



Energy-Using Product Group Analysis - Lot 5  
**Machine tools and related machinery**  
Task 7 Report – Policy and Impact Analysis

Sustainable Industrial Policy - Building on the Ecodesign  
Directive - Energy-using Product Group Analysis/2

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Berlin, August 1, 2012

EuP\_Lot5\_Task7\_August2012.doc

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## Executive Summary – Task 7

For the various market segments covered by this study several targeted policy options apply. For less complex machine tools specific requirements can be defined, but for more complex machine tools policy measures need to reflect the multitude of identified improvement options, the systems aspect, and productivity considerations. The analysis of improvement options has shown that a moderate improvement potential can be achieved solely by implementing what can be termed “good design practice”. Therefore, one proposed requirement is the mandatory usage of Good-design-practice Checklists, making it obligatory to assess the feasibility of improvement options. The final judgement regarding whether an option is suitable for a given application would remain with the machinery developer.

Besides such a checklist approach (and closely related to it), power management and information/ declaration requirements can also be defined. Whereas power management addresses the aspect of reducing power consumption in non-productive times without hampering productivity, standardised information/ declaration requirements create a transparency and comparability regarding environmental performance and life cycle costs. In particular the latter is assumed to have an influence on purchase decisions.

Such measures could be introduced either through an ecodesign implementing measure or through one or several Voluntary Agreements/ Self-Regulatory Initiatives (SRIs). No such Voluntary Agreement is currently in place, and some standards are lacking; these issues potentially impede the unambiguous implementation of a potentially feasible Voluntary Agreement.

Minimum environmental performance criteria are assessed as being unfeasible at the machine tools level, due to the broad spectrum of products, missing statistical data on current performance, and application-specific performance. However, such criteria might be feasible to set at the component level, if clearly defined as a performance indicator (e.g. energy efficiency of power transformation). Power management requirements are feasible at both levels, i.e., for the machine tool as such, and at the module / component level, but they would need to be formulated in a rather generic way. Good-design-practice checklists could similarly apply to both machine tools as such, and individual sub-modules. In addition, information and declaration requirements are applicable at the level of both machine tools per se, and at the level of sub-modules.

At a sectoral level, the following policy options might apply:

#### All machine tools

- Overarching Implementing Measure
  - Generic checklist approach
  - Power management requirements
  - Information/ declaration requirements

#### Metal working machine tools

- Exemption from the overarching implementing measure, if an SRI can be effectively implemented in the metal working machine tools sector

#### Wood working machine tools

- Covered by overarching implementing measure
- Product Carbon Footprint (PCF) declaration for light-stationary tools; this option is favoured, because the checklist and power management basically is not useful / applicable for these machine tools

#### Welding equipment

- Covered by overarching implementing measure
- Specific power consumption requirements

#### Other machine tools

- Covered by overarching implementing measure, unless any specific SRI is implemented by any sub-sector (e.g. semiconductor equipment)

#### Related machinery

- For all machinery covered by the machinery directive: Implementing measure tackling selected components with the generic checklist approach

Three policy options, assumed to yield a change in the market from 2014 onwards, are assessed against a Business-as-usual (BAU) scenario regarding their savings potential:

- **LLCC (Least Life Cycle Costs):** Implementation of a good-design-practice-checklist, accompanied by power management requirements and declaration obligations, leading to machinery improvements which correspond to the point

of Least Life Cycle Costs. This scenario yields a moderate saving estimate of a minimum 31 PJ per year in 2025, or nearly 4% compared to BAU.

- **LCC-BEP (Life Cycle Costs – Break-even Point):** This can be considered an “optimistic scenario”, where good-design-practice yields higher savings. Fiscal incentives furthermore are assumed to pay off for part of the additional machinery costs for implementing even more improvement options than in the LLCC scenario. This option results in savings estimated as slightly higher, of a minimum 38 PJ per year in 2025, compared to BAU.
- **10% VA:** A Voluntary Agreement is implemented hypothetically, setting a target that all machine tools sold in 2014 and thereafter should be, on average, 10% less energy-consuming than in 2010. **PCF (Product Carbon Footprint) label:** For light-stationary machine tools an effective PCF label scenario is calculated.

A combination of both a Voluntary Agreement with 10% reduction target, and an effective (regardless of whether mandatory or voluntary) PCF label for small units, yields an estimated total saving of 74 PJ per year in 2025, or 9% compared to BAU.

Given the typically long lifetime of the machinery considered (six out of nine Base Cases have an estimated lifetime of 17-20 years), any implemented measure is projected to yield significant overall savings results only over the mid- to long-term.

## 7 Task 7 – Policy and Impact Analysis

Product groups regulated under the ecodesign directive 2009/125/EC have to meet three criteria (Art. 15):

(a) the product shall represent a **significant volume of sales and trade**, indicatively more than 200 000 units a year (...)

