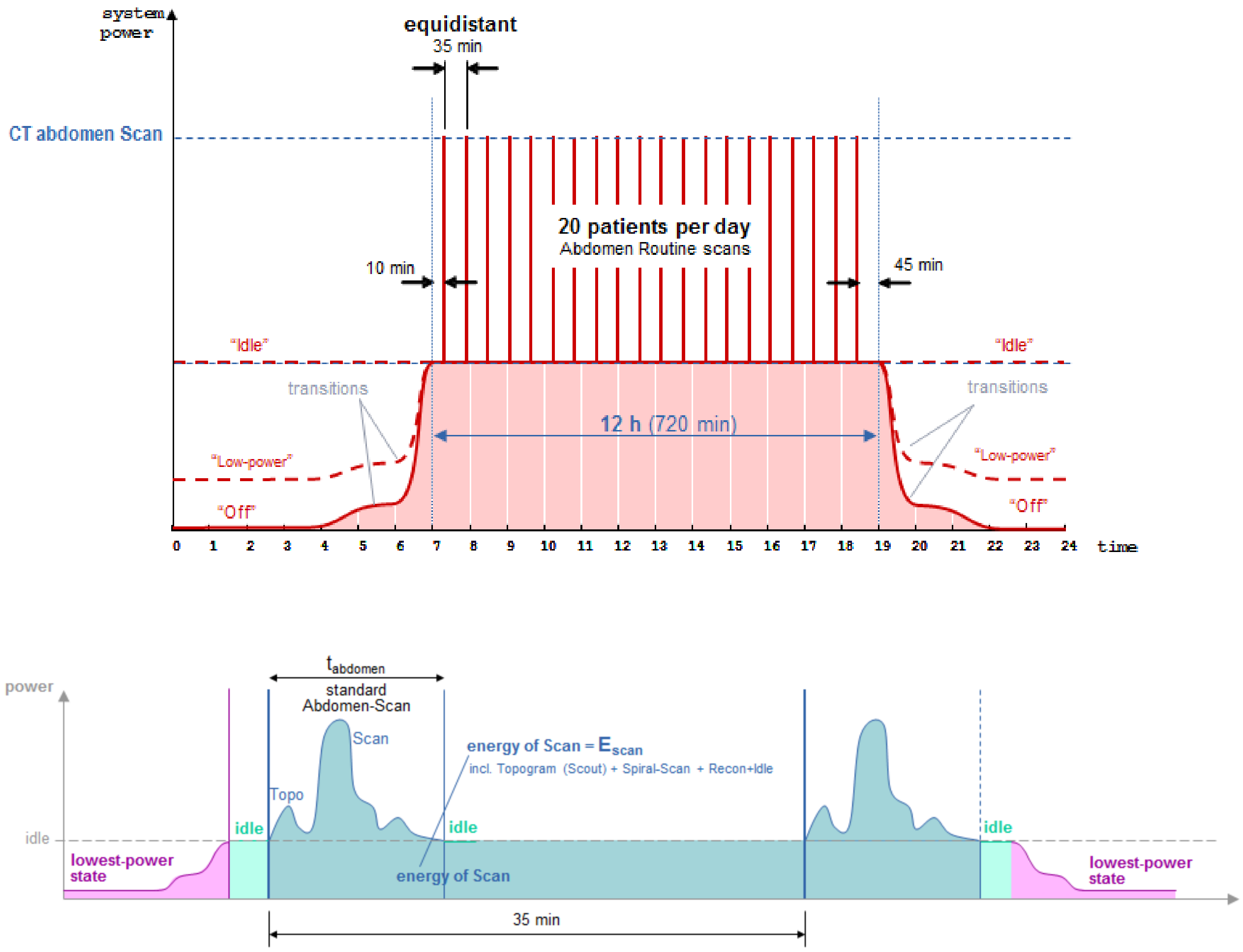

Figure 1: Representation of CT power absorption during the day and details of single scans

The power consumption was measured in each mode, but the allocation to various modules followed an engineering approach, by determining percentages per module from the total.

5.1.4 Examination of Patients

The examination of patients differs because of different injuries or diseases that need to be examined. The time needed to perform an examination depends on the scan speed of the equipment, the functionality, the chosen protocols and the time required for patient preparation, data input and archiving etc.

Despite those aspects and multiple options of variations, 4 general examinations and respective protocols have been defined by the CT experts serving as normative reference.

5.1.5 Modes

As the modes have different levels of energy consumption, the modes are investigated separately. The CT system runs in 3 energy using modes: LowPower, Idle and Scan mode.

In Off mode the scanner is switched off and consumes no energy. In this study only energy using modes have been considered and analysed.

The intensity of the use of devices varies in the different modes. Therefore not only the modules but also the different modes have been taken into account by measuring each mode individually.

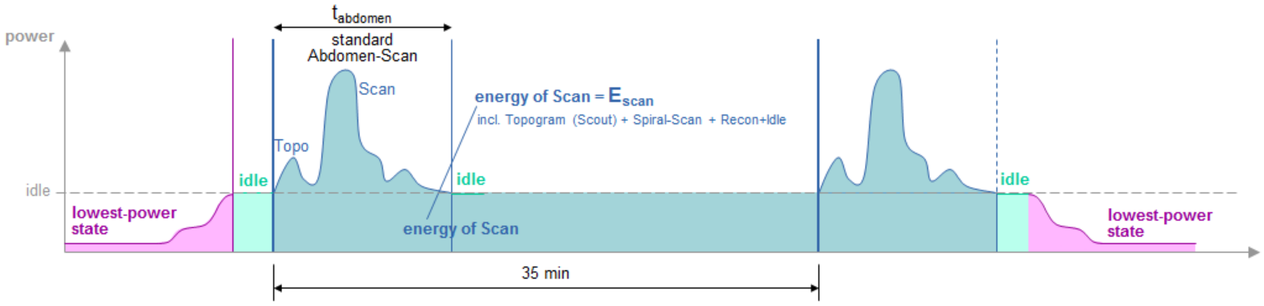

Figure 1 (see section 5.1.3) shows the power absorption of a CT during a day.

This example illustrates the energy consumption in LowPower mode as well as when the system is switched on. The example shows a LowPower time of 12 hours during nights. This 12 hour downtime is supposed to reflect the regular usage behaviour of CTs, but for many different reasons (e.g. emergency purposes) several sources indicate different use behaviour.

The example also demonstrates a “standard examination day” that has been defined by the industry in order to have comparable measurement data.

