AUSTRIAN ENERGY AGENCY

Energy Audits for Motor Driven Systems

Part 1, Overview of Programmes, Tools, Guides and Analysis of Standards and Protocols for Motor Systems Audits

Working Document

INTERIM REPORT

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IEA FORSCHUNGS KOOPERATION

Further information on EMSA is available at:
www.motorsystems.org

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Abstract

This Working Document summarises the results of the first two sub-tasks of the task “Energy Audits for Motor Systems”. This task is performed by the Austrian Energy Agency within the Electric Motor Systems Annex (EMSA) in light of the IEA Technology Collaboration Programme on Energy Efficient End Use Equipment (4E).

The goal of these two sub-tasks was to collect already existing requirements for energy audits in motor driven systems and information to be considered or to be referred to during an energy audit in this field. This information is the basis for the development of the energy audit methodology for motor driven systems in subtask 3 in 2016-2017.

Energy audits should be recognised as important as Minimum Energy Performance Standards for increasing the efficiency of motor driven systems.

An energy audit is a systematic analysis of energy consumption within a defined system in order to evaluate opportunities for improved energy performance. It is therefore potentially an effective instrument to detect optimisation potentials for existing motor systems running on-site. Especially over-sized equipment, equipment without control, wrong control strategy, leakages, old equipment, and inappropriate use and running time can be detected during an audit. The savings potential in this area lies on average between 20-30%.

This task will therefore give a systematic and comprehensive overview on how to use available standards and tools for a motor system audit considering all information available. This will help energy auditors to detect and calculate the most important energy saving potentials in these systems by considering all relevant standards.

This study provides a very comprehensive overview in a selection of countries where energy audits are mandatory or voluntary and which standard already sets requirements for energy auditing in motor driven systems.

In Denmark, Netherlands and Austria, big companies are obliged to conduct energy audits, while in Japan, big energy consumers have certain energy saving targets to reach and report on their energy consumption. In Denmark, Netherlands, Switzerland and the US, energy audits are embedded in Voluntary Agreements. Austria, Denmark, Japan, (partly Netherlands) and the United States have subsidy programmes for energy audits in small and medium-sized enterprises. Switzerland has a subsidy programme for motor specific energy audits.

The analysis of the standards shows that for energy audits in motor driven systems, all requirements of the ISO 50002, which contains a lot of general information, are relevant.

Furthermore, a lot of different standards and protocols consider motor driven systems already as major energy users and two standards concentrate on two different motor driven systems, compressed air and pumping systems. For most of the different audit steps, ranging from audit planning to data acquisition and analysis and audit reporting specific information and requirements for motor driven systems is available, either in form of tools, guidelines, or standards.

In general, the energy audit standards analysed, lack the following information:

- Parameters for the first evaluation of energy saving measures (pre-screening)
- Criteria for implementation of energy saving measures
- Calculation formulas for assessing the energy benefit of the implementation of certain energy saving measures (exception is the annex of ISO 14414)

Performance measurement protocols and guides already include motor driven systems as examples or have already specific guidelines for calculation of saving measures in this field.

In the next project phase, this Working Document will serve as basis for the development of the energy audit methodology. This document will be structured along the stages of an energy audit according to ISO 50002 and will include organisational and technical tasks to be performed during the audit. For each step it will refer to the relevant standards, guides and tools.

In addition, it will include the following information:

- Technology-specific key indicators for the recommendations of energy saving measures
- Saving calculation methods in accordance with international protocols

Contents

1 Introduction

This report was prepared within the task “Energy Audits for Motor Systems” of the Electric Motor Systems Annex within the IEA Technology Collaboration Programme on Energy Efficient End Use Equipment (4E) by the Austrian Energy Agency, as leader of this task.

The target of the task “Energy Audits for Motor Systems” is threefold: to give an overview on legal and financial incentives for conducting energy audits, to perform an analysis of existing standards on energy audits and the uptake of motor systems within these standards and finally, give recommendations how to perform energy audits for motor driven systems using tools from the EMSA group with a special reference to international standards in this field.

This work is divided into the three sub-tasks: exchange of experience, analysis of documents and development of an audit methodology.

Why are energy audits important and should be recognised as important as Minimum Energy Performance Standards for increasing the efficiency of motor driven systems?

Energy Audits are an excellent instrument to detect optimisation potentials for existing motor systems running on-site. Especially over-sized equipment, equipment without control, wrong control strategy, leakages, old equipment and inappropriate use and running time can be detected during an audit. The savings potential in this area lies on average between 20-30%.

Furthermore, policy makers already identified energy audits as important instruments to reach climate and energy efficiency targets: The energy efficiency directive of the European Union (published in 2012) foresees regular mandatory energy audits for large enterprises* (see table 1). The first audit had to be performed between 4.12.2012 – 5.12.2015.

But also standard organisations worldwide developed energy audit standards during the last years:

- On international level, the ISO 50002 Energy Audits – Requirements with guidance for use, ISO 11011 Compressed air – Energy efficiency – Assessment, ISO 14414 Pump system energy assessment
- In Europe, the EN 16247 series, with audit standards for (industrial) processes and qualification of energy audits
- In the US: ASME EA-2 – Energy Assessment for Pumping Systems, ASME EA-3 – Energy Assessment for Steam Systems, ASME EA-4 – Assessment for Compressed Air Systems

Therefore, energy audits should be used as an instrument to increase the efficiency of motor driven systems on a broader scale. The target of this task is to screen legal and normative requirements for conducting energy audits, develop an energy audit methodology coherent to most important international standards and to outline how already developed tools can help to fulfil the requirements of these standards. This will help energy auditors to detect and calculate the most important energy saving potentials in these systems by considering all relevant standards.

This document is a Working Document summarising the first two sub-tasks:

- Analysis of national programmes and initiatives concerning energy audit, qualification schemes, tools and guides for audits in motor driven systems
- Analysis of standards and protocols for conducting energy audits and the determination of energy performance

Sub task 3 will be performed in 2016-2017 and concluded with a final report including the results of all three subtasks.

Short Overview of the report

Chapter 1 is the introduction.

Chapter 2 summarises the results of sub-task 1, the exchange of experience on energy audit programmes and tools in different countries.

Chapter 3 presents the results of the analysis of existing standards on energy audits and calculation of energy performance. It includes mainly standards on ISO-level but also other international protocols.

In chapter 4, the European Motor Challenge Programme documents are analysed briefly.

Chapter 5 looks at the differences between general audit standards and motor specific audit standards (ISO 11011, ISO 14414).

Chapter 6 summarises the results of the analysis.

Finally, chapter 7 derives some conclusions and gives an outlook on sub-task 3 which focuses on the development of the audit methodology.

2 Energy Audit programmes: qualification, guides, tools

2.1 Aim

In the task “Energy Audits for Motor Systems”, current developments in the implementation of legal and financial incentives for energy audits in EMSA countries & Japan will be summarised and analysed. Furthermore, recommendations on how to perform energy audits in motor driven systems using tools from the EMSA group will be developed with a special reference to international standards in this field.

As a first step of this task information on the implementation of energy audit programmes in different countries was collected and analysed. The focus laid primarily on motor driven systems, but sometimes only general information was available.

2.2 Methodology

For the analysis of the audit programmes/countries, the following points were analysed:

- Available energy audit programmes and incentives
- Standards or requirements for competence of energy auditors (e.g. certification process)
- Trainings available for energy auditors
- Exchange on tools and guidelines for energy audits in motor driven systems

The information was collected by desk and internet research, consultation of project partners and experts as well as during EMSA meetings and conferences.

The summary of available guidelines for the optimisation of motor driven systems builds on work already done in previous phases of EMSA and includes some guidelines published in other countries (Canada, UK and Europe).

The next chapter will analyse standards for energy audits (general and/or in motor driven systems) in detail, thus those standards are not mentioned in this chapter.

2.3 Country overview on audit programmes and auditors qualification

Table 1 shows information on the implementation of energy audit programmes in the EMSA member countries & Japan. It shows the size of companies covered by the programme, incentives for energy audits, required qualification of the energy auditors and available training courses.

During the analysis, several countries reported on incentives for the implementation of energy saving measures. As this topic was not the primary goal of this study, this information is provided in the Appendix.

Table 1: Results of analysis on energy audit programs, auditor-qualification requirements and trainings for EMSA countries plus Japan

	Energy Audit Support Mechanism/Programmes/Regulation	Energy Auditors Qualification	Trainings	Tools
Australia	• Energy Efficiency Opportunities Programme (EEO), closed in 2014: Mandatory assessing and reporting on energy use was mandatory for corporations with energy consumption of > 0.5 PJ • In 2012, the program introduced voluntary participation for medium-energy users	• A research identified 33 functional skills for energy efficiency assessment		• EEO Assessment Handbook (170 pages) • Further material: NSW M&V Guidelines • EEO Opportunities Register • Representative Assessment Guide
Austria	• Mandatory energy audits for big companies acc. to Energy Efficiency Directive (EED)* • Voluntary energy audit programs: regional subsidised programs	• Listed auditors for audits acc. to EED* • Qualification defined on basis of education, trainings, experience • Different qualification requirements for auditors of subsidised programs	• EUREM Course (European Energy Manager) • klimaaktiv workshops for pumps, fans, compressed air, cooling systems	• ProTool for first evaluation, klimaaktiv audit guides (pumps, fans, compressed air, cooling systems) • Guideline for Motor Efficiency • Brochure for motor systems • Best practice collection for motor systems optimisation • Audit report template acc. to law on energy efficiency
Denmark	• Mandatory energy audits for big companies acc. to EED* • Energy Saving Obligation Scheme (for Energy Utilities) provides energy audits • Renewable energy for production process (subsidy for energy audits and implementation in SMEs) • Voluntary Agreements	• Experts employed by accredited enterprise to organise energy audits in accordance to international standards • Requirements to become registered energy consultant defined: education, experience • Registered energy		• Blue Books on System Optimisation • EMSA Tool

	Energy Audit Support Mechanism/Programmes/Regulation	Energy Auditors Qualification	Trainings	Tools
	(reimbursement of public service obligation tariff) with the following elements: implementation ISO 50001, conduct special investigations, implement EE projects	consultant (registered by Energy Agency) • Energy consultant for energy labelling		
Japan	• Energy Conservation Law: obligation for business with energy consumption of > 1,500 kl oil equiv.: appointment of an energy manager, periodically report on energy consumption status, submit medium and long term plans, reduction efforts of 1% p.a. (energy manager conducts periodically audits) • ECCJ (Energy Conservation Centre), funded by Japanese gov.: Voluntary energy audit programme for SMEs (free audits, voluntary improvement, confirmation of effect)	• Qualification and experience defined, examination, certificate (depending on annual energy consumption and sector): • Energy manager license • Energy manager seminar	• EMAK Workshops (Energy Management Action Network) • ECCJ Training course for rational use of motors and equipment	• Guidelines for rational use for equipment (based on Energy conservation law): maintenance, allocation of persons in charge; for HVAC system: operational management (operating time, set temperature), periodical measurement and recording of temperature…
Netherlands	• LTA3, MEE (Long-term Agreements for Non-ETS and ETS on energy efficiency): four year energy efficiency plans, annual report on measures, results; these companies are exempted for conducting mandatory energy audits (acc. to EED) • Green Deal (not directly for audits) • Mandatory Energy Audits for	• Mandatory audits: Report content is defined (EED Annex VI plus factors influencing energy consumption) • Certificates or specific education is not formally required • The competence of the auditor is being checked (indirectly) by the	• Workshops • Users groups on energy management and monitoring	• Knowledge network motor systems • Quickscan on motor systems • Best practices motor systems, compressed air, cooling systems, ventilation systems, pump systems • Brochure motor systems