(b) the product shall (...) have a **significant environmental impact** within the Community

(c) the product shall present **significant potential for improvement** in terms of its environmental impact without entailing excessive costs, (...)

Criterion (a) is met for the products falling under the definition of “machine tools” in task 1 as a whole (see Task 2).

Regarding criterion (b), Task 4 provided the relevant calculations: Total environmental impact in terms of total energy consumption is 646 PJ. The total energy consumption of all Base Cases is 646 PJ per year, of which 59,9 kWh is electricity. Aggregated Greenhouse Gas emissions total 28 million tonnes CO<sub>2</sub>-equivalents per year (Base Cases do not fully cover the total stock of machine tools).

Criterion (c) is addressed in Task 6: The analyses performed showed that the combination of options assessed leads to moderate Total Energy savings potentials at the point of Least Life Cycle Costs, which are in the range of 3-5% for the most relevant Base Cases. There are some indications that for individual machine tools significantly higher savings can be realised. It has to be noted that such a savings potential will be realised only slowly, as replacement rates are low, and older equipment will represent a significant share of the stock for the mid-term future (see 7.2).

As no further guidance is provided in the directive regarding the meaning of significant impact and savings potential no definite legalistic conclusion is possible, regarding whether this product group qualifies for policy measures at all. Having said this, the annual energy consumption EU-wide of the product group as a whole is considerable, and this energy use is embedded, in turn, in the products made for many sectors, in many industries, by the machine tools being addressed here. Therefore, the following policy analysis discusses the feasibility of which policy measures should be adopted, how and when.

## 7.1 Policy Analysis

This Subtask aims at introducing and discussing the range of policy options which could be subject to later regulation on the part of the policy-maker. A critical review of each option takes into account evidence provided by all previous tasks. Aside from possible implementing measures, it should be pointed out that in some part of the machine tool industry energy efficiency measures are already promoted voluntarily.

Policy options for machine tools and related machinery have to consider multiple aspects:

- Nature of measure
- Reference for specific requirements
- Type of implementation
- Product definition
- Sectoral scope

Any policy option has to be assessed against the following criteria:

- Market coverage
- Significant impact in terms of reduced environmental impacts
- Measurable criteria
- Availability of test protocols / standards

### 7.1.1 Nature of measure

Measures, first of all regardless of the policy tool used, can comprise:

- Minimum environmental performance criteria
- Power management requirements
- Information/ declaration requirements
- Good-design-practice Checklists.



Measures can be combined: A good-design-practice checklist could cover minimum environmental performance criteria and power management requirements. Information / declaration requirements could cover any of the other measures.

Minimum environmental performance criteria as a possible implementation measure impose clear and uniform rules to the manufacturer. Previous tasks demonstrated that generalization and thus making general assumptions and statements is difficult, considering the pronounced heterogeneity of the product scope, as identified in Task 1. However, it should be investigated if certain measures are useful in terms of appropriateness and effectiveness (with regard to the policy option criteria). As reasons for energy inefficiency in machine tools can be manifold, the preceding analysis has revealed that especially highly automated machines can have significant losses during non-productive periods, due to a substantial base load demand. These effects occur where the machine does not have appropriate operating power modes, or where they are not configured appropriately, such as automated stand-by after a defined period. According to the analysis in Tasks 1-6, following **minimum environmental performance criteria** are of priority relevance:

- *Electricity consumption*

For some applications further media are relevant, such as

- *Pressurized air / vacuum consumption*
- *Cooling lubricant consumption*
- *Welding gas consumption*

**Table 7-1** lists the consumption of relevant media and utilities. Most machine tools consume only a selection of these. Examples are provided, which utility is relevant for which type of machinery / equipment.

The multitude of machine tools applications and the specifics of these applications, as analysed in the preceding Tasks 1-6, does not permit the definition of general minimum environmental performance criteria for these types of utilities and media consumption.

Measurement procedures for electricity and fluids consumption are described in SEMI S23 Application Guide and Total Equivalent Energy (TEE) CalcII User's Guide as Recommended Practices for Utility Measurement<sup>1</sup>.

**Table 7-1: Utility and media consumption metrics**

Utility or Material	Basic Use Rate Metrics and Units <sup>2</sup>	Remarks
Electricity	Real Power (Watts)	Most relevant parameter for all types of machine tools
Exhaust	Pressure (Pa); Flow (m <sup>3</sup> /h); Inlet Temp (°C); Outlet Temp (°C)	Relevant for several types of machine tools, in particular also for wood working machinery, but exhaust system typically is not an integrated part of the machine tool and therefore out of scope; relevant e.g. for semiconductor manufacturing equipment
Vacuum	Pressure (Pa); Flow (m <sup>3</sup> /h)	Relevant for numerous machine tools
Dry Air / Nitrogen (N <sub>2</sub> )	Pressure (Pa); Flow (m <sup>3</sup> /h)	Relevant as pressurized air for numerous machine tools, nitrogen being relevant as shielding gas for thermal processes e.g. in semiconductor manufacturing
Cooling Water	Supply Pressure (kPa); Return Pressure (kPa); Flow (l/h); Inlet Temp (°C); Outlet Temp (°C)	Relevant for e.g. tool cooling, laser source cooling and thermal processes in semiconductor manufacturing
Ultrapure Water (UPW)	Purity Requirements; Inlet Temp (°C); Flow (l/h)	Relevant for some semiconductor manufacturing equipment
Cooling lubricant consumption	Flow (l/h)	Relevant for working of metal and other hard materials
Welding gas consumption	Type; Flow (l/h)	Typically depending on user settings