This standard day defines 20 examinations per day. This means that there are 20 scans per day while the system runs. If the system is switched on, it always runs in Idle mode. When a scan is prescribed, the mode changes from Idle to Scan. Each scan only lasts for some minutes (at most five minutes). While the system is warming up, between the scans and when the system runs down, the CT runs in Idle mode. The red lines in

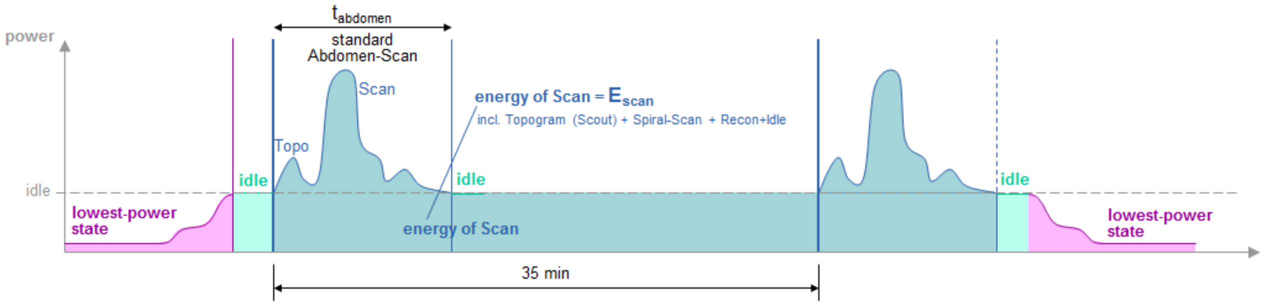

Figure 1 show the peaks in energy consumption that occur while the CT is scanning. These peaks only last for some minutes each as stated above.

Not only in Idle and Scan mode, the CT consumes energy but also during LowPower mode, some of the devices need to run and cannot be totally switched off (i.e. computation). But as shown in

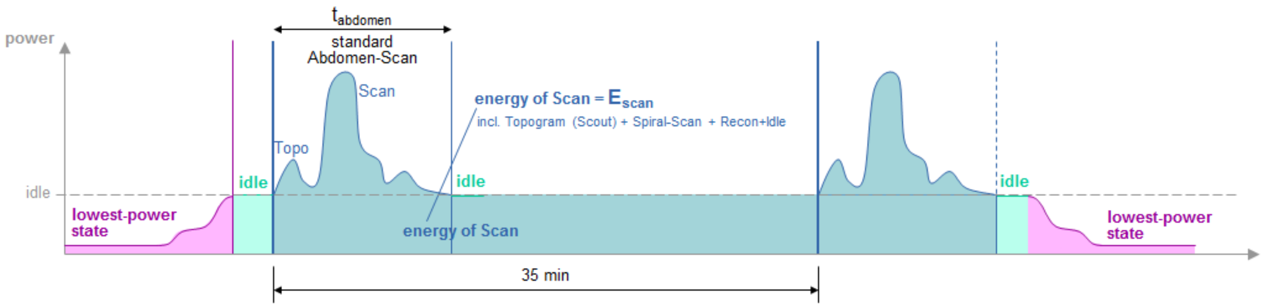

Figure 1 this level of energy consumption is a lot lower than the energy consumption in Idle and Scan mode. This difference in energy consumption between the modes points up an important energy consumption factor:

How much energy the CT consumes isn't only dependent on the technical constraints but can also be influenced by the usage. The longer the CT stays in LowPower mode, the better for the energy saving. There are several possibilities and time slots when the CT could be switched to LowPower but actually isn't as analyses of the SRI SC identified[1]. This is based on different use cases: one use case of CT scanners is the usage in emergency departments where they are never switched off or turned to LowPower mode during night time because of emergency concerns. Another result of the SRI investigation was that the CT scanners used in other departments also seem to be left in Idle mode during the night. Reason could be that users don't want to lose time by waiting for the system to warm up. Keeping in mind that the energy consumption between Idle and Off or LowPower mode differs significantly, this shows the impact on energy consumption of possibly influenced user behaviour.

5.1.6 Future Trend

The future trend of CT systems foresee several technical improvements that will allow the system to

- reduce the x-ray dose
- achieve a faster scanning
- have a higher image quality and resolution
- use of multi-detector CT with two tubes for image series with different kVp (80 and 140 kVp) and the elimination of misregistration artifacts
- provide a better signal technology and detailed data acquisition and calculation
- establish faster shut down and warm up phase

But there's no real common industry trend that could be set as standard trend for all CT scanner.

[1] More information available on the COCIR "SRI CT Report " and on the "SRI Status Report 2012", both available at COCIR website.

5.2 Description of the Approach

5.2.1 General Considerations for Energy Improvements of CTs

Influence on the potential for improvement can either be exerted in a quantitative or a qualitative approach. Quantitative energy improvements either mean less energy consumption while the functions of the CT scanner keep similar or even keeping the energy demand on a certain level why achieving more output. Examples for these mechanisms showing the complexity and challenge of single targets are:

- A decrease of energy consumption typically derives from increase of efficiency. However, the product CT is a mature technology that is already highly efficient. Therefore, only slight efficiency increases will be achievable which won't have a certain impact on the energy consumption.

Examples from other products show that typically one main function allows the target setting for higher efficiency, e.g. external power supply units, electric motors, transformers or TV sets. Though TV sets already showed the challenge that watching TV is not necessarily a feasible functional unit the efficiency can refer to. Performance aspects such as screen size, quality of picture, number of pixels, contrast range are influencing the efficiency but are difficult to get reflected quantitatively by a changing functional unit. Thus, it can be seen that the complexity of functions to be delivered and the constant change and increase of functions through innovation and development on CT devices make the application of one single factor impossible.

- A higher rate of examination of patients whilst the energy consumption per day keeps similar, would lead to less power per examination. But as the average scan duration is only a few minutes, the influence of a faster scan on the examination frequency per day is limited and therefore negligible. A faster scan wouldn't implicitly mean that a huge technological improvement has taken place.

  The true value of CTs is in the amount of information that can be given to medical experts. The information is based on imaging of things which cannot be seen from outside but depends on the type, quality, perspective, resolution, static or dynamic visuals, material and concentration and many aspects more. Different investigations and different CT models need different time spans. The shorter the good, but the investigation options rule typically the timing. Thus, it is impossible to compare and track timing of the numerous options theoretically possible and the numerous combinations of all possible scenarios. Consequentially at this stage of the SRI it is yet impossible to realize and measure shorter investigation times within the constraints of the defined and fixed investigation sequences, which is necessary to fix in order to have a solid and fixed reference point for comparison.

Examples from other products show that increased performance resulting into fulfilling function in shorter time works, if the reference or functional unit is clearly quantified. Those products are dishwashers, washing machines or dryers, which have a clear, singular, quantifiable function and the environmental impacts can be decreased in case the run time is shorter.

- Another quantitative improvement could be the development of new aggregates that results in new functionalities. The combination of existing functions and additional new functions in one product avoids several independent devices to fulfil respective functions. Typically such combinations can use many synergies and therefore result in less environmental impacts. Clearly, the new increase of functionalities would not have a direct effect on energy consumption. However, the CTs increase the functions of providing images constantly by innovations and new developments as well as by combination with other medical examination disciplines. This leads into an even more complex set of performance requirements, an extension by additional devices, modules and sub-modules as well as to entirely new functions and is still identified as a CT product. In order to identify the synergies quantitatively an allocation could take place that identifies the energy consumption per each function, which is not possible with CT, because of missing clear boundary conditions or system boundaries for applying allocation.

Examples from other products can be given on the so called multi-function devices (MFD) from printing and imaging market. They combine clearly identifiable functions such as printing, faxing and scanning, for which discrete products also exist. Thus a comparison between discrete products and MFDs can take place and the allocated shares of the MFD typically are lower than the discrete products. This approach is not applicable to CTs, because of either missing discrete products for comparison or unclear allocation options.