	Energy Audit Support Mechanism/Programmes/Regulation	Energy Auditors Qualification	Trainings	Tools
	large energy users not part of LTA3/MEE (EED)* • Local regional programmes offering advice	company that hires the auditor and via the audit report that in the end is checked by the competent authority.		
Switzerland	• Target-Agreements (TA) for companies to save electricity (average target - minus two percent) (act energy): target agreement, energy-check up, implementation of saving measures, monitoring and reporting; • TA are also the basis for reduction of CO_2-tax and grid utilisation charge (depending on electricity costs as share of production costs)	• EnAW: Criteria defined; technical education (university degree or similar), eidg. Energie- und Effizienzberater, oral exam (incl. further training necessities) • Act energy specialist: Criteria defined; technical education (university degree or similar), working experience, reference projects, accreditation process: oral exam	• eidg. Energie-Effizienzberater (incl. motor systems) • University Luzern/Topmotor s Industrial energy optimisation • Top Motors Workshops • One day seminar: efficient drives (WERZ) • act-Seminar compressed air	• topmotors programme: Tip sheets for efficiency in motor driven systems • Energie Schweiz campgaign: e.g. compressed air-, cooling systems • Topmotors Tools: SOTEA, ILI+, STR • EnAW Checkup-Software 300 standard measures for cross-sectional technologies, incl. ventilation, cooling, compressed air
United States	• Technical Assistance Programs: • Better Plants Program: Sign a voluntary agreement to reduce energy intensity by 25% over ten years organisation-wide, develop energy use baseline, annual reports • Former Save Energy Now LEADERS Program (Free and cost-shared audits) offered three days audit for companies with of	• AEE: Certified Energy Auditor (CEA) • AEE: Certified Energy Auditor Master-Class • Qualified specialists in Industrial Assessment Tools	• AEE's preparatory CEA training seminars • Two and a half days workshop for use of Industrial Assessment Tools • Free one day workshops (e.g.	• Motor Master+ • AirMaster+ • Pumping System Assessment Tool • Fan System Assessment Tool • Chilled Water System Analysis Tool • Motor Decision Matters Tools • Guidebooks/Tip Sheets for EE for

Energy Audit Support Mechanism/Programmes/Regulation	Energy Auditors Qualification	Trainings	Tools
> 500 BTU/year primary energy consumption (approx. 150 GWh) • IAC-(Industrial Assessment Centres, university based) Audits for SMEs (e.g. below 500 employees, energy bill 100,000-2.5 Mio USD): One or two days assessment; free of charge; • Superior Energy Performance concentrates on ISO 50001 certification		compressed air) ○ http://www.industrialee.org/	Fans, Pumps, Compressed Air, Motors • Energy Management for Motor Driven Systems

*Definition of big companies in European Energy Efficiency-Directive (EED): A company with at least 250 full-time employees or an annual turnover of at least EUR 50m and an annual balance of at least EUR 43m calculated according to annual financial statements.

Sources:

- Austria: http://www.monitoringstelle.at/index.php?id=685; http://www.klimaaktiv.at/energiesparen/schulungen.html; http://www.klimaaktiv.at/energiesparen/betriebe_prozesse/beratung_foerderung/beratungsleist_bdld.html; http://www.klimaaktiv.at/energiesparen/betriebe_prozesse/technologieschwerpunkte.html;

- Australia: http://eex.gov.au/energy-management/energy-efficiency-opportunities/; http://eex.gov.au/energy-management/energy-efficiency-opportunities/resources-energy-efficiency-opportunities-program/;

- Denmark: European Commission: A Study on Energy Efficiency in Enterprises: Energy Audits and Energy Management Systems, European Union 2016; Order on mandatory energy audits for large enterprises

- Japan: http://www.asiaeec-col.eccj.or.jp/sector/com-resident/eneauditprog.pdf; http://www.eccj.or.jp/education/index.html; http://www.asiaeec-col.eccj.or.jp/law/pdf_fac_e/g-1.pdf; presentation: Energy Management Regulation & ESCO Industry Update in Japan, Nov. 2015 (Tetsuya Maekawa, JAESCO); personal communication: Tohru Shimizu, IEEJ

- Netherlands: European Commission: A Study on Energy Efficiency in Enterprises: Energy Audits and Energy Management Systems, European Union 2016; personal communication: Maarten van Werkhoven (TPA advisors); Ronald Vermeeren (RVO)

- •Switzerland: Flyer act Energiespezialist www.act-schweiz.ch/de-wAssets/.../act_Flyer_Energiespezialist_web.pdf, act formular Akkreditierung; http://www.act-schweiz.ch/de/praxis/beraterliste.php; Information: Akkreditierung von KMU-Beratern der EnAW, Jan 2015; topmotors.ch; https://www.energieschweiz.ch/unternehmen/stromeffizienz/effiziente-kaelte.aspx ; https://www.energieschweiz.ch/unternehmen/stromeffizienz/effiziente-druckluft.aspx; personal communication: Marton Varga (act-energy), Armin Eberle (CEO, EnAW); Rita Werle (impact energy)

- United States: IAC: http://energy.gov/eere/amo/industrial-assessment-centers-iacs; Better plants: http://energy.gov/eere/amo/better-plants; CEA, CEAM: http://www.aeecenter.org/i4a/pages/index.cfm?pageid=4552; http://www.aeecenter.org/i4a/pages/index.cfm?pageid=4096

2.4 Summary of energy audit programmes

In the EU-countries covered by this analysis (Denmark, Netherlands & Austria), energy audits are mandatory for big companies according to the Energy Efficiency Directive. In Japan, organisations with big energy consumption have to prove reduction efforts, report their energy consumption and appoint an energy manager. In Australia, (until 2014) big companies had to assess and report their energy use.

In Denmark, Netherlands, Switzerland and the United States, energy audits are embedded in Voluntary Agreements. When joining, companies are obliged to set and fulfil certain targets and (to some extent), conduct energy audits.

Austria, Denmark, Japan, (partly Netherlands) and the United States have subsidy programmes for energy audits in small and medium sized enterprises. Switzerland has a programme for motor specific energy audits.

In most countries, the qualification of energy auditors is specified.

In Austria (klimaaktiv guidelines and best case database), Denmark (bluebooks, EMSA tool), United States (Industrial Assessment tools), Switzerland (Energie Schweiz campaigns, topmotors tools,) and the Netherlands (Quickscan, best practices, brochure), motor specific tools for supporting energy auditors were developed and in most cases, regular trainings are organised for using these tools.

In Austria, Switzerland and the US motor systems are part or the main focus of awareness raising campaigns or programmes.

In Japan legal requirements are set for the maintenance and operation of certain motor driven systems.

2.5 Overview on Tools and Guides

In the Appendix, an overview is given of guides and tools for the optimisation of the different motor driven systems identified during this project.

3 Analysis of Energy Audit Documents

3.1 Aim

For developing an energy audit methodology for motor driven systems, existing standards in this field have to be analysed in order to see if they already stipulate requirements in this field.

This chapter analyses existing energy audit standards and standards and guidelines for the measurement of energy savings.

The standards were chosen according to the following criteria:

- International standards for energy audits for companies and/or motor driven systems (ISO and/or European level).
- International standards and protocols for the measurement of energy performance.
- In addition, if more specific information with high relevance for motor driven systems was available on national level, such documents were included in the analysis.

The above mentioned ASME standards for energy audits in pumping and compressed air systems were not analysed as they formed the basis for motor specific ISO standards which were included in this study.

All documents were analysed according to a uniform structure and each chapter highlights the relevance of the document for audits in motor driven systems.

3.2 Methodology

In the following chapters, relevant standards (ISO 50002, EN 16247 – Series) are analysed and relevant aspects that have to be considered for auditing of motor systems specified.

For each standard, the following details were analysed:

- Main target of standard
- Selected, main terms defined, relevant for evaluation of “energy systems”
- Content relevant for auditing and metering of motor driven systems
- Are motor driven systems mentioned explicitly?
- Examples for auditing, metering and calculation of energy savings (e.g. in motor driven systems)
- Main relevance for auditing motor driven systems

The following standards and guidelines were analysed:

Table 2: List of standards analysed

International Standard	Name of standard	Content relevant for Auditing and Metering Main Relevance for Motor Driven Systems	Motor Driven Systems mentioned explicitly?
Energy Audit standards			
ISO 50002	Energy Audits – Requirements with guidance for use	Defines the process of energy auditing	Yes (as an example)
EN 16247-1	Energy audits - Part 1: General requirements	Very similar to ISO 50002, therefore not analysed in detail	
EN 16247-2	Energy audits - Part 2: Buildings	No, not analysed further Motor systems (except HVAC systems) are not mentioned in detail	No
EN 16247-3	Energy audits - Part 3: Processes	Defines the process of energy auditing in production companies, gives details on how to collect data, analyses them and gives examples of energy saving measures	Yes
EN 16247-5	Energy audits – Part 5: Competence of energy auditors	Specifies the requirements on the competence of energy auditors	Yes
ISO 11011	Compressed air -- Energy efficiency -- Assessment	Specifies requirements for conducting a compressed air energy efficiency assessment	Yes
ISO 14414	Pump system energy assessment	Specifies requirements for conducting a pumping system energy efficiency assessment	
ISO 50006	Energy management systems – Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance	Describes the process of calculating the energy performance with Energy performance indicators (EnPI) and gives examples of EnPI (also for motor driven systems)	Yes
ISO 50015	Energy management systems – Measurement and verification of energy performance of organisations – General principles and guidance	Describes the elements of an Measurement and Verification Plan, esp. relevant for measurement of energy saving measures	No
Metering Protocols			
IPMVP	International Performance Measurement and Verification Protocol	Gives the methodology of how to calculate energy savings with examples of motor driven systems (pump, fan, compressed air) based on measurements	Yes

International Standard	Name of standard	Content relevant for Auditing and Metering Main Relevance for Motor Driven Systems	Motor Driven Systems mentioned explicitly?
FEMP M&V Guidelines 3.0		Contains guidelines for quantifying the savings resulting from energy efficiency equipment implemented through federal energy savings performance contracts, e.g. • Constant Speed Motors • Variable Speed Motors • Chillers	Yes
NSW Measurement and Verification Operational Guide	NSW Measurement and Verification Operational Guide	Describes the process of measuring energy savings, with detailed further operational guides for motor driven systems (e.g. pumping systems, compressed air, cooling systems), incl. variables to be considered	Yes

3.3 ISO 50002 Energy Audits –Requirements with guidance for use

The standard ISO 50002 Energy Audits-process requirements published in 2014 is the first (worldwide) international standard on energy audits and is therefore analysed here in detail.