Electricity consumption requirements need to be defined on a thorough modes definition. ISO 14955-1 (Draft) defines the operating states for metal working machine tools and Table 7-2 provides an abridged version of these in comparison with the modes defined for arc welding equipment in IEC 60974-1 ed.4 (FDIS), and SEMI S23 for semiconductor equipment.

<sup>1</sup> referencing SEMI E6-0303 Guide for Semiconductor Equipment Installation, SEMI S23-0708, Guide for Conservation of Energy, Utilities, and Materials Used by Semiconductor Manufacturing Equipment, and Semiconductor Equipment Association of Japan (SEAJ) E-002E, Guideline for Energy Quantification

<sup>2</sup> Corresponds with the metrics defined in SEMI S23 for semiconductor manufacturing equipment where these are affected

**Table 7-2: Comparison of modes and states of operation**

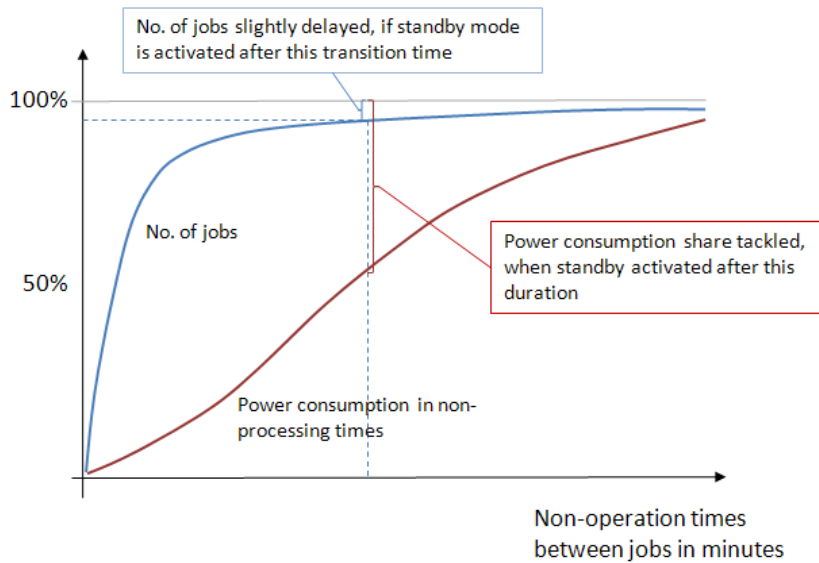
SEMI S23	ISO 14955-1 (draft)		IEC 60974-1 ed.4 (FDIS)
	metal-cutting machine tools	metal-forming machine tools	
<b>process mode</b> - equipment is energized and performing its intended function on target materials	<b>processing</b> - mains ON, machine control ON, peripheral units ON, machine processing unit ON and MACHINING, machine motion unit ON and axes MOVING	<b>cycling</b> - mains ON, control voltage ON, peripherals ON, all drives ON and axes MOVING	Not defined
<b>idle</b> - equipment is energized and readied for process mode (all systems ready and temperatures controlled) but is not actually performing any active function such as materials movement or processing	<b>warm up</b> - mains ON, machine control ON, peripheral units ON, machine processing unit ON but no machining takes place, machine motion unit ON and axes MOVING	<b>ready for operation</b> - mains ON, machine control ON, peripherals ON, all drives ON	<b>idle</b> - operating state in which the power is switched on and the welding circuit is not energized
	<b>ready for operation</b> - mains ON, machine control ON, peripheral units ON, machine processing unit ON HOLD, machine motion unit ON HOLD (ON HOLD describes the situation where the unit is ON but not operating, i.e. no processing takes place, no movements are carried out)		
<b>sleep</b> - equipment is energized but it is using less energy than in idle mode; initiated by a specific single command signal, either from an equipment actuator, an equipment electronic interface, or a message received through factory control software	<b>extended standby</b> - Mains ON, machine control ON, peripheral units ON, machine processing unit OFF, machine motion unit OFF	<b>extended standby</b> - mains ON, machine control ON, peripheral units ON, auxiliary drive(s) ON, main drive(s) OFF This state is an intermediate state and the machine tool is remaining in it until enabled for main drives – e.g. until oil temperature is in an admissible range	
	<b>standby</b> - Mains ON, machine control ON, peripheral units OFF, machine processing unit OFF, machine motion unit OFF	<b>standby</b> - mains ON, machine control ON, peripheral units ON, all drives OFF	
Not defined	<b>off</b> - Mains OFF	<b>off</b> - Mains OFF	<b>standby</b> - non operating state in which the supply circuit on/off switching device is off