- Introduction or specification of a new mode during the use of a product. Because of the unpredictable real usage cycle of the CT and because it is also a medical equipment that is used for emergency purposes (and therefore needs to be quickly ready for use at any time), it could be worth to distinct between more different modes than specified already today. For example the Idle mode in between scans during one examination and the Idle mode in between examinations of patients is not the same mode. However, as it is understood today it is the same, but a better differentiation and detailed investigation of necessary and less necessary modules during these phases and consequential shut down or LowPower stages could be approached. Since CT products are complex and need to provide required functions according to specification, safety and securely it is not an option to be solved ad hoc with fast and easy procedures.

An example from other product groups in which a new mode has been introduced is the standby without network access and the standby with network access, applicable for example to smart sleep mode of Set-Top-Boxes, that allows the box to “listen” to the network, that is part of function and not standby and therefore can consume more energy than typical stand-by function would require.

As consequence from the above identified challenges and in order to provide a quantifiable functional unit, scans of specific body regions and protocols had been defined being representative for typical examinations of representative CTs. This serves as reference for measurements as well as for quantifying the energy consumption per module and mode. An examination is composed of scans (scan time) and time in between scans (idle time). Scan time is mostly fixed due to physical constraints but varies between the CT models.

5.2.2 CT Categories

The categorisation of different models of CT scanner is not significant. The number of slices and other parameters has been identified as giving a hint for categorisation. But categorization based on such elements does not represent different energy consumption behaviours. Therefore the SRI SC decided to consider all CT scanners altogether in one single category with the exclusion of some high-end very specific model (dual source scanners and 256 or more slices scanners).

5.2.3 Data Collection

According to the functional unit and the scope and regulations for data collection that was agreed between the partners, measurements of models were provided by industry. The measurement provides scan time and idle time (while Lowpower time has been set as fixed) as well as energy consumption in the different modes. The energy consumption of each mode is then allocated and divided to the module accountable for the energy consumption. Because of the above mentioned economic and technical constraints for measuring the energy consumption of different modules, the percentage of the energy consumption was provided through an engineering approach.

PE INTERNATIONAL collected the data from each company to calculate market averages and discussed and verified the provided data with the individual companies and COCIR in a confidential manner.

5.2.4 Innovation cycle

The innovation cycle is defined as the time needed to develop new or enhanced products and place them on the market. For Ct it can be estimated around 5 years.

The below listed activities for CT requires on the average:

- Research and development - 1 year
- Verification and Validation - 3 years
- Regulatory Approvals - 1 year

5.2.5 Identification of Improvement Potentials

According to the scope of this analysis, in individual interviews companies were asked to provide not only information on the power consumption of the different modules but also on their assumptions of improvement potentials per module with a 5 years horizon. In addition to quantified improvement potentials, companies provided also an outlook of possible technical developments.

Four possible effects to reduce energy consumption of CT equipment have been defined as possible improvement potentials:

- Decrease of energy consumption by increase in energy efficiency
- Faster scan whilst energy consumption keeps similar

- Increase of functionalities with limited influence on energy consumption
- Implementation of new smart LowPower modes

But how could these methods be applied? To understand the real improvement potential of those effects, we need to remind on the short time span of the scan time. Thus, the influence on the overall energy consumption per day of energy efficiency wins or energy consumption reduction in Scan mode are constricted.

Given this restriction, the highest power reduction is located in the Idle and LowPower mode. The Idle mode has relatively high power consumption according to the fact that the system is running for several hours a day. If we look at a typical day in the hospital with several emergencies that evoke suddenly during day and night, we can assume that the CT equipment is not switched off during nights in order to have an available system all time. But beside this rather clear demand situation – to be ready for any emergency – the switching off into LowPower mode of CTs is barely used for any CT, mostly because of either bad information of the end user or kind of inconvenience feeling if the equipment is not immediately ready to scan, though there are no planned use demands.

This usage behaviour doesn't take into account that the real energy reduction potential is not dependent on the technical improvements for the Scan mode but that there's a significant difference in power consumption during LowPower mode and Idle mode.

As the warming up and cool down phases of the CTs become continuously shorter, there's no reason to keep it running during nights.

5.3 Reasons and Advantages of this Approach

For a better insight and to understand the location of the improvement potentials of the products, the different modules as well as the modes needed to be investigated.

- Complexity of products regarded by modularisation
- Functional unit quantified as much as possible
- Quantitative base for reference and comparison created
- Market importance identified and scope reduced to significant aspects
- Communication about ecodesign motivated and in between partners established
- Moderation as objective third party enabling open discussion about improvements
- Improvement potentials identified and quantified
- Provide profound base for calculating the SRI target
- Solution for target setting because of an intensive communication process
- Common agreement to identify improvement scenarios as the quantitative improvement potentials based on technical developments are limited

6 CT Potential for Improvement

This chapter presents the results of the data collection and represents a summary of the information exchanged between companies and PE INTERNATIONAL regarding the actual situation of the technology and the expected developments and improvements of the CT sector. As information about technical improvements is highly confidential, the summary tries to provide an overview of possible improvements by respecting the agreement not to provide any details of individual improvements of a company. PE INTERNATIONAL's role in this process was characterized by being an independent third party operator. Thus, PE INTERNATIONAL got information about individual developments and improvements and advised COCIR on the target setting.

6.1 Assessment of Data

Basis of the results is the measured data that was provided by the following companies:

- GE Healthcare
- Hitachi Medical Systems Europe
- Philips Healthcare
- Siemens Healthcare
- Toshiba Medical Systems Europe.

Data have been collected taking into account:

- Differentiation between three modes:
  i. LowPower
  ii. Idle
  iii. Scan mode
- Differentiation between 7 modules:
  i. Tube and generator chain
  ii. Detector
  iii. Power distribution unit and other power supplies
  iv. Computation, Controls
  v. Cooling
  vi. Patient table
  vii. Gantry motor

6.2 Results from Data Collection

6.2.1 Summary of Results for CT scanners

First of all, the measured average power load of the products has been identified (see Figure 2).