3.3.1 Main Target of Standard

This standard specifies the process requirement for carrying out an energy audit. The energy audit process consists of the following stages:

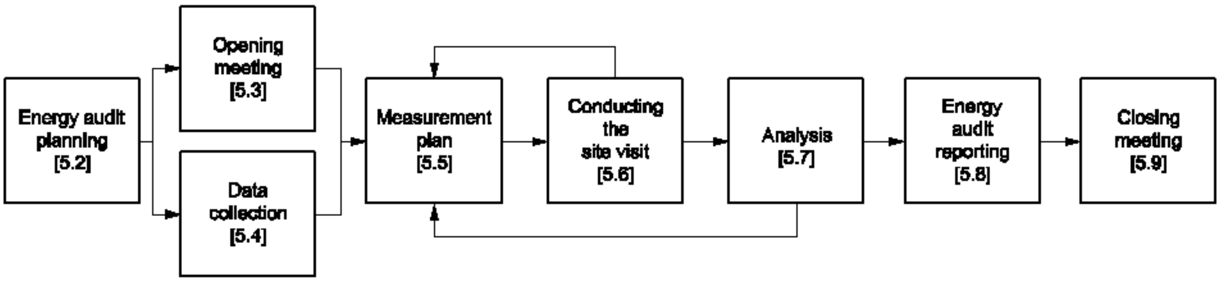

Figure 1: Energy audit process flow diagram (ISO 50002:2014)

Annex A.1 specifies that the applicability and use of this International Standard and individual requirements will be dependent upon a number of factors, e.g. purpose of the audit, energy costs and reduction opportunities. This means that for smaller companies and/or motor driven systems with low energy consumption, it is not recommended to follow the entire audit process.

3.3.2 Selected, main Terms defined, relevant for Evaluation of “Energy Systems”

The term “energy audit” refers to “systematic analysis of energy use and energy consumption within a defined energy audit scope, in order to identify, quantify and report on the opportunities for improved energy performance.”

“Energy Performance” is defined as “measurable results related to energy efficiency (3.8), energy use and energy consumption. ISO 50006 specifies this term further: “results can be expressed in units of consumption (kWh), specific energy consumption (SEC, kWh/unit), and peak power (kW)”.

“Energy Performance Indicator” is defined as quantitative value or measure of energy performance, as defined by the organisation.

The term “relevant variable” is defined as “quantifiable parameter impacting energy consumption”. Examples include ambient weather indicators, operating parameters (indoor temperature, light level) working hours, production throughput.

3.3.3 Content relevant for Auditing and Metering of Motor Driven Systems

In the beginning it is mentioned that "the measurements and observations are appropriate to the energy uses and consumption."

Examples of organisational issues to be considered during the energy audit planning:

- Agreement between the energy auditor and the organisation on the energy audit scope, boundaries and objectives
- Information of the organisation of commercial or other interest of the energy auditor which could influence the conclusions or recommendations derived from the energy audit

During the opening meeting, the following issues should be considered (among others):

- Confirmation of unusual conditions that may affect the energy audit or energy performance (as examples are mentioned maintenance work, significant changes in production)
- Requirements for any special measurements, if needed
- Procedures to be followed for installation of measuring equipment, if needed

For data collection, the auditor should collect (among others):

- A list of energy consuming systems, processes and equipment
- Detailed characteristics of the energy uses within the defined scope
- Historical and current energy performance data (energy consumption, relevant variables, related measurements)
- Monitoring equipment
- Design, operation and maintenance documents (drawings, control system data)

The measurement plan should include the following items:

- List of current and identification of additional measurement points
- Accuracy and repeatability required for measurement
- Measurement duration, frequency
- Representative time period
- Relevant variables to be provided
- Responsibilities
- Calibration of equipment

There are three important stages during the implementation of the measurement plan, which are mentioned in Annex A7:

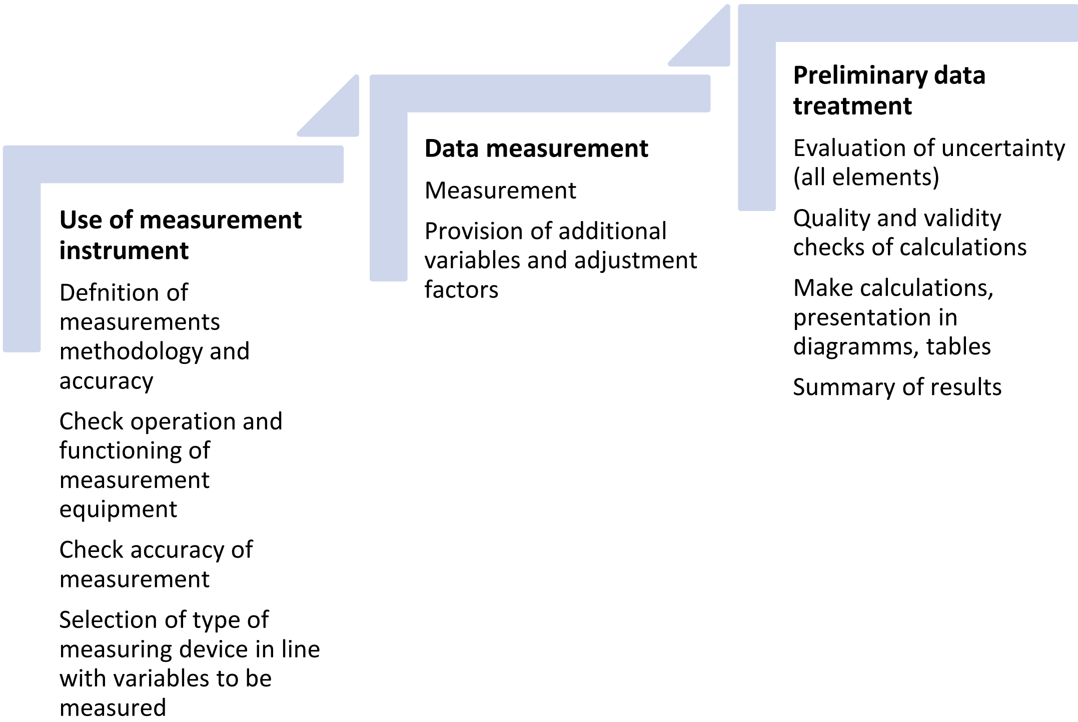

Figure 2: Stages of the development and implementation of a measurement plan

The site visit should include for example:

- Evaluation of the energy use and consumption according to the energy audit scope, boundary, objectives
- Understanding operating routines and user behaviour and their influence
- Generation of preliminary ideas
- List of areas and processes for which additional data is needed for later analysis
- Ensure that measurements, observations and past data are representative of operational practices (day, night, evening, weekend, seasonal differences)
- Installation of data loggers and energy monitoring equipment

During data analysis, the methods used and assumptions made should be documented. Furthermore, the variables that affect measurement uncertainty and their contribution to the results should be taken in account.

When evaluating current energy performance, the following points should be considered:

- Compare energy uses with high energy consumption with reference values
- Analyse historical patterns of energy performance
- Evaluate expected improvements
- Relate energy performance and relevant variables (where appropriate)
- Evaluate existing EnPI, propose for new one

The following aspects should be analysed when identifying opportunities:

- Evaluate design and configuration options to address system needs
- Operating lifetime, condition, operation and level of maintenance of the audited objects
- Existing technology in comparison to most efficient on market, operational control and behaviours

For each opportunity, energy and financial savings, investments, agreed economic and other criteria, non-energy gains, ranking of opportunities and finally, potential interaction should be analysed.

The chapter energy reporting includes the identification of the relevant measurements made during the energy audit including details as frequency, consistency, rationale for measurements, difficulties encountered during the audit and measurement uncertainty.

Furthermore, the energy audit report content is stipulated.

3.3.4 Motor Driven Systems mentioned explicitly?

“Motors” are not mentioned but, as an example of historical energy performance data “compressed air survey” is given. Furthermore in the Annex, compressed air system audit is mentioned as an example of a type 3 audit (which is a comprehensive energy audit).

3.3.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

There are no examples for metering or calculation given in this standard (incl. Annexes).

3.3.6 Main Relevance for Auditing Motor Driven Systems

The main information to be provided during an energy audit for motor driven systems is:

During data collection:

- A list of energy consuming systems, processes and equipment
- Detailed characteristics of the energy uses, incl. energy performance data
- Monitoring equipment
- Design, operation and maintenance documents

For measurement:

- Definition of relevant variables
- Data measurement plan specifies how data measurement has to be done (incl. determination of uncertainty)
- Ensure that measurements, observations and past data are representative of operational practices (day, night, evening, weekend, seasonal differences)

For evaluating current energy performance and identifying opportunities:

- Evaluate design and configuration options to address system needs
- Operating lifetime, condition, operation and level of maintenance of the audited objects
- Existing technology in comparison to most efficient on market, BAT operational control and behaviours

3.4 EN 16247-3 Processes

EN 16247-1 is not analysed here, as the ISO 50002 was developed on basis of EN 16247-1 and therefore both standards are very similar.

3.4.1 Main Target of Standard, Scope

This European standard specifies the requirements, methodology and deliverables of an energy audit within a process. It applies to sites where the energy use is due to processes, e.g. production lines, offices, laboratories, research centres, packaging and warehouses. The standard has to be applied together with: EN 16247-1, Energy audits - Part 1: General requirements.

3.4.2 Selected, main Terms defined, relevant for Evaluation of "Energy Systems"

A "utility process" is defined as a set of utility equipment and distribution, e.g. motor driven systems (fans, pumps, motors, compressors, etc.).

3.4.3 Content relevant for Auditing and Metering of Motor Driven Systems

This standard specifies some points in addition to EN 16247-1, therefore for certain elements only some additional information is given:

During the start-up meeting, energy performance indicators have to be agreed.

When collecting data, the auditor should collect information on- site, utility, production processes and energy sources. During the preliminary data analysis, he/she should develop an energy balance and establish adjustment and energy performance indicators. For the measurement plan, objectives, parameters, content as well as required measurement conditions should be defined.

The aim of the field work is among others:

- To confirm the current operational conditions (set points) of utilities and the impact with energy use and consumption
- To collect relevant information from identification plates, runtime information, interviews with operators, etc.

During the analysis, the energy auditor shall investigate the maximum achievable energy performance of the process and benchmark it with the actual energy performance. Furthermore he/she will compare the sizing of the process and the energy needs and evaluate the optimal quantity of energy and utilities for the process.

When identifying opportunities, the following measures should be considered:

- Measures in order to reduce or to recover the energy losses; (e.g. reduction of leakage of compressed air, waste heat recovery);
- Replacement, modification or addition of equipment (e.g. variable speed motor);
- More efficient operation and continual optimisation (e.g. set point adjustment, maintaining);
- Behavioural change and improvement of energy management (e.g. metering).

3.4.4 Motor Driven Systems mentioned explicitly?

Yes, as an example for a utility process.

3.4.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

In the Annex B of EN 16247-3, examples of parameters to be collected are given. In Appendix 2 of this report the parameters for motor systems are listed.

3.4.6 Main Relevance for Auditing Motor Driven Systems

For audits in motor driven systems, the main requirements are

- collecting operational conditions of utilities, information from name plates, runtime information
- interviews with operators
- consideration of sizing of processes
- establishment of energy performance indicators.

Furthermore, examples of different energy efficiency opportunities are explicitly mentioned in the standard (e.g. leakage reduction in compressed air systems, installation of variable speed motors).

3.5 EN 16247-5 Energy audits, Part 5: Competence of energy auditors

3.5.1 Main Target of Standard, Scope

This European standard specifies the requirements on the competence of energy auditors (a combination of trainings, skills and experience).

3.5.2 Selected, main Terms defined, relevant for Evaluation of “Energy Systems”

The following terms are defined: training, skill, experience, and competence.