The *provision of an interface to an external or internal energy monitoring and control system* could be a mandatory requirement for CNC machine tools. Such an interface optionally should enable any of the following:

- Stand-alone solutions are designed in such a way that they can be applied for a broad variety of machines; hence, that there is a very low need of specialized machine interfaces.
- Module-based systems are functions usually integrated into the CNC-control software by the control unit manufacturer, in which energy consumption-related PLC commands are addressed.
- As far as external and factory integrated systems are concerned, PROFIenergy is a widely-used protocol in the mechanical engineering industry. Its implementation, however, requires the existence of a communication infrastructure based on the open industrial Ethernet standard PROFINET.

**Power management** requirements have a high potential for improvement, but quantitative requirements (transition times from one mode to another, or even power consumption thresholds in distinct modes) are difficult to quantify across technologies. Productivity is severely hampered, if too short transition periods from any processing mode to a sleep/ standby mode of the machine tool, or parts thereof are made obligatory. This is because warm-up and bringing back the machine to full operating state delays the processing. However, for a given application scenario (job sequence), it is possible to identify a transition time to low-power modes which do not interfere with the majority of jobs which the machine has to handle, but which still allow significant power savings (see schematic graph below).

Typically, for a given application, a correlation can be established between the time span between individual processing jobs and the number of jobs, which are initiated after the respective time span. Such a correlation allows the identification of a suitable transition time, but essentially requires an analysis per individual use case.



**Figure 7-1: Schematic illustration of time between jobs vs. number of jobs**

Given the anecdotal evidence provided by a bending machine manufacturer, for bending the vast majority of jobs (>95%) is initiated latest 7 minutes after the preceding job.

Power management requirements need to be based on mode definitions as provided in Table 7-2.

Power management requirements could be formulated as follows:

- *Provision of a manual low power option:* In case the operator wants to interrupt the process on the machine due to a scheduled break or an unexpected event, the machine should be equipped with a stand-by mode which can be triggered manually.
- *Set a transition time to a low-power mode:* At least "x" minutes (e.g. 10 minutes) after the mode idle / ready for operation / warm up is entered and no processing job is initiated, the machine tool should automatically switch into a low-power mode (sleep / extended standby / standby).
  - The operator should be able to change the settings for the transition time to the low power mode
- *Set a minimum reduction target regarding power consumption in low-power compared to idle/ ready for operation:* In low-power mode the machine tool should consume maximum "x" % of the power consumption in idle/ ready for operation (given the evidence provided in Task 5, an appropriate level for "x"

could be 20%). Even if in idle / ready for operation modes certain auxiliary units are powered down, this should count towards the power reduction in low-power mode.

- The power savings in low-power mode should be stated in %.
- If power savings on the required level cannot be achieved, a justification must be provided
- Remark (1): Without defining a quantified or at least a relative consumption reduction target, there is the risk that the power management requirement is implemented with only a negligible power consumption difference between modes, thus limiting the potential for greater savings.
- Remark (2): Taking the idle/ ready for operation mode as benchmark bears the risk that this mode is implemented with high power consumption just to achieve the reduction target – therefore power saving features implemented for this mode should already count towards the reduction. Similarly, taking the process mode as a reference would result in the additional effect that power consumption in this mode depends on numerous process parameters and thus could only be determined with difficulty.
- Definition of a low-power mode should follow those provided in Table 7-2:
  - For metal cutting machine tools: Mains ON, machine control ON, peripheral units OFF, machine processing unit OFF, machine motion unit OFF.
  - For metal forming machine tools: Mains ON, machine control ON, peripheral units ON, all drives OFF.
- Remark: This approach requires individual operation state definitions for different types of machine tools, with respect to technological differences

If the machine tools manufacturer does not implement a default transition time to a low-power mode or any other requirements, this must be justified (see also the acceptable justifications provided below, in the paragraph on good-design-practice checklists). Energy management requirements may also be applicable solely for machine tools with an advanced level of automation (also see level of automation classification in Task 1).

Power management at the machine tools level is important, but generic requirements could be set at a broader level, as the power management of a machine tool should

enable not only a “machine-wide” low power mode, but should also enable the powering down of its auxiliary units and parts (e.g. pumps, using variable speed drives), whenever these are not needed, or are run under reduced load. This is a much more complex approach, as it has to reflect the individual configuration and use patterns of machine tools in detail. Therefore, such kind of component-wise power management rather qualifies as a generic design requirement and could be formulated as follows: All [major] power consuming sub-components shall feature the possibility to be switched to a low- or no-power-mode automatically, if no function is provided and if this feature does not entail the following issues: performance losses, conflicts with safety requirements, or if it leads to additional costs which exceed potential energy savings under typical production conditions (to be documented).