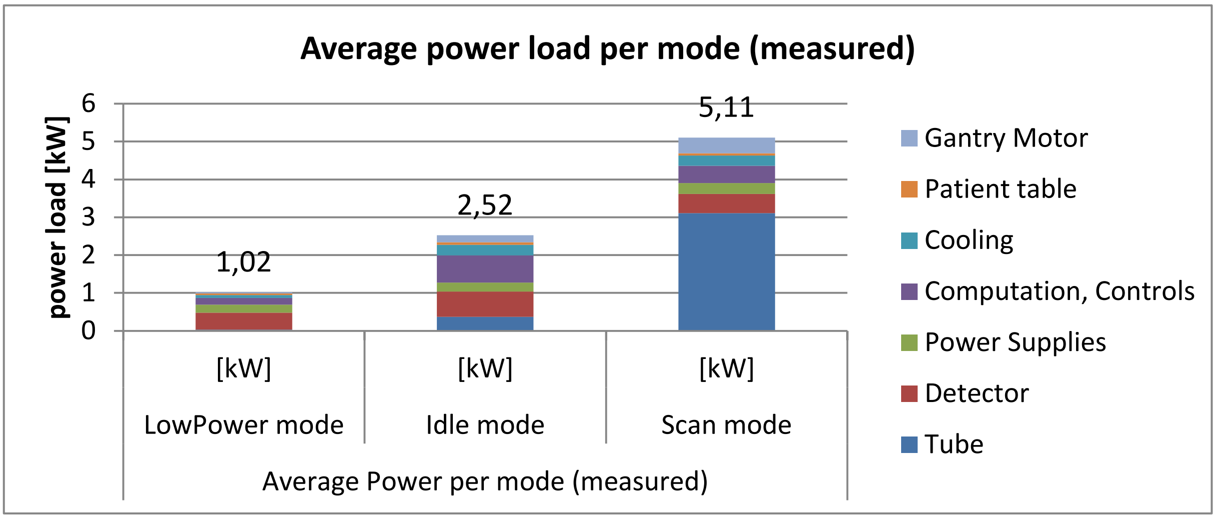

Figure 2: Average power load per module and mode (in kW) for the CT scanners

Figure 2 shows the average of the measured power load allocated per module and mode. A calculation took place for each product and was summed up afterwards to create the average values. We can see that the power load in Idle mode is 1.5 times higher than LowPower mode. On the other hand the Scan mode has more than twice the power load of the Idle mode. But this figure only shows the power load and doesn't take into account the short time span of Scan mode. Therefore, one can see that the power load of the tube is significant but compared to the short time of the Scan mode the influence of the tube regarding the energy consumption is rather minimal as Figure 3 will show.

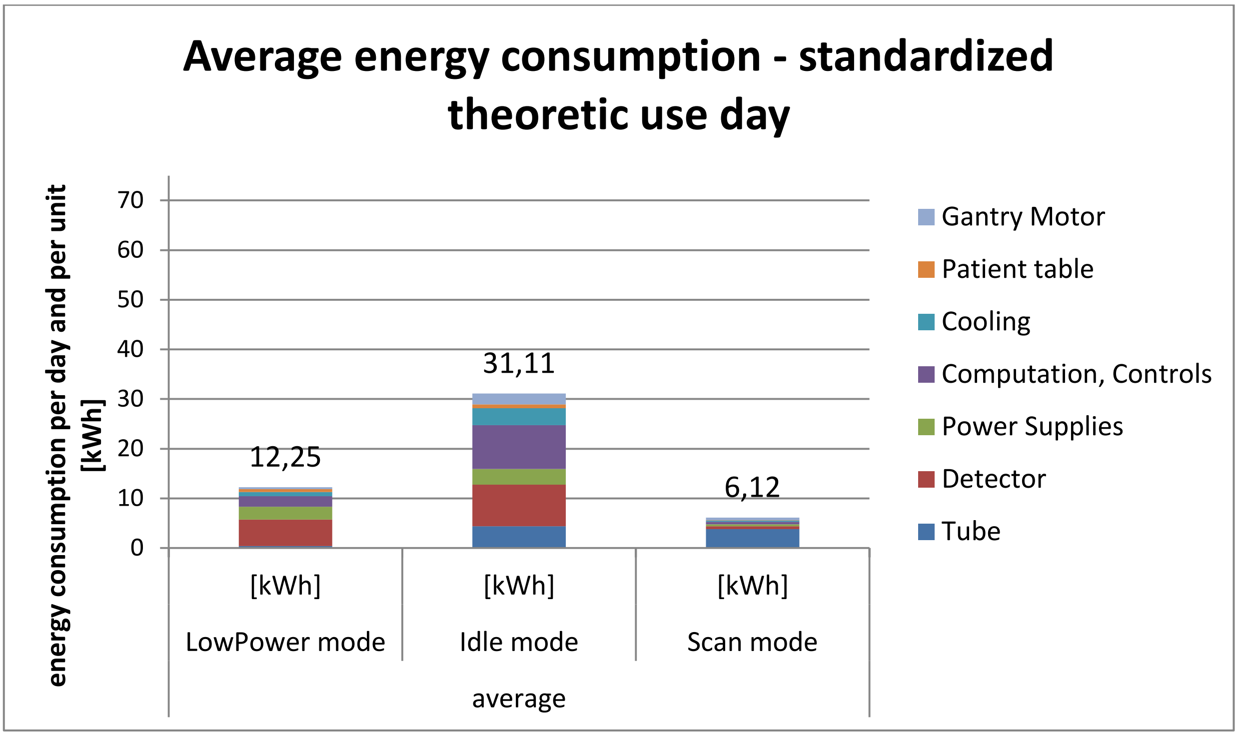

Figure 3: Average energy consumption per day (in kWh)

Figure 3 shows the results of Figure 2 multiplied by the respective mode duration leading from kW to kWh. This calculation is based on the assumption of a theoretic use day (12 hours LowPower mode, ca. 11 hours Idle mode, and 20 examinations per day).

As the scans last only for some minutes the energy consumption itself is only half as high in Scan mode than in LowPower mode and even five times lower than in Idle mode. One reason for this major portion of the energy consumption allocated in Idle mode is the time the CT scanner stays in Idle mode and another reason is that a lot of modules need to run during Idle mode in order to be ready for use, i.e. scan, and therefore the energy consumption in this mode is comparably high.

The figure shows that the biggest energy consumers of CT scanners in LowPower mode and Idle mode are detectors and the computation whereas in Scan mode the tube causes the biggest part of the energy consumption (3.77 kWh).

Table 1 shows the typical time distribution of Scan, Idle and LowPower mode, using the examination distribution adopted for the use scenario the duration of each mode per day can be derived. The duration of the LowPower mode has been set as a fixed[2] value for all models as a theoretical day usage (12 hours LowPower mode).

[2] For additional information refer to the “SRI for Computer Tomography” report or the “SRI Status Report 2012” available at www.cocir.org

Table 1: Typical time distribution of the modes during a day assuming the theoretical day

Mode	Description	Average time in mode per day (hours)
Idle mode	System ready to scan. Gantry and x-ray tube off.	10.8 (varies)
Scan mode	System is scanning. Gantry and x-ray tube on.	(varies)
LowPower mode	System is “sleeping” for fast/automatic reactivation	12

As the scan time varies between the different CT models, the Idle mode also varies assuming that the system is switched to LowPower mode for 12 hours. In average, the models that were analyzed in this study were 10.8 hours in Idle mode depending on the time the models needed for the scans.

6.2.2 Improvement Potentials per Module and per Mode

Figure 4 shows possible technical improvements for the energy consumption of the CT scanners in different modes. The improvements were identified from the individual interviews with each company and consider improvements and technical developments within the next years. As some technical improvements or additional functionalities can lead to a higher level of energy consumption, the energy consumption in Scan mode may turn to be higher after improvements. Naturally, this affects most notably the Scan mode as this is the mode where additional functions are most useful as they can improve the quality of the examination.