3.5.3 Content relevant for Auditing and Metering of Motor Driven Systems

Concerning **personal attributes**, the auditor shall have communication skills to communicate with technical and non-technical persons at various levels of the organisation. The auditor should also have, among others, the capacity for observation, measurement and analysis.

Furthermore, he/she should act in an impartial and objective manner.

Concerning **knowledge and skills**, the auditor should apply the methodologies described in the other audit standards of the EN 16247 series.

He/she shall have knowledge on different aspects relevant for the auditing of motor driven systems e.g. on: tariff and tariff structure, physical principles related to energy (electrical, fluid mechanics etc.), metering and measuring equipment, measuring plan, analysis methods (Sankey diagram, regression analysis), knowledge on energy efficiency improvement opportunities, calculation of energy performance (indicators), calculation methods of energy savings, financial assessments (payback period, NPV, ROI).

The energy auditor shall demonstrate suitable education (e.g. technical science), work experience and training (e.g. HVAC, industrial processes).

3.5.4 Motor Driven Systems mentioned explicitly?

Yes, HVAC, as an example of training.

3.5.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

No, but calculation methods are mentioned (on a general level) in the context within the calculation of the energy performance and for energy savings.

3.5.6 Main Relevance for Auditing Motor Driven Systems

For audits in motor driven systems, the main requirements are: the possibility to make a measurement plan, make measurements and analyse them, the knowledge on energy efficiency improvement opportunities and the calculation of energy performance indicators. Furthermore, in addition to appropriate education and experience, the auditor shall update technical knowledge from technology specific professional training, e.g. HVAC.

3.6 ISO 11011 - Compressed air – Energy efficiency - Assessment

3.6.1 Main Target of Standard

The target of this standard sets requirements for conducting and reporting the results of a compressed air system assessment that considers the entire system, from energy inputs to the work performed as the result of these inputs.

The system consists of three subsystems:

- Supply
- Transmission
- Demand, including all compressed air consumers (applications, waste)

3.6.2 Selected, main Terms defined, relevant for Evaluation of “Energy Systems”

This standard gives a comprehensive list of a lot of terms, e.g. different flow and pressure terms.

3.6.3 Content relevant for Auditing and Metering of Motor Driven Systems

The audit comprises the following process steps:

Table 3: Summary of the main requirements of ISO 11011

Sub-section of the standard	Main requirements
Roles and responsibilities	• Identification of assessment and team members, site management support, communications, access to equipment, assessment objectives and objective check.
Initial data collection and evaluation	• General • Plant background, function, system definition, inventory of key end-use air demand, heat recovery • Baseline period and duration of data logging (for typical operation, required for measurement of power, pressure, flow and temperature and different operating conditions) • Energy use (incl. annualised estimated base-year energy use and cost) • Document system volume, pressure profile, flow rate • Compressed air waste (leakage, inappropriate use) • Air treatment • Compressor control • Storage • Maintenance
Analysis of data from assessment	In this part further details are given how to analyse the following elements: • Baseline profiles (power, demand, supply efficiency) • System volume, pressure profile (incl. pressure loss) • High pressure air demand • Demand profile • Critical air demand • Compressed air waste • Air treatment • Reduced pressure • Balance of supply and demand (control strategy) • Maintenance opportunities
Reporting and documentation	• Content of assessment report is given

3.6.4 Motor Driven Systems mentioned explicitly?

The whole standard is on energy assessment of compressed air system.

3.6.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

In the Annex, pressure, flow and electrical test points are identified for the different parts of the system (supply, transmission, demand).

Furthermore, tables for data collection for all elements of a compressed system - air supply, transmission and demand - are given in Annex C, D and E:

Table 4: Tables for data collection in the Annexes of ISO 11011

Part of the compressed air system	Information to be collected, stipulated in the tables of the Annexes
Compressed air supply	Compressor information, after cooler, air receiver and air treatment. (Annex C)
Transmission	Piping system (e.g. material, length, diameter), air receiver: dryer, filtration and condensate drains
Demand	Compressed air waste (e.g. leak), end use application (e.g. average peak flow rate, operating pressure (min. max), air treatment (equipment), air receiver close to the point of use)

3.6.6 Main Relevance for Auditing Motor Driven Systems

The whole standard is on energy assessment of compressed air system.

The most important points are: The comprehensiveness of the audit process (audit team) and the audit content (esp. detailed analysis of supply, transmission and demand based on measurements).

3.7 ISO 14414 – Pump system energy assessment

3.7.1 Main Target of Standard

The standard sets requirements for conducting and reporting the results of a pumping system energy assessment that considers the entire pumping system, from energy inputs to the work performed as the result of these inputs.

3.7.2 Selected, main Terms defined, relevant for Evaluation of “Energy Systems”

This standard lists only a few terms, e.g.:

“Parasitic power”, is power imparted to the shaft of a pump and not power used to move the fluid through the system.

For most terms, the standards refer to others specific for terms for liquid pumps and pumping systems: ISO 17769-1 and -2.

3.7.3 Content relevant for Auditing and Metering of Motor Driven Systems

The audit is structured in the following steps:

Sub-section of the standard	Main requirements
Identification of the assessment team, authority and functions	Identification of assessment team structure, facility management, communications, assessment objectives, boundaries, action plan, initial data collection
Conducting the Assessment	Assessment levels (1-3) • Walk Through (required for level 2 and 3): List of identification of conditions associated with inefficient pumping system operation • Understanding system functional requirements • Determining system boundaries and system energy demand • Information needed to asses efficiency of a pumping system: lists in detail electrical motor information, pump information (rotodynamic pumps, positive displacement pumps), liquid properties information, detailed system data (e.g. static head, system curve) • Data collection: measurement of pump and motor operating data (pressure, flow, input power) • Cross validation • Wrap up meeting and presentation of initial findings
Reporting and documentation	Final assessment report, review

The Annexes lists a lot of more information

Annex	Content
Annex A	Report Contents: • Executive Summary • Introduction and facility information • Assessment objectives and scope • Description of systems studied • Assessment data collection and measurement • Data analysis • Annual energy consumption baseline • Performance improvement opportunities identification and prioritisation • Recommendations for implementation activities
Annex B	Recommendations on efficient system operation and energy reduction: • Figures on Best Efficiency Point (BEP) • Common causes and remedies for excessive energy consumption for rotodynamic pumps are mentioned • Examples of energy saving-calculations for pumping systems
Annex C	Expertise, experience and competencies relevant to be mastered by the assessor (system performance, pumps, motors)
Annex D	Contains guidelines for analysis software
Annex E	Example of pre-screening worksheet

Annex F	Specific Energy
Annex	Pumping system parasitic power (formulas)
Annex H	Example of pumping system efficiency indicator (formula)

3.7.4 Motor Driven Systems mentioned explicitly?

The whole standard deals with energy assessment of pumping systems.

3.7.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

The standard gives conditions associated with inefficient pumping system operations. Furthermore, detailed data requirements and some requirements for measurements are included.

In Annex B.3, common causes and remedies for excessive energy consumption for rotodynamic pumps are mentioned.

Annex B.4 gives several examples of energy saving-calculations for pumping systems.

3.7.6 4.7.6 Main Relevance for Auditing Motor Driven Systems

The whole standard is based on the energy assessment of the pumping system.

The most important points are: pre-screening of systems in level 1 assessments, data requirements, calculation formulas and key criteria for proposing energy saving measures.

3.8 ISO 50015 Energy management systems – Measurement and verification of energy performance and organisation – General principles and guidance

3.8.1 Main Target of Standard

This standard establishes a common set of principles and guidelines to be used for measurement and verification (M&V) of energy performance (and improvement) of the organisation or its components.

3.8.2 Selected, main Terms defined, relevant for Evaluation of “Energy Systems”

Measurement and verification (M&V) is defined as a process of planning, measuring, collecting data, analysing, verifying and reporting energy performance or energy performance improvement for defined M&V boundaries.

The term M&V boundary refers to organisational, physical, site, facility, equipment, systems, process or activity limits within which energy performance or energy performance improvement is measured and verified.

“Reporting period” is a selected time period for calculation and reporting of energy performance.

The “baseline period” is a specific time period used as the reference for comparing to the reporting period.

“Energy baseline” is defined as a quantitative reference(s) providing a basis for comparison of energy performance.

3.8.3 Content relevant for Auditing and Metering of Motor Driven Systems

As general principles for M&V, accuracy transparency, competence of the MV practitioner, impartiality and confidentiality are mentioned.

This standard defines six fundamental steps within the M&V process which are specified in the M&V plan.

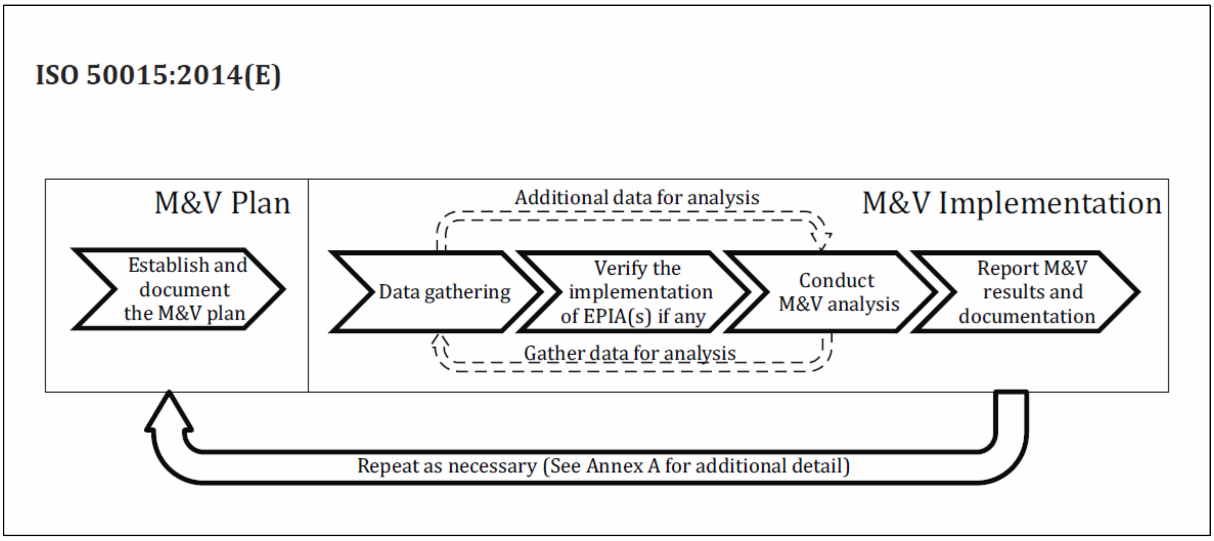

Figure 3: Fundamental steps in the M&V process

The 12 elements of an M&V plan are described in detail in the standard; the following table gives a summary of this:

Table 5: Summary of the elements of an M&V plan

Elements of M&V Plan	Further explanation
Scope and purpose	Organisation, reason for M&V, what is being measured, M&V methods used, summary of the data to be collected
Energy performance improvement actions (EPIA)	Description of EPIA, how or why EPIA improves EP (Energy Performance), responsibility of EPIA, timeframe, locations, costs
M&V boundaries	Determined by scope and purpose of M&V, nature of EPIA, M&V method
Preliminary M&V plan assessment	High level identification of energy systems, data and materials to be used. (e.g. document current energy uses, equipment characteristics, energy consumption pattern, identify representative period of time for conducting M&V, define data needed for data-gathering plan and for energy baseline)
Characterisation and selection of energy performance metrics, incl. EnPI	Quantifying EnPIs (Energy Performance Indicators) is the main purpose of M&V, the characterisation of the EnPI should include mathematical equation to determine energy performance metric; metrics: e.g. kWh/m^2
Characterisation and selection of relevant variables and static factors	This should be done in several steps: establishing criteria for relevant variables, identification of relevant variables and static factors (incl. operating range, representative period of time, etc.)
Selection of M&V Method	Selection of appropriate methods

Elements of M&V Plan	Further explanation
Data gathering plan	This plan should describe: name of variable, data source, data quality, frequency at which data will be collected, individuals responsible, preparation of access to measurement points, operating constraints, type of meter (sensor) to be used
Energy Baseline establishment and adjustments	Data used gathered according to data-gathering plan and analysed according to the M&V Plan. M&V practitioner can establish the energy baseline after the implementation of EIPA(s) on condition that the data required to establish the energy baseline are available. M&V plan should document how the energy baseline is established (e.g. raw data used, specific time period, process to establish baseline) M&V method can require energy baseline to be adjusted to conditions of reporting period.
Resources required	Statement, that resources are appropriate
Roles and responsibilities	Documentation of M&V plan

Further steps for the implementation of the M&V plan are:

- Data gathering (according to plan)
- Verification of implementation of EPIA(s) (if implemented EPIAs differ from description in M&V plan, adjustment should be made)
- Observation anticipated or unforeseen changes (should be documented)
- M&V analysis, reporting

Furthermore, uncertainty should be documented.