It should be noted that compliance with any quantitative requirement (e.g. power consumption in a low-power mode in relation to idle/ ready for operation mode) can only be verified by the machine tools manufacturer once the whole machinery has been constructed and is running for the first time. Given the complexity of machine tools, it is only at this point that reliable measurements are possible. Therefore, where measurement show non-compliant results, a redesign of the machine tool would typically mean excessive costs to implement changes. For custom-made machine tools (which are a major share of the total market) this is even more challenging, as every machine tool has to be subject to such measurements.

**Information/ declaration requirements** are targeted at

- the machinery purchaser, who should be supported in their purchase decisions
- the machinery operator, to inform and enable him/ her to make use of energy-saving features and other environmental performance settings
- the wider public/ policy-makers/ market surveillance authorities, to review the impact of any policy measure.

For the purchaser, a transparency and comparability of life cycle costs is essential. Therefore a *standardised life cycle costs calculation*, including electricity and media costs, should be provided by the machinery manufacturer, unless the purchaser specifies a life cycle costing scheme of their own. The only standard currently available is *VDMA Einheitsblatt 34160:2006*, for which VDMA also provides a comprehensive suite

of Excel tools for calculations<sup>3</sup>. Although allowing for a very transparent calculation, the consideration of energy consumption in use in various modes requires some additional assumptions, for which VDMA Einheitsblatt 34160:2006 does not provide detailed guidance.

Furthermore, the purchaser should get access to information about the *design features* (design checklist results as outlined above) related to reduction of environmental impacts. This allows for a certain transparency regarding the design measures implemented, and enables the purchaser to specify in detail that certain criteria of the checklist should be met.

The declaration should also include *power (and possibly media) consumption in the various modes* defined above, including a description under which settings consumption was measured<sup>4</sup>. The list of utility and media consumption depicted in Table 7-1 should be provided. Furthermore, *power management default settings* need to be explained in the declaration (the sequence in which the machine tool enters a power saving mode).

For the operator, instructions are required, relating to:

- *how power management settings could be changed*, including information regarding the impact on power and media consumption (information to be provided in the manual and by the CNC system, if applicable)
- *any other instructions*, which enable the operator to operate the machine tool in a manner which reduces environmental impacts

The control panel menu should feature:

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3 Download:  
[http://www.vdma.org/wps/portal/Home/de/VDMAThemen/Management\\_und\\_Recht/Management/BW\\_Download\\_LCC\\_Berechnungswerkzeug?WCM\\_GLOBAL\\_CONTEXT=/vdma/Home/de/VDMAThemen/Management\\_und\\_Recht/Management/BW\\_Download\\_LCC\\_Berechnungswerkzeug](http://www.vdma.org/wps/portal/Home/de/VDMAThemen/Management_und_Recht/Management/BW_Download_LCC_Berechnungswerkzeug?WCM_GLOBAL_CONTEXT=/vdma/Home/de/VDMAThemen/Management_und_Recht/Management/BW_Download_LCC_Berechnungswerkzeug)

4 The Federal Environmental Agency proposed to require potentially a sensitivity check, or an online tool to calculate energy consumption under specific settings. However, a sensitivity analysis would be even more challenging to provide as this would not only require the definition of one test workpiece / cycle etc. (see 7.1.2), but also alternatives to these and to undertake related measurements. A calculation tool would require the development of parameterized calculation models, i.e. a machinery simulation, which would indeed allow a customized calculation but requires extensive parameter testing for each machine tool individually.



- *power (and media) consumption values* in real time (for the machine tool as a whole) and a historic energy consumption profile (minimum time frame: 24 hours)
- *level of refrigerants and status of oils* in the system. in order to identify losses.

The control panel menu could feature:

- *power (and media) consumption values in real time* (at the component / sub-module level) and a historic energy consumption profile,
- *a warning before a low-power mode* is entered automatically.

For market surveillance (under any type of implementation), it is essential that certain data on the environmental performance are provided, which could include:

- power consumption savings compared to a "standard machine tool" (which requires the definition for a comparable standard machine tool, which is problematic, considering the interruptive new technologies and performance levels, which were not achievable with previous machinery designs). The CECIMO SRI proposal (work in progress) is based on this approach.
- power consumption in absolute terms (requires the definition of "typical" use patterns).

Even without setting any performance thresholds, information requirements as stated above could help to close knowledge gaps in terms of the performance of machine tools on the market at large. This could be instrumental for the revision of any policy measure, since it will serve as the basis for setting further requirements reflecting the status of the market and its evolution.