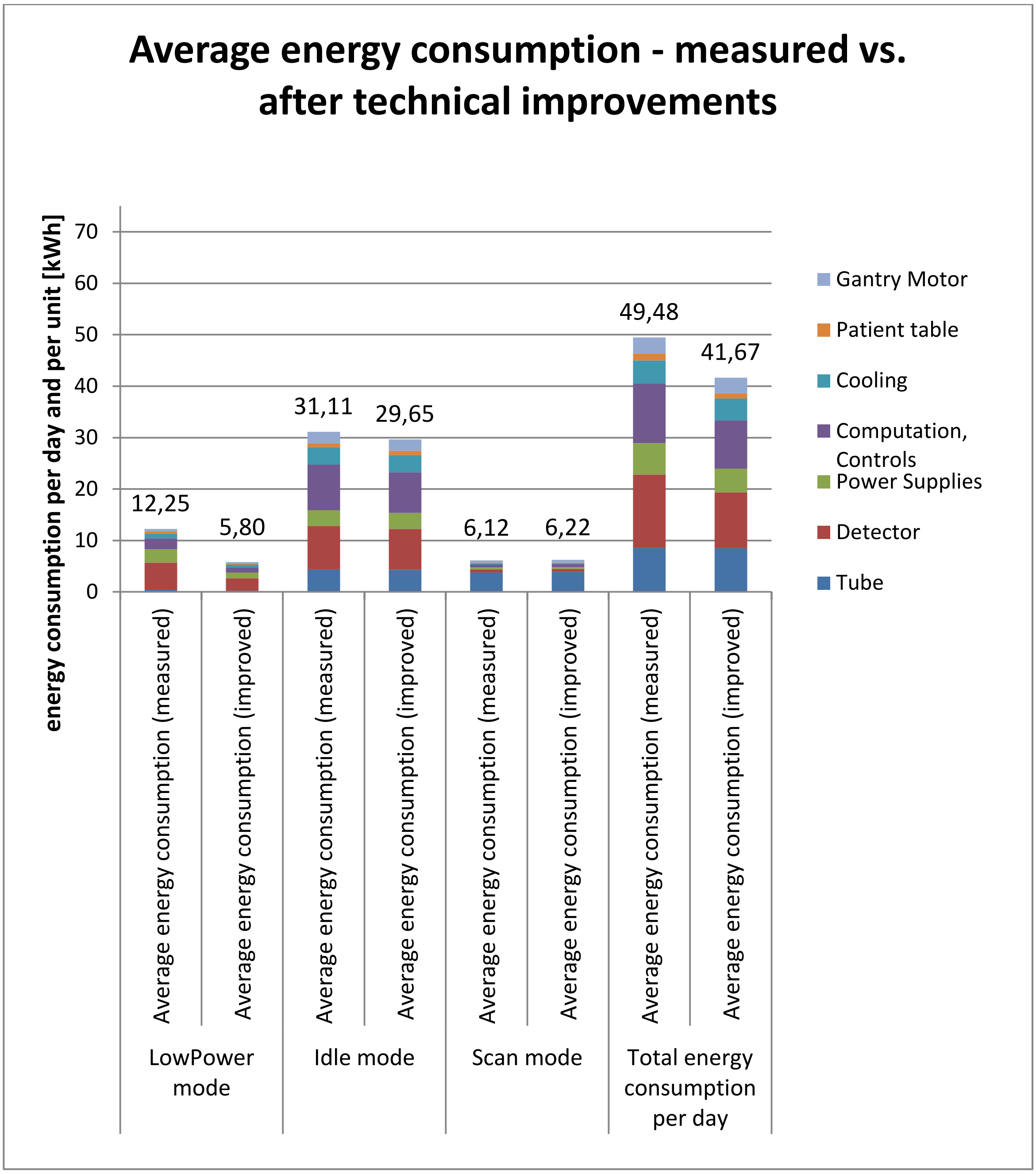

Figure 4: Average energy consumption and improvement scenario (measured energy consumption vs. energy consumption after possible improvements), in kWh

Figure 4 shows the current measured average energy consumption per day per unit and the average energy consumption after possible improvements that have been identified by the companies. The first six bars illustrate the energy consumption of the different modules in different modes and the last two bars show the total energy consumption per day given the theoretical use day with 12 hours LowPower mode.

The biggest improvement potential (about 50%) has been defined in LowPower mode. While the improvements in Idle mode are extremely low compared to the technical efforts (below 5%), the energy consumption even rises after the improvements in Scan mode as some devices will consume more energy and at the same time provide more or better functionalities. Overall, there's a theoretical potential of energy reduction of about 16% per day and per unit.

This figure shows also that after the improvements the energy consumption in LowPower mode is five times lower than in Idle mode. Taking into account the identified user behaviour, we can conclude that the highest potential for reducing energy is in increasing the time when the system is in LowPower mode. The change from Idle mode to LowPower mode is already possible with all CT models but it is not used, therefore the industry needs to motivate the clients to switch off the machine while it is not used, especially at night. Technically, the change from Idle to LowPower mode could be made easier by integrating a smart LowPower mode that provides a fast or automatic warm-up phase of the whole system.

The reduction of energy consumption during Idle mode is rather difficult as several modules need to run for technical reasons: The CT scanner in Idle mode needs to be ready for scanning all time to react to emergency cases which can't be scheduled.

In detail the following overview provides the results of improvement potentials in a confidential manner, since future developments must be understood as highly competitive in the CT market.

<u>Selection of improvement potentials of CT with respect to energy consumption</u>

LowPower mode

- In general:
    - Implementation of a smart LowPower mode which causes the deactivation of several devices which don't necessarily need to run

- Detector:
    - Reducing the standby power by timer control
    - Introduction of new intelligent components to have a faster switch on
    - Replacing DC power supply units with ones with high conversion efficiency (AC -> DC)

Idle mode

- Tube:
    - Deactivation of the cooling fan when X-ray tube equipment is cold enough
- Computation:
    - Turning the reconstruction engine into sleep mode while not scanning and reconstructing
    - Minimization of hardware and thus, reduction of energy consumption
    - Turning more components, i.e. the hard drive into sleep mode while no scan is executed

Scan mode

- Computation/Controls:
    - Upgrade of reconstruction engines because the scan speed will be faster

All modes:

- Replacement of the reconstruction engines with engines that allow a high performance process and simultaneously have small energy consumption

Summary

Summarizing from all the technical interviews and investigations it can be stated that the most important and most feasible improvements can be seen in a smart switch off of several modules, whenever they are not directly used, that applies mostly for Idle and LowPower mode. As the technology of CT is highly matured, there are physical boundaries of further technical improvements regarding the energy consumption of the modules.

Overall, like quantitatively shown in Figure 4 and qualitatively described above using examples of possible improvements, the improvement potentials towards energy reduction aren't very significant, except in LowPower mode. However, at latest here a further aspect comes into consideration i.e. the use behaviour of the clients. Like identified, the system is not often – if at all – shut down. This leads to the situation that the potential to reduce energy is not fully exploited, rather applicable at all. Therefore the technical improvements during LowPower mode seem rather to be impractical, if their positive effect on energy consumption is not realised.