3.8.4 Motor Driven Systems mentioned explicitly?

No

3.8.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

No

3.8.6 Main Relevance for Auditing Motor Driven Systems

To calculate the energy performance of motor driven systems and improvement effects of saving measures in this area, an M&V plan is very helpful. Therefore, the twelve elements of the M&V plan, incl. definition of energy performance metrics, the identification of variables and the definition of data gathering plan, incl. type of meter, are important to be defined.

It is also important to state the difference between a measurement plan for on-site energy auditing (e.g. ISO 5002, EN 16247-3) and a measurement and verification plan (e.g. ISO 50015) for verification of an energy saving measure.

3.9 ISO 50006 Energy management systems – Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance

3.9.1 Main Target of Standard

"This standard provides guidance to organisations on how to establish, use and maintain energy performance indicators and energy baselines as part of the process of measuring energy performance." (To be used with ISO 50001:2011)

3.9.2 Selected, main Terms defined, relevant for Evaluation of "Energy Systems"

Baselines and indicators are key elements that enable measurement and management of energy performance in an organisation.

A "significant energy use (SEU)" is an energy use accounting for substantial energy consumption and/or offering considerable potential for energy performance improvement.

"Energy performance" is defined as measureable results related to energy efficiency, energy use and energy consumption. Energy Performance results can be expressed in units of consumption (kWh), specific energy consumption (SEC, kWh/unit), peak power (kW).

3.9.3 Content relevant for Auditing and Metering of Motor Driven Systems

In order to effectively measure energy performance, EnPIs (Energy Performance Indicators) and EnBs (Energy Baselines) are used.

Therefore, energy consumption (different forms of energy) must be quantified and energy uses (e.g. compressed air) should be categorised. On this basis, energy efficiency or other energy performance indicators should be applied, e.g. at system level. Energy performance changes are calculated using EnPIs and EnBs (the corresponding information in the baseline period).

For obtaining relevant energy performance information, the following steps are necessary:

- Definition of EnPI boundaries:
  - Individual boundaries: defined around physical perimeter of one facility/equipment/process, e.g. steam production equipment
  - System boundaries: defined around physical perimeter of a group of equipment interacting with each other, e.g. steam production and steam use equipment (or correspondingly: motor system, e.g. pump and water user)
  - Organisational boundaries: defined around equipment, incl. responsibility of energy management, e.g. steam purchased
- Definition and quantification of energy flows across EnPI boundary, appropriate metering for measuring energy consumption that crossed SEU boundary.

- Definition and quantification of relevant variables
- Definition and quantification of static factors (e.g. change in product type, shifts per day)
- Specification of data to be collected and ensuring data quality

The identification of energy performance indicators starts with measurement; energy consumption should be measured and calculated by using data over a specified period of time, considering existing measurement and monitoring capabilities. The organisation should take measurements for each energy value and relevant variable necessary to calculate the selected EnPI and EnB.

Measurements can be taken on a spot basis (portable meters), on a temporary basis (using data loggers) or continuously (SCADA-supervisory control and data acquisition). If continuous measurement is not possible, spot or temporary measurements should be made during periods that are representative of the typical pattern of operation. Measurements should be accurate, repeatable and the corresponding meters calibrated, while the measured values should also be validated.

For data collection, the frequency should be defined (also depending on the model used: statistical or engineering based models).

Energy performance indicators should be adapted to end users´ needs.

The standard gives an overview on possible types of EnPIs:

- Measured energy value: does not measure energy efficiency
- Ratio of measured values: can express energy efficiency of a system, possible for only one relevant variable, for systems with little or no base load

Example: kWh/MJ for cooling systems; kW/Nm^3 for compressed air system

- Statistical model: system with several relevant variables, for systems with baseload, requires normalisation, illustrates relationship between energy consumption and relevant variable

Example: relationship between energy consumption of a pump/fan and the flow rate

- Engineering model: evaluating energy performance from operational changes where variables are numerous, systems involving feedback loops, systems with interdependent variables (temperature and pressure), design state

Example: model of the electricity consumption of a chiller using the demand for cooling, the outside temperature (condensing temperature) and inside temperature (evaporating temperature)

For establishing energy baselines, a suitable baseline period must be defined (typical: twelve months) and should also be tested.

For using energy performance indicators and energy baselines, three steps must be taken:

- Determining when normalisation is needed
- Calculating energy performance improvements
- Communicating changes in energy performance

3.9.4 Motor Driven Systems mentioned explicitly?

Yes, as examples for EnPI Energy Performance Indicator (see below).

3.9.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

Examples of Energy Performance Indicators are given: kWh/MJ for cooling systems; kW/Nm^3 for compressed air systems.

3.9.6 Main Relevance for Auditing Motor Driven Systems

This standard is not directly applicable for energy audits as the main purpose is to rather use and maintain energy performance of the organisation and its parts. However, the process of definition of the energy performance of equipment can also be used (as explicitly mentioned on the level of systems and equipment) for motor driven systems. Though the whole purpose of the standard is not for spot evaluation but for long-term evaluation of performance, the key concept should however be also used for energy auditing.

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3.10 IPMVP- International Performance Measurement Verification Protocol

3.10.1 Main Target of Standard

IPMVP stands for International Performance Measurement Verification Protocol. It defines standard terms and suggests best practice for quantifying the results of energy efficiency investments and increased investment in energy and water efficiency, demand management and renewable energy projects. IPMVP has become the main standard for measurement and verification in many countries worldwide.

3.10.2 Selected, main terms defined, relevant for Evaluation of “Energy Systems”

An “independent variable” is a parameter that is expected to change routinely and has a measureable impact on energy use of a system or facility.

Adjustments are defined as increments in consumption or demand of the baseline or the reporting periods as a consequence of applying a common set of conditions to address simple comparison of demand or consumption before and after implementation of an energy conservation measure.

3.10.3 Content relevant for Auditing and Metering of Motor Driven Systems

The purpose of IPMVP is to increase certainty and reliability of energy and cost savings through specific measurement methods. The main target is to compare energy consumption before the implementation (the corresponding time period is called baseline period) and after the implementation (which is called reporting period) of an energy saving option. To make those two energy consumptions comparable, so called adjustments have to be made.

With the four options IPMVP provides, savings can be determined:

Option (A) Retrofit Isolation: Key Parameter Measurement

- Savings are determined by field measurement of the key performance parameter(s) which define(s) the energy use of the energy conservation measure's (ECM) affected system(s) and/or the success of the project. Parameters not selected for field measurement are estimated. Estimates can be based on historical data, manufacturer's specifications or engineering judgment. Documentation of the source or justification of the estimated parameter(s) is required.

Option (B) Retrofit Isolation: All Parameter Measurement

- Savings are determined by field measurement of all key performance parameters which define the energy use of the ECM-affected system.

Option (C) Whole Facility

- Savings are determined by measuring energy use at the whole facility or sub-facility level.

Option (D) Calibrated Simulation

- Savings are determined through simulation of the energy use of the whole facility or of a sub-facility. Simulation routines are demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skills in calibrated simulation.

3.10.4 Motor Driven Systems mentioned explicitly?

As a typical application of option B, which means a measurement of all parameters, the installation of a VSD is given:

„Application of a **variable speed drive and controls to a motor** to adjust pump flow: Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. In the baseline period this meter is in place for a week to verify constant loading. The meter is in place throughout the reporting period to track variations in power use.“ Page :7 (IPMVP, Core Concepts)

In the version of IPMVP Volume I, 2012, motor driven systems are mentioned in detail by the following paragraphs below:

„Measurement of proven proxies for energy use: For example, if the energy use of a motor has been correlated to the output signal from the **variable speed drive controlling the motor**, the outputsignal could be a proven proxy for motor energy.“ (p. 16, IPMVP 2012)

„If measurement is not continuous and meters are removed between readings, the location of the measurement and the specifications of the measurement device should be recorded in the M&V Plan, along with the procedure for calibrating the meter being used. Where a parameter is expected to be constant, measurement intervals can be short and occasional. **Electric motors** in an industrial plant provide a common example of constant power flow, assuming they have a constant load. However **motor-operating periods** may vary with the type of product being produced from day to day. Where a parameter may change periodically, the occasional measurements of the parameter (operating hours in this motor example) should happen at times representative of the normal system behaviour. "(p. 19, 20)

"Low Energy Variation & Low-Value ECM: Low-value ECMs cannot typically afford such M&V, based on the 10%-of-savings guideline, especially if there is little variation in the measured energy data. Such combined situations would tend to favour use of Option A, and short reporting periods, for example, in the case of **a constant-speed exhaust-fan motor** that operates under a constant load according to a well-defined schedule." (p 46)

3.10.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

As an example the installation of a VSD is given (see above). In IPMVP Volume I, 2012, two energy saving options concerning motor driven systems are given:

- Pump/Motor efficiency improvement as example for Option A.
- Compressed air leakage management as example for Option B

3.10.6 Main Relevance for Auditing Motor Driven Systems

The IPMVP gives the framework to develop measurement plans for energy saving measures in general but also in motor driven systems and therefore to develop the basis for verifying the energy saving effects of these measures.

3.11 FEMP M&V Guidelines 3.0

3.11.1 Main Target of Standard

"This document contains procedures and guidelines for quantifying the savings resulting from energy efficiency equipment…improved operation and maintenance… implemented through ESPCs (federal energy savings performance contracts)." (p.1-2)

3.11.2 Selected, main Terms defined, relevant for Evaluation of "Energy Systems"

In this guideline, many key-concepts for measuring energy savings are explained and specified.

3.11.3 Content relevant for Auditing and Metering of Motor Driven Systems

The guideline gives an overview of the M&V process and issues and provides the context for the specific M&V requirements for a federal ESPC project. Chapter 11 includes guidance on determining savings from the most common technologies, e.g. constant speed motors, variable speed motors, and chillers.