A **screening Life Cycle Assessment** could provide user information in terms of environmental performance throughout the product life cycle. Standards are in place (ISO 14.040), but still lack detail to make them applicable unambiguously. Requiring any LCA data for complex investment goods, such as machine tools, solely on the basis of the ISO standards or similar could risk incentivising the misuse of the concept of LCA. In January 2012, product category rules (PCR) were published for CPC Subclass 44214: Machines-tools for drilling, boring or milling metal v1.0, based on CTME's prac-

tical experience with LCAs for machine tools<sup>5</sup>. Although this PCR is a huge step forward towards unambiguous guidance, regarding how LCA data should be calculated (via its definition of background data for upstream processes, system boundaries and cut-off criteria, functional unit, etc), it still lacks a standardisation of the use scenarios, which hampers a fair comparison of machine tools (see discussion on test workpieces below, which would be required as well as a reference unit for LCA calculations). Consequently, the above-referenced PCR does not qualify as a mandatory requirement; however, it could be a component in voluntary activities to enhance information flow. Only for rather simple equipment is such an LCA approach potentially feasible, via a policy framework. For light-stationary tools/ power tools an EPTA working group drafted a procedure for measuring Product Carbon Footprint of power tools. EPTA is currently evaluating this procedure with several of their members during 2012 and will compare results later in the year<sup>6</sup>. The methodology is not published yet, and was not accessible to Fraunhofer, but given the rather narrow field of equipment covered, it might be specific enough to allow for credible publication of comparable Product Carbon Footprint data.

**Good-design-practice checklists** are a somewhat “soft” requirement as these outline numerous design aspects, which then have to be checked by the designer regarding suitability for implementation. Designers could be required to state for each design measure how it was addressed, and where it was not addressed, to provide a full explanatory justification. Examples of acceptable justifications are:

- Measure is technologically not applicable for a given machine tool (e.g. requirement for an improved vacuum system where there is none)
- Measure would not result in relevant savings, due to certain specifics of an application (e.g. high-efficiency motors mounted on a movable axis result in increased moved masses, thus higher power consumption), calculation to be provided
- Measure is in conflict with another measure with a higher impact (e.g. implementation of an electrical drive which could simultaneously be replaced by a variable speed drive pump for a hydraulic system, or implementation of an en-

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<sup>5</sup> Product Category Rules (PCR) for the assessment of the life-cycle environmental performance of UN CPC 44214 "Machine-tools for drilling, boring or milling metal", <http://www.environdec.com/en/Product-Category-Rules/Detail/?Pcr=7945>

<sup>6</sup> See also: EPTA: Flyer on Product Carbon Footprint, January 12, 2011, [http://www.epta.eu/upload/2011-02-01\\_PCF-FLYER\\_701.pdf](http://www.epta.eu/upload/2011-02-01_PCF-FLYER_701.pdf)

ergy-efficient axis-drive which simultaneously could be replaced by a counter-weight balance), correlation to be explained

- Measure results in significant negative impacts on productivity and/or yield (e.g. a stable machinery temperature is essential for high precision micro-machining equipment, hence shut-down in production breaks is not tolerable)
- Measure is in conflict with safety requirements
- Measure would not result in a return on investment (ROI) within an acceptable timeline (acceptable timeline to be defined), total-costs-of-ownership calculation to be provided

Existing good-design-practice checklists and similar, which could constitute a basis for any measures, are:

- *Measures listed in Task 4* (basically for all types of machinery covered by the scope of the study, but as yet not formulated as design checklist, covering life cycle aspects beyond energy in use)
- *Informative Annex of ISO 14955-1* (metal working machine tools only, energy in use only)
- *IHOBE: Guías sectoriales de ecodiseño – Máquina herramienta*, February 2010 (metal working machine tools only, description of individual measures, partly company specific solutions, covering life cycle aspects beyond energy in use, in Spanish only)
- *EN 14717:2005: Welding and allied processes — Environmental check list* (for welding equipment only, very generic guidance only: the focus is on proper operation of the equipment, but less on equipment design as such, additional aspects beyond energy consumption covered)
- *SEMI S23-0311: Guide for Conservation of Energy, Utilities and Materials used by Semiconductor Manufacturing Equipment* (for semiconductor manufacturing equipment only)

Regarding SEMI S23, it should be noted that some semiconductor manufacturing equipment is basically covered by the scope of the study as “machine tools” and overlaps also with the metal working machine tools (e.g. wafer saws, laser drilling etc.), but other types of semiconductor manufacturing equipment are covered only as “related

machinery”, i.e., at the modular level (e.g. lithography equipment, plasma etching, sputtering).