As the use behaviour is not fully transparent it is not known how many clients exactly switch off the CT equipment. Therefore different use cases have been defined for pointing out the possible influence of the user behaviour on the energy consumption of the CTs and therefore their environmental impact.

6.3 Scenario of expected typical business day assuming no switch to LowPower mode

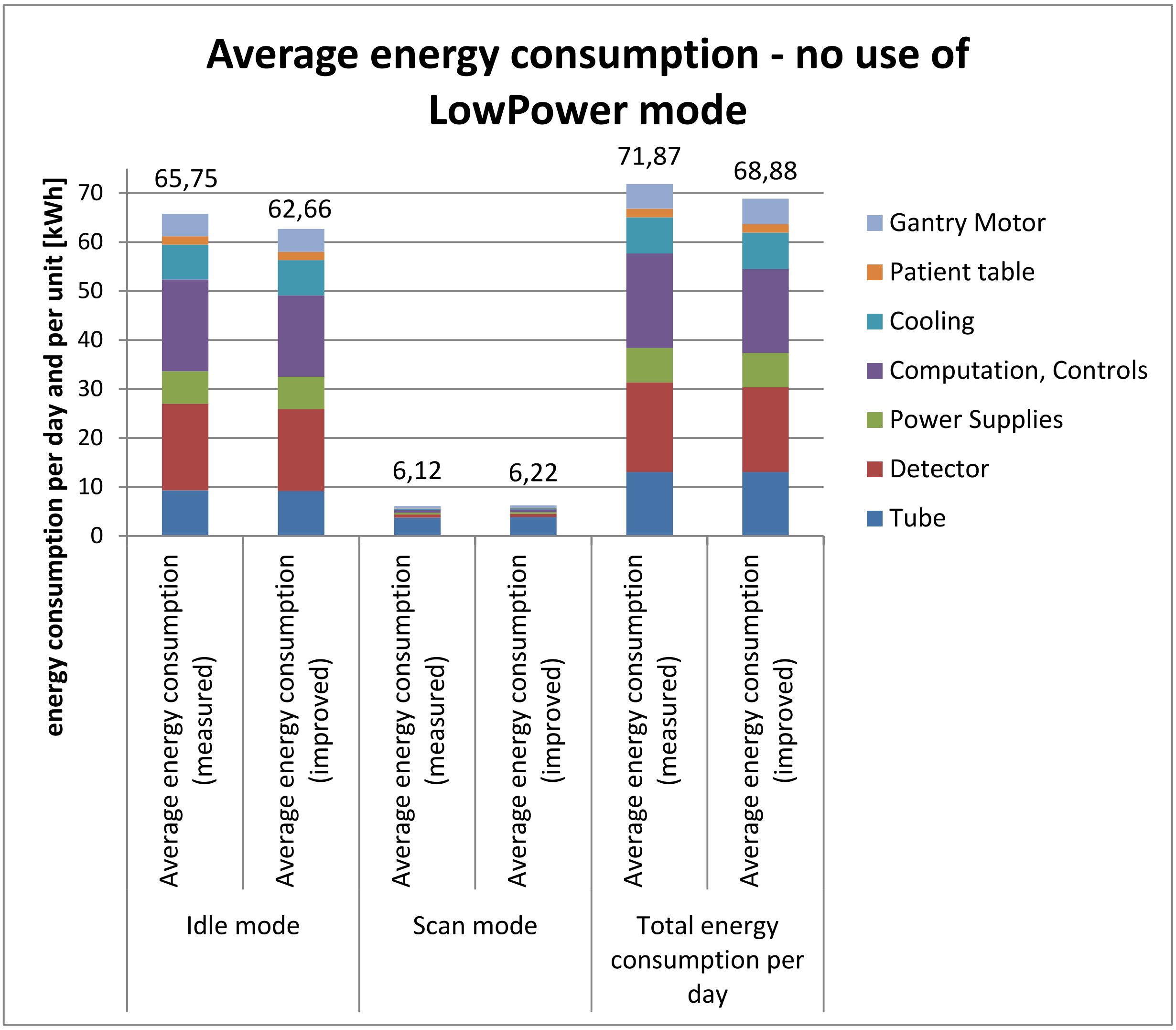

Figure 5: Energy consumption (today and with improvements (in kWh), assuming a day without switch to LowPower mode overnight

In the scenario shown in Figure 5 it is assumed that the client doesn't switch the CT equipment to LowPower mode at all, which might be one of most probable cases. The left bars of each mode show the measured average energy consumption, whereas the right bars display the average energy consumption assuming several improvements as given in Figure 4 for Idle and Scan mode. The two bars on the right hand show the total energy consumption per day. This scenario shows that the total energy consumption per day is certainly higher than if the scanner is switched to LowPower mode. It is about 45% higher than in the theoretic use day scenario (Figure 3) and the energy consumption after improvement is even around 65% higher, since the high reduction potential within LowPower mode has no effect. The improvements in the theoretic use day scenario were about 15% whereas in a world where the CT is not switched off, the improvement potential is only around 4%.

The biggest influence on the power consumption of the product can be identified by the variation of Idle and LowPower mode. Instead of keeping the system running in Idle mode while no scan is expected, a shutdown of the system could have the biggest impact on the energy consumption per day. Assuming the scenario starts from 0% time LowPower mode Figure 6 shows scenarios with 4h, 8h and the original 12h LowPower time. If we take into account these different usage scenarios and user behaviour, the average energy consumption in the LowPower mode as well as in the Idle mode changes tremendously. As the change between LowPower and Idle mode during night doesn't affect the scans during day, the average energy consumption in Scan mode keeps identical in all scenarios of Figure 6.