3.11.4 Motor Driven Systems mentioned explicitly?

Yes, several times.

3.11.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

"To determine energy savings, some measurement processes need to be conducted to identify the pre-retrofit and post-retrofit conditions. These measurements typically include energy consumption and energy-related variables." (Page 7-5)

This guideline contains very detailed information on how to measure energy saving effects of

- Constant speed motors
- Variable speed motors
- Chillers

This includes details for the equipment inventory (e.g. motor survey data form), definition of operating hours, verification of constant loading and the formula for savings calculation. In this context, the savings calculation needs measurements of the post-installation performance.

In Annex H, a standard M&V plan for chiller replacement projects is given.

For further details on measurement the FEMP Guidelines, refer to ASHRAE Guideline 14, which is a guideline for reliably measuring the energy, demand and water savings achieved in conservation projects. It gives standard procedures for measuring physical characteristics, including power, temperature, flow, pressure and thermal energy. Furthermore, it describes standards for measuring the performance of chillers, fans, pumps, motors, boilers/furnaces and thermal storage.

3.11.6 Main Relevance for Auditing Motor Driven Systems

This guide is mainly relevant for the development of a measurement plan for the suggested energy saving measures. Partly the information can also be used to develop and measure performance indicators for motor driven systems.

3.12 Measurement and Verification Operational Guide,Best Practice M&V Processes

3.12.1 Main Target of Standard

The Measurement and Verification Operational Guide of the Government of New South Wales (in Australia) has been developed to help M&V experts translate M&V theory into successful projects. By following the guide, the IPMVP will be implemented.

3.12.2 Selected, main Terms defined, relevant for Evaluation of "Energy Systems"

"M&V is the process of using measurement to reliably determine actual savings for energy, demand, cost and greenhouse gases within a site by an Energy Conservation Measure".

3.12.3 Content relevant for Auditing and Metering of Motor Driven Systems

The guideline is structured along the M&V process, for which detailed information is given:

- Proposed Energy Conservation Measure (ECM) (Start)
- Decision on approach for pursuing M&V
- M&V Design
- Prepare M&V plan
- Measure baseline data
- Develop energy model and associated uncertainty
- Implement ECM
- Measure post retrofit data
- Savings analysis and uncertainty
- Reporting
- Finish

3.12.4 Motor Driven Systems mentioned explicitly?

The following practical guides for different technologies (incl. motor specific topics) are published:

- NSW Government, Office of Environment & Heritage: Measurement and Verification, Operational Guide: Motor, Pump and Fan Applications, NSW Government, Office of Environment & Heritage, Sydney, Dec. 2012
- NSW Government, Office of Environment & Heritage: Measurement and Verification, Operational Guide: Boilers, Steam and Compressed Air Applications, NSW Government, Office of Environment & Heritage, Sydney, Dec. 2012
- NSW Government, Office of Environment & Heritage: Measurement and Verification, Operational Guide: Commercial Heating, Ventilation and Cooling Applications, NSW Government, Office of Environment & Heritage, Sydney, Dec. 2012
- NSW Government, Office of Environment & Heritage: Measurement and Verification, Operational Guide: Commercial and Industrial Refrigeration Applications, NSW Government, Office of Environment & Heritage, Sydney, Dec. 2012

For the above mentioned M&V process, those guides outline the specific information required for the different systems: e.g. energy saving conservation measures for all technologies and parameters to be monitored are defined; specific information for data sources, operating time, M&V boundaries etc. are given.

3.12.5 Examples for Auditing, Metering and Calculation of Energy Savings (e.g. in Motor Driven Systems?)

For the above mentioned technologies (almost all motor driven systems), examples for metering and calculation of energy savings are given.

3.12.6 Main Relevance for Auditing Motor Driven Systems

These guides are mainly relevant for the development of a measurement plan for the suggested energy saving measures. The information can partly also be used to develop and measure energy performance indicators for motor driven systems.

4 Motor Challenge Programme-Documents

„The Motor Challenge Programme is a European Commission voluntary programme (launched in February 2003) through which industrial companies are aided in improving the energy efficiency of their Motor Driven Systems. Any enterprise or organisation planning to contribute to the Motor Challenge Programme objectives can participate.“ (http://iet.jrc.ec.europa.eu/energyefficiency/motorchallenge)

In the following part, the Motor Challenge Programme documents are analysed, which give already quite specific and concise information requirements for energy audits in this field.

For the development of the action plan, the following “Module” documents were developed in 2003 and 2005:

- Motor Challenge Programme – Drive Module
- Motor Challenge Programme – Fan Module
- Motor Challenge Programme – Pump Module
- Motor Challenge Programme – Compressed Air Module
- Motor Challenge Programme – Refrigeration and Cooling Module

All documents have the same structure, which also describes a kind of “audit approach” in motor driven systems, incl. the follow up of saving measures:

- Inventory
- Assessment of the applicability of possible energy savings measures
- Action plan, presented to the Commission, which defines what the Partner has decided to do to reduce operating costs by improving energy efficiency
- Annual report of progress on the Action Plan

For each technology, detailed information on parameters to be collected (or measured), energy saving measures to be assessed and on the form or action plan, are given:

For the inventory tables, for the following steps are given:

- A - Basic system description
- B - Documentation and measurement of system operating parameters
- C - Global indicators of system performance

For the assessment of energy saving measures, a list of energy saving measures with some (short) information are given, incl. potential for energy savings. Furthermore, a table for the description of the energy saving measures is given (annual savings, investment cost, annual O&M costs and estimated payback time)

For the action plan, a table is stipulated for each technology (with the main energy saving measures).

The annual report section is the same for all module documents, including tables how it should look like.

In general, the MCP documents give more specific information concerning motor driven systems than general energy audit standards.

5 Comparison of ISO 11011, ISO 14414 and ISO 50002

This chapter compares the structure and content of the following audit standards:

- ISO 11011 Compressed air efficiency assessment
- ISO 14414 Pumping system energy assessment
- ISO 50002 Energy audits - Requirements with guidance for use

The general structure of the standards ISO 50002, ISO 11011, and ISO 14414 is to some extent the same (see also table in Appendix 3 with the list of contents compared for all three standards). For details on ISO 50002 and the process steps, see chapter 4.
ISO 11011 gives details on an assessment methodology and defines specific parameters for compressed air systems to be collected and their determination during the following assessment process steps:

- Data collection
- Data analysis
- Reporting

ISO 14414 defines (after planning the assessment, establishing of measurement requirements and the scheduling of the assessment) the following steps:

- Initial data collection and evaluation
- Conducting the assessment
- Walk through
- Information needed
- Data collection (incl. measurement)
- Wrap-up meeting
- Reporting and documentation

In addition to ISO 11011, a closing meeting is required. ISO 50002 gives some organisational information on the following parts of energy audits:

- Preliminary contact
- opening meeting
- initial data collection
- field work, and site visits

For these points, ISO 11011 defines some data to be collected during a compressed air assessment, e.g. in Annex B - Assessment activities, general. ISO 14414 defines the specific data to be collected for a pumping system audit.

As an example of the different level of information given in the three standards, the different energy saving measures mentioned in the standards are listed in the following paragraphs:

As in ISO 50002, no specific saving measures are quoted two (of several) saving measure categories defined in EN 16247-3 are listed:

- Measures in order to reduce or to recover the energy losses (reduction of leakage of compressed air, waste heat recovery etc.)
- Replacement, modification or addition of equipment (variable speed motor etc.)

The following saving measures are mentioned in ISO 11011:

- Check for too high system pressure (e.g. because to overcome pressure instability)
- Reduce peak air demand (storage, elimination of waste)
- Reduce system resistance, optimise components for proper airflow capacity, create piping loop connections
- Modify high pressure end-use device to operate at lower supply pressure
- Define end-use air-flow rate necessary for application
- Leak reduction (target definition, energy savings calculation)
- Alternatives for inappropriate use (calculation of net savings)
- Check supply-side and point-of-use air treatment (calculate energy demand and pressure loss)
- Reduce system operating pressure
- Control automation for multiple compressors
- Apply trim compressors
- Shut down compressors
- Change of control strategy
- Maintenance of condensate drains, filters, piping
- Heat recovery

The following saving measures are mentioned in ISO 14414:

- Minimising friction losses
- Increasing internal pipe diameter
- Reduction of number of pipe bends, large radius
- Minimise static head
- Reduce system head losses (examples of saving measures are given)
- Reduction of system flowrate (examples of saving measures are given)
- Ensure that components operate close to best efficiency.
- Change pumping system run time

Furthermore, ISO 14414 contains examples for the calculation of energy saving measures and specific energy indicators with formulas. This standard defines three levels of assessment, starting with level 1 for a pre-screening of the systems for a closer evaluation in levels 2 and/or 3.

The analysis shows that the specific motor standards - though not following the same audit steps as the ISO 50002 - are proposing, to some extent, a similar audit procedure as the ISO 50002 and are not contradictory to this standard. Therefore, for further work, ISO 50002 will be the basis for the energy audit methodology development and if more detailed information is given for certain steps (e.g. data collection or evaluation of saving measures), it will be referred to these standards.

6 Specifications for energy audits in motor driven systems

The target of this study (Subtasks 1 and 2) was to identify standards and tools relevant for energy audits in motor driven systems.

As already identified all requirements of ISO 50002, although not containing specific information on motor systems, are relevant for energy audits in motor systems. Therefore, ISO 50002 will serve as a guideline for further work to develop a methodology for energy audits in motor driven systems. For certain audit steps it will be referred to the more detailed information given in ISO 11011 and 14414. The following table gives an overview of the content of ISO 50002 and at which step motor specific tools can help to fulfil the standard for energy audits in this specific field.