The good-design-practise checklist approach principally incorporates the peculiarities of the product scope. It considers uncertainties in product properties and provides the greatest possible freedom in implementing individual efficiency measures for the manufacturer. This approach is supported by CECIMO’s SRI concept in which it is stated that “the complexity of the individual machine tool types within the given product group is challenging and not obviously definable. Talking about machine tools means describing a product group with about 400 different types/ machines categories and defining a product group with about 2.000 different machine tools.” Hence, the “comparability between machine tools is limited” and “a functional unit of a machine tool cannot be defined unambiguously”.<sup>7</sup> This appraisal corresponds with evidence provided in Tasks 1-6. To fulfil basic assessment criteria as stated above, and to achieve a wide market coverage, the good-design-practice checklist should either be:

- Generic for all of the ENTR Lot 5 scope, i.e., including all related machinery and components; or
- Specific for technologically-similar machine tools (which requires a distinction of cutting, forming and joining machinery types, differentiating metal, wood and other material processing).

The market coverage can additionally be extended if the checklist is to be used when retrofitting machine tools. The checklist can be combined with standardised process media measurement methods, since a fundamental analysis of the current state of the energy profile of the product is required initially. The checklist and measurement methods should give information about the determination of system boundaries, the definition of existing operating states, functions, modules, and typical use profiles from the customers. It should be clarified at the beginning, if such measurement should allow the comparability of different machine tools (e.g. for a certain machining tasks) or individually (existing methods will be introduced when referencing specific requirements, later in this task).

Thus, besides a basic selection of technological and organizational improvement options, the checklist as a whole needs to subsume further tools and methods, to: (i) ana-

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<sup>7</sup> CECIMO: *Concept Description for CECIMO’s Self-Regulatory Initiative (SRI) for the Sector Specific Implementation of the Directive 2005/32/EC (EuP Directive)*, 2009.

lyze and decipher the current state; (ii) identify energy intensive functions and modules; (iii) develop an overall concept; (iv) assess, select, and implement design features; and (v) monitor and record the process.

### 7.1.2 Reference for specific requirements

Any specific requirement needs a well-defined reference basis:

- consumption per machine tool/ module (absolute values)
- consumption per machine tool/ module compared to a standard configuration (relative improvement)
- consumption per work piece/ output/ cycle (productivity, efficiency)

A requirement regarding consumption per workpiece/ output/ cycle requires the definition of either

- a test workpiece; or
- a standard test cycle.

Both approaches do not necessarily approximate the real application of the machine tool, and thus they might result - in individual cases - in non-optimal machinery use, for specific use patterns/ cycles.

The **test workpiece** approach allows the definition of an exact product reference for benchmarking, taking into account also productivity. However, this approach is limited, for two reasons:

- *Test workpieces are not (yet) available for all technologies.* There is no all-inclusive “test workpiece” suitable for all types of machine tools. Instead, technology-specific standard work pieces need to be defined, reflecting the processing type (milling, cutting, forming etc.), machine type (number of axes), quality (surface roughness), and certain general performance criteria, if needed (micro machining, high speed processing etc.). Such test workpieces have been defined e.g. by the German NC-Gesellschaft e.V. (NCG) to allow for a performance assessment of various metal working machine tools, used for acceptance testing (see Table 7-3). Typically, test workpieces are also defined by customers to reflect their individual preferences. Standardized (by the NCG or others) test workpieces are not available for all types of machine tools, not

even for the complete range of metal working machine tools<sup>8</sup>. Hence, some form of test workpiece standardisation would be required before this could be made the sole reference point for (energy) consumption.

**Table 7-3: List of selected test workpieces**

Test workpiece	Reference
Test workpiece for 5-axis micro-milling machines	NCG-2007, Mikroprüfwerkstück für 5-Achsen-Mikrofräsmaschinen (under development), NC-Gesellschaft e.V.
Test workpiece for water-jet cutting	NCG-2006, Prüfwerkstück für Wasserstrahlschneiden, NC-Gesellschaft e.V.
Test workpiece for five-axis simultaneous milling machining	NCG-2005, Prüfwerkstück für die 5-Achs-Simultan-Fräsbearbeitung, NC-Gesellschaft e.V.
Test workpiece for High Speed Cutting	NCG-2004, Prüfrichtlinien und Prüfwerkstücke für hochdynamische Bearbeitungen (HSC), NC-Gesellschaft e.V.