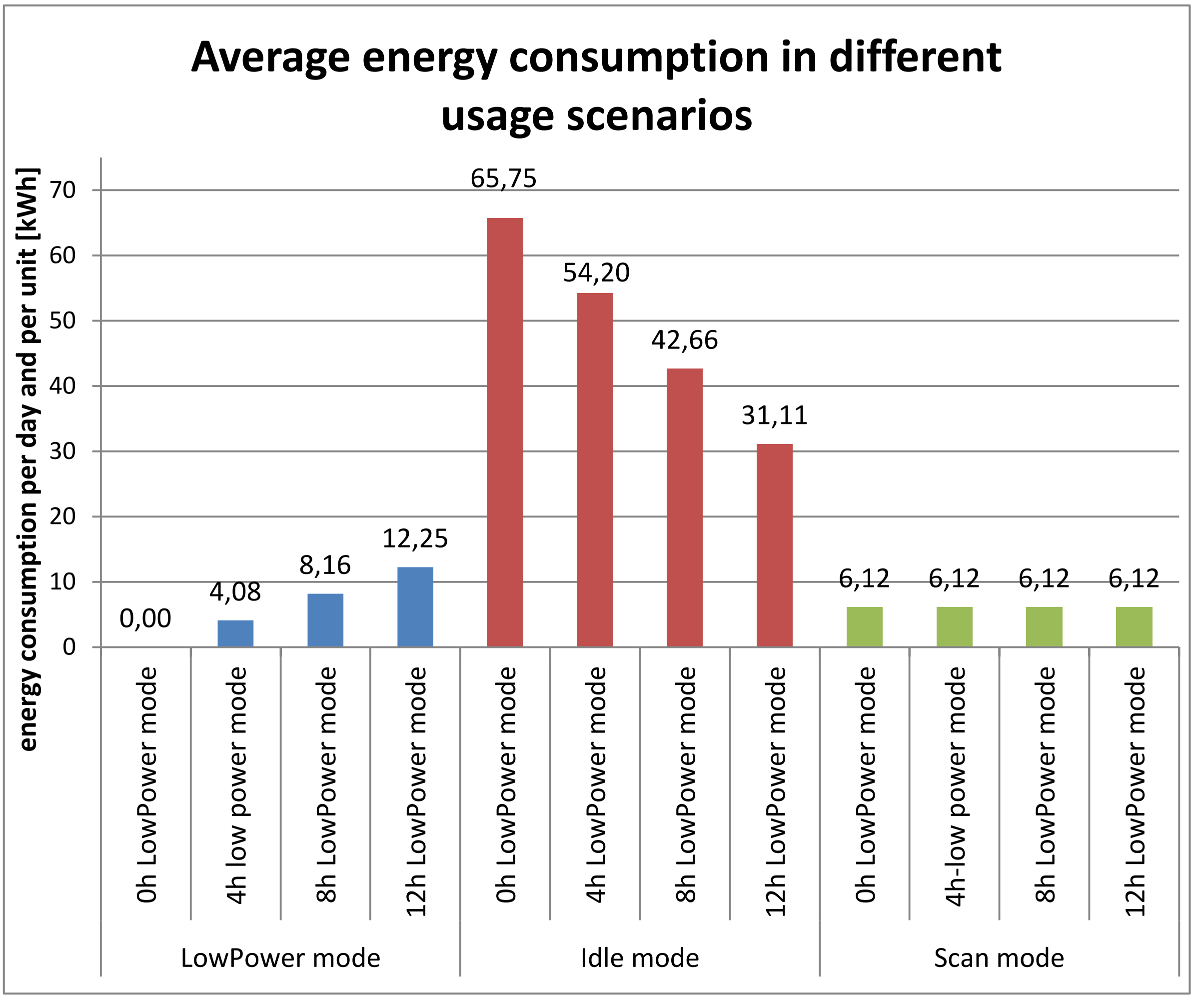

Figure 6: Average energy consumption in different usage scenarios (per mode, 0h LowPower mode, 4h LowPower mode, 8h LowPower mode and 12h LowPower mode (in kWh))

The effect of rising energy consumption in LowPower mode by extending the time is overcompensated by the reduction potential occurring accordingly in Idle mode. If the system is switched to LowPower mode for 12 hours, the energy consumption in Idle mode is reduced by 53% (around 34 kWh) compared to the scenario when the CT is not switched to LowPower mode during nights. In comparison to this, the difference of energy consumption in LowPower mode between 0h and 12h LowPower mode is only 12 kWh.

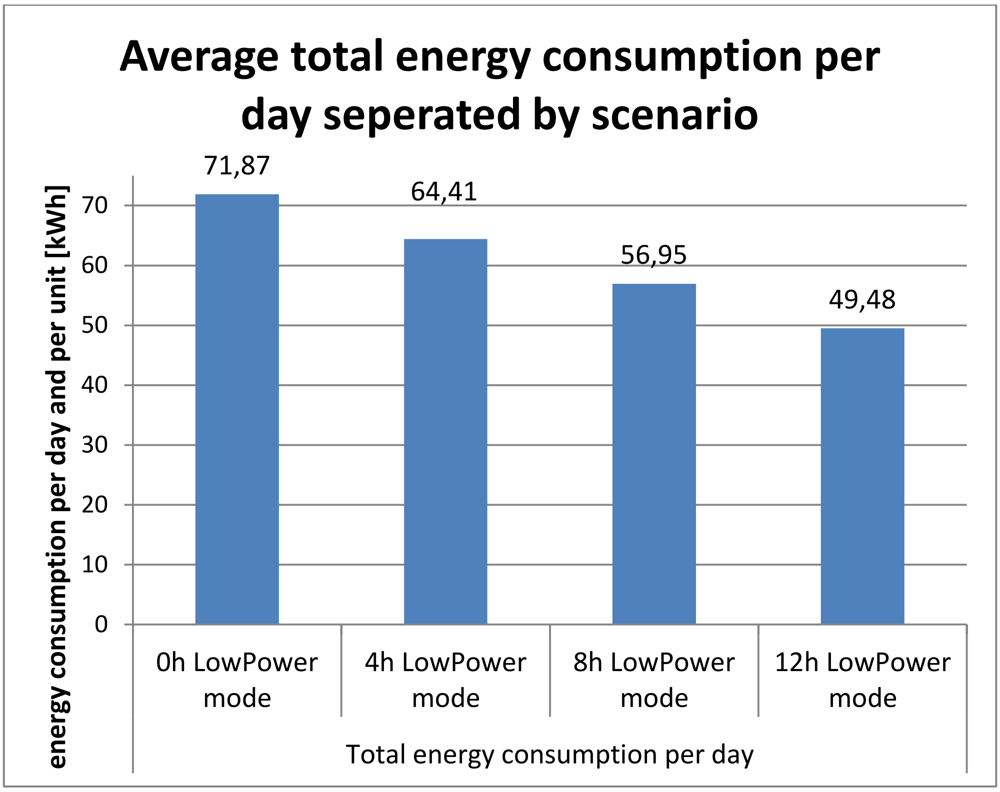

Figure 7: Average total power consumption per day (applying different usage scenarios) (in kWh)

Figure 7 shows the total amount of energy consumption per day as single value per scenario, derived from Figure 6. If one assumes that the system is shut to LowPower mode for 12 hours during nights, the total energy consumption per day is only about 49 kWh (see Figure 4) instead of 72 kWh when the system always runs.

Figure 8 shows the reduction potential of the scenarios 4h LowPower mode, 8h LowPower mode and 12 h LowPower mode compared to the scenario 0h LowPower mode.