Table 6: Summary of requirements of ISO 50002 for energy audits and available motor specific information for each element

ISO 50002	Content of Energy Audit Standard (summary of each element)	Examples of sources for motor specific information (to be completed during the next project phase)*
4.1 General	• Energy audit provides information on which an organisation can act in order to improve its energy performance • Energy auditors are selected on energy audit scope, objectives and their competencies	
4.2 Energy auditor		
4.2.1 Competency	Energy auditor has to have the knowledge and skills to complete defined energy audit scope: appropriate education, experience, training (or national guidelines); technical skills to energy uses, legal requirements, knowledge of audit standards	Motor Competence (trainings, guides, tools, certificates)
4.2.2 Confidentiality	Confidentiality shall be agreed upon by organisation and auditor	
4.2.3 Objectivity	Auditor shall act independently; conflicts of interest shall be identified and disclosed!	
4.3 Energy audit	Following principles must be considered: • Consistent with scope • Measurement are appropriate to the energy uses • Collected energy performance data is representative of the activities, processes • Used data is consistent, process of data collection is traceable • Energy performance improvement opportunities are based on appropriate technical and economic analysis	
4.4 Communication	Auditor establishes communication channels for energy team and with the organisation	
4.5 Roles and responsibilities	Roles, responsibilities and authority shall be determined	
5 Performing an energy audit		
5.1 General	Overview on audit process flow	

ISO 50002	Content of Energy Audit Standard (summary of each element)	Examples of sources for motor specific information (to be completed during the next project phase)*
5.2 Energy audit planning	• Gather preliminary information: scope auf audit, level of detail (type 1-3 audits, Annex defines indicative types), time period, data available prior to the start of the audit, reporting format; • Auditor requests information on: regulatory requirements, strategic plans (affecting energy performance), management systems, ideas for energy saving measures	• Sotea • General company data table (ISO 11011 Annex A)
5.3 Opening meeting	• Organisation should assign person to assist energy auditor, inform personnel about energy audit and their responsibilities, ensure cooperation of affected parties, inform on significant changes in production volume; • Auditor should have access to the company, know about health, saftey security issues, available energy data, requirements for measurements (installation of measurement equipment)	Possible table in Annex B to EN 16247-2 (parties of an energy audit)
5.4 Data collection	Auditor should collect: • List of energy consuming systems, processes, equipment • Detailed characteristics of energy uses (incl. variables influencing energy consumption) • Historical energy performance (energy consumption, variables, measurements) • Monitoring equipment • Design, operation, maintenance documents • Previous energy audits • Electricity rates • Energy distribution system [power quality, power network]	• Table with general data • Motor Inventory List (MCP, ILI+) • ProTool (PINE-Tool) • US Tools

ISO 50002	Content of Energy Audit Standard (summary of each element)	Examples of sources for motor specific information (to be completed during the next project phase)*
5.5 Measurement plan	For any on-site data measurement and collection the auditor and the organisation should agree a measurement plan, that includes, e.g.: • List or relevant measurement points • Additional measurement points For the measurement to be defined: • Accuracy (incl. uncertainty), duration, frequency, representative time period, relevant variable (production data), calibration of equipment, responsibilities;	Measurement Plan (IPMVP, FEMP Guideline 3.0, NSW Guidelines, ISO 17741) STR (Standard Test Report, CH) US Tools
5.6 Conducting the site visit		
5.6.1 Management of field work	• Observe energy uses and compare with information already provided • Evaluate the energy use • Check user behaviour, operating routines • Suggest saving measures • List processes were additional data is needed • Ensure measurements and past data are representative for normal practice • Inform organisation of difficulties	
5.6.2 Site visits	• The organisation should identify individuals to guide the auditor and give him access to drawing manuals and technical documentation, competences to carry out direct operations, permit installation of measurement equipment as agreed	
5.7 Analysis		
5.7.1 General	Auditor shall: • use and document transparent, appropriate calculation methods • Assure variables that affect measurement are taken into account • Consider legal circumstances for energy improving energy performance	Measurement: IPMVP; NSW Guides, FEMP Guideline 3.0, ASHRAE Guideline 14

ISO 50002	Content of Energy Audit Standard (summary of each element)	Examples of sources for motor specific information (to be completed during the next project phase)*
5.7.2 Analysis of existing energy performance	• Analyse of current energy performance • Break down of the energy consumption by use and source • Compare energy uses accounting for substantial energy consumption with reference values • Analyse historical patterns of energy performance • Evaluate expected improvements • Relate energy performance and relevant variables (where appropriate) • Evaluate existing EPI, proposals for new one	• Parameters for possible energy saving measures (tbd) • ProTool (PINE Tool) • ILI+ • Standard Test Report (STR) • EMSA Tool • US Tools
5.7.3 Identification of improvement opportunities	The following aspects should be analysed when identifying opportunities: • Evaluate design and configuration options to address system needs • Operating lifetime, condition, operation and level of maintenance of the audited objects • Existing technology in comparison to most efficient on market, BAT operational control and behaviours	• US Sourcebooks • MCP Module Documents • klima:aktiv auditguides • EMSA Design Tool
5.7.4 Evaluation of improvement opportunities	For each opportunity evaluation should be based on: energy and financial savings, investments, agreed economic and other criteria, non-energy gains, ranking of opportunities, potential interaction	
5.8 Energy audit reporting		
5.8.1 General	• Meet energy audit requirements agreed with organisation • Identification of relevant measurements • State if analysis is made on estimates, assumptions and uncertainty • List of energy saving measures, recommendations for their implementation	
5.8.2 Content of report	• Executive summary (energy use, consumption; ranking of opportunities, implementation programme) • Background (e.g. general information on organisation, context) • Energy audit details (measurement plan, analysis of energy performance, basis for calculations) • Opportunities for improving energy performance	• MCP Action Plan • Audit Report Template (based on information compiled above)
5.9 Closing meeting	Presentation of results, identify need for further analysis	

*For some steps energy audit steps in ISO 50002 no further motor specific information is needed

7 Conclusions and Outlook

Conclusions

The analysis shows that for energy audits in motor driven systems, all requirements of the ISO 50002, which contains a lot of general information, are relevant.

Furthermore, many different standards and protocols consider motor driven systems already as major energy user. Two standards concentrate on two different motor driven systems, namely compressed air and pumping systems.

For most of the different audit steps - from audit planning to data acquisition and analysis and audit reporting - specific information and requirements on motor driven systems are available, either in form of tools, guidelines or standards.

In general, the energy audit standards analysed lack the following information:

- Parameters for first evaluation of energy saving measures (pre-screening)
- Criteria for implementation of energy saving measures
- Calculation formulas for assessing the energy benefit of the implementation of certain energy saving measures (exception is the annex of ISO 14414)

Performance measurement protocols and guides already include motor driven systems as examples or have already specific guidelines for saving measures in this field.

Outlook

This document will serve as basis for the development of the energy audit methodology for the next project phase (Subtask 3). This document will be structured along the different steps necessary for an energy audit according to ISO 50002 and will include organisational and technical tasks to be performed during the audit. For each step it will refer to the relevant standards, guides and tools.

In addition, it will include the following information:

- Technology-specific key indicators for the recommendations of energy saving measures
- Saving calculation methods in accordance with international protocols

8 Appendix

8.1 Appendix 1: Selected incentives for the implementation of saving measures

In the Netherlands, the implementation of saving measures with payback time below five years is mandatory for all medium and large energy users (annual consumption of >25,000 m3 gas, >50,000 kWh electricity). (Note: in practice this is not met in most cases.) For medium energy users, a list of mandatory measures is available per sector.

In Switzerland, for compensation for electricity fed into grid, electric-intensive companies must invest part of the saved charge under the KEV-regime ("Kostendeckende Einspeisevergütung"). Companies with heat consumption of >5 GWh or electricity consumption of >0.5 GWh, are required to set energy efficiency measures in some „Kantons".

In Austria, the implementation of energy saving measures is subsidised under some circumstances: generally, a minimum investment of 10,000 Euro is subsidised, the pay-back of measures must range from three to five years or higher, de-minimis rules must be considered (max. 200,000 Euro of subsidy per company within three years), in practice the subsidy is between 30-35% of eligible costs.

8.2 Appendix 2: Overview of Selected Guides and Tools

Table 7: Overview on Guides relevant for Auditing of Motor Driven Systems

Part of Motor System	Name of Guide and Link
Motors, Variable Frequency Drives	• Natural Resources Canada (2009): Variable Frequency Drives, Energy Efficiency Reference Guide www.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/pdf/industrial/equipment/vfd-ref/pdf/variable-frequency-drives-eng.pdf
	• US Department of Energy, Energy Efficiency and Renewable Energy (2008): Improving Motor and Drive System Performance: A Sourcebook for Industry www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor.pdf
	• Office of Industrial Technologies: Energy management for Motor driven Units, Energy Management for Motor Driven Systems
	• Carbon Trust: Motors and Drives www.carbontrust.com/resources/guides/energy-efficiency/motors-and-drives
	• Industrial Efficiency Technology Database: Motor Systems Guides www.ietd.iipnetwork.org/node/725
	• Blue Book on System Optimisation, Denmark
	• European Commission: Motor Challenge Programme, Drives Module
Fans	• US Department of Energy, Energy Efficiency and Renewable Energy (2003): Improving Fan System Performance: A Sourcebook for Industry www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/fan_sourcebook.pdf
	• Carbon Trust (2011): CTV 046, Heating, Ventilation and Air-Conditioning, Saving Energy Without Compromising Comfort www.carbontrust.com/resources/guides/energy-efficiency/heating,-ventilation-and-air-conditioning-%28hvac%29
	• European Commission: Motor Challenge Programme, Fan Module
	• klimaaktiv Energyaudit Guide for Ventilation Systems
Pumps	• US Department of Energy, Energy Efficiency and Renewable Energy (2006): Improving Pumping System Performance: A Sourcebook for Industry www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/pump.pdf
	• CEATI International (2008): Pump Systems Energy Efficiency Reference Guide www.ceati.com/freepublications/7026_guide_web.pdf
	• European Commission: Motor Challenge Programme, Pump Module

Part of Motor System	Name of Guide and Link
	• klimaaktiv Energyaudit Guide for Pumping Systems
Refrigeration	• Carbon Trust (2011): CTV 046, Refrigeration Systems: Guide to Key Energy Saving Opportunities www.carbontrust.com/media/13055/ctg046_refrigeration_systems.pdf
	• European Commission: Motor Challenge Programme, Refrigeration and Cooling Module
	• klimaaktiv Energyaudit Guide for Cooling Systems
Compressed Air	• US Department of Energy, Energy Efficiency and Renewable Energy (2003): Improving Compressed Air System Efficiency: A Sourcebook for Industry www1.eere.energy.gov/manufacturing/tech_assistance/compressed_air.html
	• Carbon Trust: Compressed Air www.carbontrust.com/resources/guides/energy-efficiency/compressed-air
	• Natural Resources Canada (2007): Compressed Air Energy Efficiency Reference Guide energent.com/sites/default/files/compressed-air-ref-eng.pdf
	• EnergieSchweiz: Compressed Air Information Sheets (German only) www.energieschweiz.ch/de-ch/unternehmen/stromeffizienz/druckluft/publikationen.aspx
	• European Commission: Motor Challenge Programme, Compressed Air Module
	• klimaaktiv Energyaudit Guide for Compressed Air Systems
Energy Audits	• EEO Assessment Handbook (170 pages), this guide was developed as part of the EEO Program and provides examples and guidance for conducting a rigorous energy efficiency assessment. It includes techniques to use energy data to aid understanding of energy usage as well as guidance on investing in sub-metering. • http://eex.gov.au/resources/energy-efficiency-opportunities-eeo-assessment-handbook/
Measurement and Verification	• NSW Government, Office of Environment & Heritage: Measurement and Verification Operational Guide, Best Practice M&V processes, Dec. 2012 (and technologic specific guides: motors, pumps, fans, compressed air, chillers) • http://www.eec.org.au/uploads/images/NEEC/Information%20Tools%20and%20Resources/M&V%20Operational%20Guide.pdf

The following table gives an overview of examples of independent tools for the calculation of energy saving measures in the field of motor driven systems:

Table 8: Currently Available Energy Saving/System Optimisation Calculators

Name and Link	Description
Motor Systems Tool http://www.energy.gov/eere/amo/articles/motormaster	• Developed by the International Energy Agency Energy Efficient End-Use Equipment (IEA 4E) Electric Motor Systems Annex, the Motor Systems Tool calculates the efficiency of a complete motor system (motor plus VFD, gear and transmission). It is intended to assist engineers, machine builders, machine component suppliers, energy consultants and others working on optimising machine systems to benefit from reduced electricity consumption. • More information on the Motor System Tool is included in Attachment C.
AIRMaster+ http://www.energy.gov/eere/amo/articles/airmaster	• AIRMaster+ is a free online software tool that helps users analyse energy use and savings opportunities in industrial compressed air systems. It can be used to benchmark existing and model future system operations improvements, and evaluate energy and dollar savings from many energy efficiency measures. AIRMaster+ provides a systematic approach to assessing compressed air systems, analysing collected data, and reporting results.
Pumping System Assessment Tool (PSAT) http://www.energy.gov/eere/amo/articles/pumping-system-assessment-tool	• PSAT, distributed by the US Department of Energy, helps users assess energy savings opportunities in existing pumping systems. It relies on field measurements of flow rate, head, and motor power or current to perform the assessment. Using algorithms from the Hydraulic Institute and standards and motor performance characteristics from the US DOE Motormaster database, PSAT estimates existing pump and motor efficiency and calculates the potential energy/cost savings for a system optimised to work at peak efficiency.
Fan System Assessment Tool (FSAT) http://www.energy.gov/eere/amo/articles/fan-system-assessment-tool	• FSAT is a free online software tool that helps industrial users quantifies energy use and savings opportunities in industrial fan systems. It can be used to calculate the amount of energy used by a fan system, determine system efficiency, and quantify the savings potential of an upgraded system. The tool also provides a pre-screening filter to identify fan systems that are likely to offer optimisation opportunities based on the system's control, production and maintenance and effect. • FSAT estimates the work done by the fan system and compares that to the system's estimated energy input. Using typical performance characteristics for fans and motors, indications of potential savings (in energy and dollars) are developed.
VSD Calculator for Pumps/VSD Calculator for Fans https://ecenter.ee.doe.gov/EM/tools/Pages/VSDCalcPumps.aspx	• These tools calculate the estimated energy and cost savings that would result from installing a VSD on a pump/fan system. Required inputs include nameplate horsepower, efficiency, motor load, annual operating hours, pump/fan type, and cost of electricity. Using these inputs and the duty cycle, the tool calculates the current energy use, potential energy use with a VSD, potential energy savings, and potential cost savings.
Motor Decisions Matter Tools www.motorsmatter.org/tools/index.asp	• The Motor Decisions Matter (MDM) campaign has developed a variety of credible, third-party tools to help demonstrate the benefits of motor efficiency, planning, and system analysis. The MDM tools and resources are publically available, to assist decision makers interested in energy efficiency and process reliability improvement in properly designed, maintained and operated motor systems.

Name and Link	Description
S.A.F.E. Software Tools www.topmotors.ch/Tools	• Excel-based software tools developed by the Swiss Topmotors program of S.A.F.E. help industrial users to assess the savings potential of their existing motor systems: • SOTEA (software tool to estimate potential energy savings) is used to assess the efficiency potential of motor systems in one plant. The goal is to give the industrial user a rough number of possible savings which largely depends on the age of the installed motor stock. • ILI+ (intelligent motor list) is used to compile a list of motors, from which motors with the highest savings potential can be chosen for retrofit. The Decision Maker of the tool helps users identify a relatively small number of motors representing a relatively large share of total possible savings. • The STR (Standard Test Report) is a standardised template for a motor systems analysis protocol and helps to summarise motor test results and proposed motor systems efficiency measures together with the expected costs and savings.

8.3 Appendix 3: EN 16247-3, Motor data

In the Annex of EN 16247-3 examples of parameters to be collected are given. For the following table motor systems were selected and the order of the parameters was unified.

Table 9: Parameters to be collected during an energy audit for motor driven systems

Electric distribution and equipment	Chillers	Pumps	Fans	Compressed Air
List of the main pieces of equipment and characteristics: transformers, low voltage panel, capacitor bank, power plant (turbines, electricity generating sets), inverters, networks, engines, pumps, fans, compressors	Description of the system, installed capacity and its matching data to operational needs	Description of the system, installed capacity and its matching data to operational needs	Description of the system, installed capacity and its matching data to operational needs	Description of the system, installed capacity and its matching data to operational needs
Variable speed drives, etc.	Types and number of machines (compression- or absorption-based refrigerating unit, compressor, condenser, air cooler, heat pump)	Pump description	Fan description	Type and number of compressor

Electric distribution and equipment	Chillers	Pumps	Fans	Compressed Air
Operation (for each of the main pieces of equipment)	Capacity (refrigerating, electric)	Pump type	Fan type	Pressure
Annual consumption by station and sector	Nature of the refrigerant	Pump application	Fan application	Power
Regulation (for each of the main pieces of equipment)	Temperatures of the input/output secondary refrigerant	Physical location of pump, installed motor data (rated nameplate power, voltage, full load amperage, and frequency)	Physical location of fan, installed motor data (rated name-plate power, voltage, full load amperage, and frequency	
	Metering	Control method (e.g. control valve, VSD, bypass)	Control method	Flow rate
	Control	Annual operational hours (or % operation)	Annual operational hours (or % operation)	Control
	Number of operating hours	Flow rate		Operation
	Annual consumption	Pressure		Annual consumption
		Input/output temperature	Input/output temperature	
		Pumped media (liquid)		Input/output temperature
		General condition of pumps	General condition of fans	Air production and quality
	General condition of the material and the distribution net-work (system, pump)			General condition of the equipment and network (insulation, leaks, traps, etc.)

8.4 Appendix 4: ISO 11011/ISO 14414/ISO 50002

The table in this section compares the table of contents of the standards ISO 11011 (Compressed Air Efficiency Assessment), ISO 14414 (Pump system energy assessment), and ISO 50002 (Energy audits -- Requirements with guidance for use).

Table 10: Table of Contents of ISO 50002, ISO 11011, and ISO 14414

ISO 50002	ISO 11011	ISO 14414
Introduction	Introduction	Introduction
1. Scope	1. Scope	1. Scope
2. Normative References	2. Normative References	2. Normative References
3. Terms and definitions	3. Terms and definitions	3. Terms and definitions
4. Principles	4. Roles and Responsibilities	4. Identification of the assessment team, authority and functions
4.1 General	4.1 Identification of assessment team members (incl. resources, coordination, CAS knowledge, competency)	4.1 Identification of assessment team functions 4.2 Assessment team structure, leadership and competency
4.2 Energy auditor	4.2 Site management support	4.3 Facility management support
4.2.1 Competency	4.3 Communications	4.4 Communications
4.2.2 Confidentiality	4.4 Access to equipment, resources, and information	4.5 Access to facilities, personnel and information
4.2.3 Objectivity	4.5 Assessment objectives and scope	4.6 Assessment objectives, scope and boundaries
	4.6 Identification of other assessment team members	
4.3 Energy audit	4.7 Objective check	
4.4 Communication	5. Assessment methodology	
4.5 Roles, responsibilities and authority		
5. Performing an energy audit	6 Parameters and their determination 6.1 General 6.2 Measurement 6.3 Pressure 6.4 Flow rate 6.5 Power	5.5 Information needed to assess the efficiency of a pumping system 5.5.1 General 5.5.2 Electrical motor/drive information 5.5.3 Pump information 5.5.4 Liquid properties information 5.5.5 Detailed system data

ISO 50002	ISO 11011	ISO 14414
		5.5.6 Measured data
5.1 General		
5.2 Energy audit planning		4.7 Action plan
5.3 Opening meeting	7 Initial data collection and evaluation 7.1 General 7.1 Plant background 7.3 Plant function	4.8 Initial Data Collection and Evaluation
5.4 Data collection	7.4 Compressed air system definition 7.5 Inventory of key end-use air demands 7.6 Heat recovery 7.7 Baseline period and duration of data logging 7.8 Energy use 7.9 Compressed air system supply efficiency 7.10 System volume 7.11 Pressure 7.12 Flowrate 7.13 Critical air demands 7.14 Compressed air waste 7.15 Air treatment 7.16 Compressor control 7.17 Storage 7.18 Maintenance 7.19 Ambient intake conditions	5.6 Data Collection 5.6.1 System information 5.6.2 Measurement of pump and motor operating data 5.6.3 Pressure 5.6.4 Flow 5.6.5 Input power
5.5 Measurement plan	Annex C: Test points –Supply Annex D: Test points – Transmission Annex E: Test points – Demand	
5.6 Conducting the site visit	See above	5.1 Assessment Levels (1-3 level assessment) 5.2 Walk through
5.6.1 Management of field work	See above	
5.6.2 Site visits		
5.7 Analysis	8 Analysis of data from assessment	
5.7.1 General	8.1 General	
5.7.2 Analysis of existing energy performance	8.2 Baseline profiles (control, power, demand, supply efficiency, operating periods, annualised energy use) 8.3 System volume 8.4 Pressure profile	Annex A.7: Annual energy consumption baseline Annex F: Specific Energy Annex H: Example of pumping system efficiency indicator

ISO 50002	ISO 11011	ISO 14414
	8.5 Perceived high-pressure demand 8.6 Demand profile 8.7 Critical air demands 8.8 Compressed air waste (leakage) 8.9 Optimised air treatment 8.10 Reduced system operating pressure 8.11 Balance of supply and demand 8.12 Maintenance opportunities 8.13 Heat recovery opportunities	
5.7.3 Identification of improvement opportunities	9.3 Energy-saving opportunities	Annex B Recommendations on efficient system operation and energy reduction - examples
5.7.4 Evaluation of improvement opportunities	9.3 Energy-saving opportunities	
5.8 Energy audit reporting	9 Reporting and documentation of assessment findings	6 Reporting and documentation
5.8.1 General		
5.8.2 Energy audit report content	9.1 Assessment Report (incl. content)	6.1 Final assessment report (content Annex A) 6.2 Data for third party review 6.3 Review of final report by assessment team members
5.9 Closing meeting	9.2 Confidentiality 9.3 Energy-saving opportunities 9.4 Data for third party review	5.8 Wrap-up meeting and presentation of initial findings and recommendations

9 Abbreviations

ASME EA	The American Society of Mechanical Engineers Energy Assessment
AEE	Association of Energy Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAT	Best Available Technology
BEP	Best Efficiency Point
CEA	Certified Energy Auditor
EC	European Commission
ECCJ	Energy Conservation centre Japan
ECM	Energy Conservation Measure
EE	Energy Efficiency
EED	European Energy Efficiency Directive
EEO	Energy Efficiency Obligation Scheme
EMAK	Energy Management Action Network
EMSA	Electric Motor System Annex
EN	European Standard
EnB	Energy Baseline
EnPI	Energy Performance Indicator
EPIA	Energy Performance Improvement Action
ESPC	Federal Energy Savings Performance Contracts
ETS	Emission Trading System
EUREM	European Energy Manager
FEMP	Federal Energy Management Programme
IAC	Industrial Assessment Centre
IEA 4E	International Energy Agency – Technology Collaboration Programme on Energy Efficient End Use Equipment

ILI	Intelligent Motor List
IPMVP	International Performance, Measurement and Verification Protocol
ISO	International Standard Organisation
IPEEC	International Partnership for Energy Efficiency Cooperation
LTA3	Long Term Agreements, 3rd generation agreements
M&V	Measurement and Verification
MCP	Motor Challenge Programme
MEE	Long-Term Agreement for the energy efficiency of ETS enterprises (MEE)
NSW	New South Wales
SCADA	Supervisory Control and Data Acquisition
SEC	Specific Energy Consumption
SEU	Significant Energy Use
STR	Standard Test Report
TA	Target Agreement
UK	United Kingdom
UNIDO	United Nations Industrial Development Organisation

10 List of figures

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AUSTRIAN ENERGY AGENCY