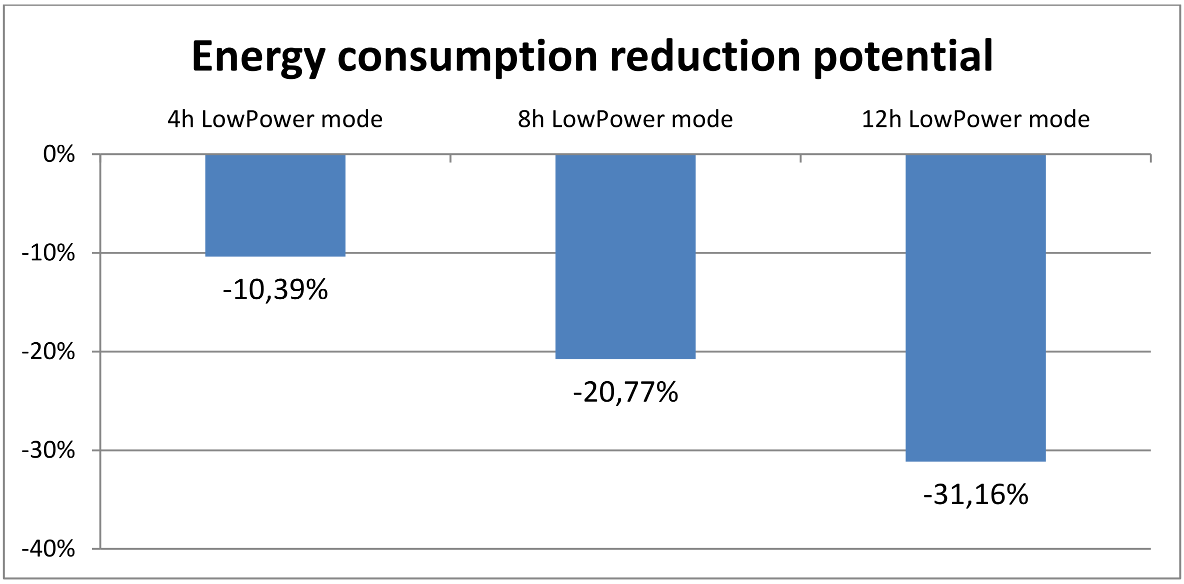

Figure 8: Power consumption reduction potential

Due to the uncertainty and gap of knowledge how much time a CT is realistically in LowPower mode the baseline or reference scenario is not definable. The only option to quantify the savings is by giving scenarios. Basis of these reduction potential calculations is the 24 hours day where the CT system is never switched to LowPower mode. Depending on the user scenario, in which the system is switched to LowPower power for 4 hours, 8 hours or even 12 hours, the average energy consumption reduction potential of all investigated CT products rises from 10 % (4h LowPower mode) to 31 % (12h LowPower mode). In other words, after about 6 hours LowPower mode within 24 hours the improvement potential is almost as high as all theoretical, technical measures together and applied to a scenario of 12 hours LowPower, which seems far away from true use reality. That means, the highest reduction potential from today perspective is to enable or motivate LowPower mode as often as possible.

Based on this, PE INTERNATIONAL recommends increasing the client information on the environmental effects of their use behaviour following to Article 14 of the ErP Directive (EU Directive 2009/125/EG). Information can have an influence on the energy consumption if people change their use behaviour and shut down the system while not needed (change from Idle mode to LowPower mode).

In order to emphasize the order of magnitude of the measure to inform and motivate users compared to potential technical improvements, Figure 9 shows again the maximal possible reductions per mode. As a consequence, once LowPower mode application is ensured and better data show true percentages of times of which CTs are in LowPower mode, it makes sense to commit to effort related technical improvement, that again give a further reduction the more LowPower mode time the product CT will face.

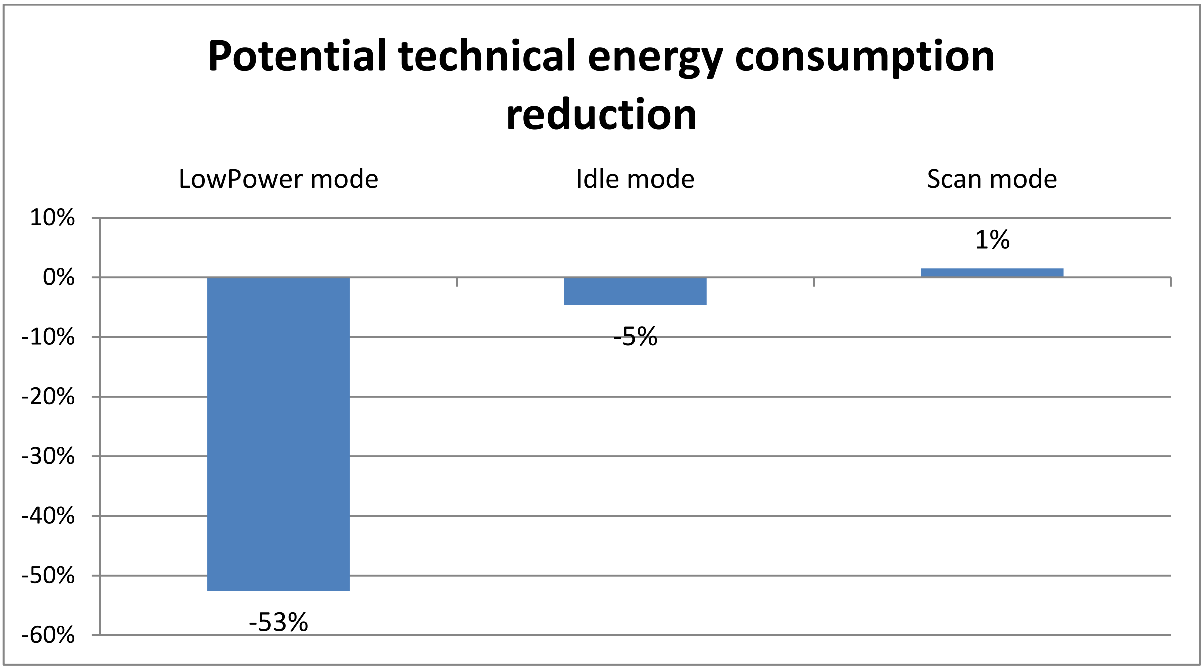

Figure 9: Potential technical energy consumption reduction

6.3.1 Summary of the Findings

CTs typically come with three different modes that all consume energy: LowPower mode, Idle mode and Scan mode.

Off mode does not consume energy and therefore as not been included in this study. Savings obtained by switching the scanner in Off mode are obviously higher. This mode is less likely to be used by users due to the time required, in most cases, to bring the scanner to Idle mode. More details are presented in the COCIR SRI Report on Computer tomography and in the SRI Status Report 2012.

As a standard theoretic use case and as basic for their measurements the COCIR member companies agreed on a standard theoretic use day where the system is switched to LowPower mode during night for 12 hours. Assuming this as a basic scenario the technical improvements lead to around 16% reduction of total energy consumption per day as maximum. The improvements in LowPower mode are about 53%, but these improvements are already on a relatively low consumption value and its reduction does not significantly influence the total day. This becomes even less effective considering the LowPower mode not to be applied.

Assuming that the LowPower mode is never used and instead of this the Idle mode is applicable the entire night time (12h) a significant saving potential comes from switching from Idle mode into LowPower mode.

Unfortunately there's no reliable information on the usage available yet therefore a basic case that reflects the real usage behaviour of the CTs can't be measured and calculated at this stage. Therefore in this product group of CTs, the calculation for the SRI is based on theoretic usage scenarios. Based on the aim to increase the use of LowPower mode, the SRI should focus on an educational advertising or intensive information policy for the

CT manufacturers' clients on the best available use behaviour. For example the suppliers inform their clients about the possibility and advantages to switch off the CT. This information policy is according to Article 14 of the ErP (EU Directive 2009/125/EG).

Defining a quantitative target requires survey data on user behaviour to identify the average standard use day that can be used as baseline as well as motivating the clients for a change of their user behaviour

Therefore this study can be seen as starting point for future surveys and evaluations and is also basis for the highest achievable result, which means to enforce the customers to a change of their use behaviour and therefore increase the impact on energy consumption.