- *Common test workpieces do not reflect the specifics of a distinct application.* By nature, test workpieces are rather intended to test the limits of a machine tool, not to represent a typical, average processing task. Consequently, power consumption values measured for a test workpiece will deviate from the power consumption for the later real application. However, test workpieces should be suitable to benchmark power consumption of different machine tools (which are intended for the same purpose).
- *Definition of suitable common test workpieces affects Intellectual Property of machinery manufacturers.* Knowledge about the distinct operation of machines and typical production tasks is considered valuable know-how and a competitive advantage by (some) machinery manufacturers. Willingness to share such information with the public is low. It might be acceptable, if an intermediate (such as an Independent Inspector under a Voluntary Agreement) were given access to the test workpiece design and was allowed to verify measurements. However, even under such conditions, each manufacturer would develop individual company sample parts, which would then only allow the calculation of (and disclosure of) a kind of “fleet consumption”, or “fleet efficiency” (and related year-to-year changes), and would not allow the comparison of machine tools from different manufacturers. Consequently such an approach could work under a Voluntary Agreement, but has limitations with regard to user informa-

<sup>8</sup> JMTBA points out in a stakeholder comment, that “even if each manufacturer in each country collects the machining data by different workpieces, the consumer and industry can be expected to be confused.”

tion. Basically, the approach of *individual test workpieces* could work as follows:

- Every machine manufacturer defines a set of sample parts which represent his market, considering materials, geometries (both of the processed input material and the product output), and quality requirements.
  - Such a set of sample parts would have to remain unchanged for a longer period of time, to allow for year-to-year comparisons.
  - Energy and consumption of other media for processing these sample parts (potentially including also non-operational times, see below) is measured and calculated as efficiency indicator(s) for each type of machine tool in the individual portfolio of a manufacturer.
  - Based on efficiencies of each type of machine tool, a use scenario and annual sales figures for an annual "fleet" consumption and efficiency is calculated.
- *Common test workpieces would always disadvantage some manufacturers, because their machines are optimised for another market segment.* In this case manufacturers would then be faced with the choice of either optimizing their machines for the common test workpieces or for their customers (and thus implementing options which lead to real energy savings in production)
  - *Quantifying the environmental impacts on a per test workpiece basis does not include the aspect of down time, and other non-operational period of time.* As the analyses in Tasks 4-6 show, the non-productive times are among the most relevant aspects in terms of environmental impacts, and also represent a significant potential for improvement. These aspects can be addressed only if a standard test cycle is referenced.

A **standard test cycle** for metal working machine tools is currently under development by the German NC-Gesellschaft e.V. (NCG)<sup>9</sup>. The first discussion draft of this test cycle is defined as a 15 minutes cycle, 50% thereof tools change time, 25% machining time and the remaining 25% standby time. The tools change cycle is defined in several steps, starting from a status where the main spindle(s), pumps and chip conveyor are

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<sup>9</sup> Kaufeld, M.: Energieeffizienz – eine Kennziffer á la NCG für den Anwender, nc transfer, no. 49, September 2011

switched off, covers tool placement in the magazine, rotation of the magazine, tool fitting, movement of all axes back to the working space, cooling lubrication system and chip conveyer activated. This cycle is repeated for 7,5 minutes. The machining time is represented by simultaneous oscillation and rotation of all axes for 3,75 minutes, followed by 3,75 minutes all drives switched off or in stand-by respectively. Based on this cycle a technology independent energy efficiency indicator  $EE_{NCG}$ , including electricity and compressed air consumption, is proposed with correction factors for travelling distances of X-, Y-, Z-axes, rotation angles, pressure of the cooling lubricant system, maximum rotational speed, movement speed:

$$EE_{NCG} [1/(kW/h \cdot m^3/h)] = (n \cdot 4) / (E_{electr} \cdot Q_{compr\_air})$$

Such an approach allows the measurement of more realistic power (and compressed air) consumption, although there will be operation scenarios, where much less frequent tool changes are required, or where typically there are much longer standby times.

This test cycle is applicable for machining centres (intended for metal working, but a similar cycle with minor modifications seems to be applicable for woodworking machining centres as well). Similar test cycles are not yet defined for other machine tools and related machinery, such as presses, saws, welding equipment etc.

An alternative approach to **quantify consumption per output** is based on the amount of material processed. This approach is applied for example for plastics injection moulding (see EUROMAP 60, referenced in Task 1), but is not suitable for other than primary shaping processes. Although a machine which is able to remove more material with the same amount of energy is more efficient than another which consumes the same energy, but at a lower material removal rate, this approach is clearly hampered when considering other technical parameters, in addition. Taking the amount of material removed as a basis to assess cutting machine tools would incentivise machine tools with a high removal rate at low accuracy. For bending machine tools, a suitable reference is completely missing. For welding, a typical process/ equipment parameter is the length of the welding seam produced in a given time. However, this parameter depends on numerous other characteristics, such as:

- Welded material(s)
- Weld wire material
- Material thickness
- Welding seam geometrics.



### 7.1.3 Type of implementation

Any requirements could be implemented through various means:

- Implementing measure
- Voluntary Agreement / Self-Regulatory Initiative
- Energy Efficiency Labelling
- Fiscal instruments.

An **Implementing Measure** actually could be based on the same standards as a Voluntary Agreement, i.e. SEMI S23 for semiconductor equipment or ISO 14955-1 for metalworking machine tools. According to the analysis above, an implementing measure could include:

- Mandatory requirements to apply certain standards for machinery design, or to apply similar design checklists for types of machine tools for which suitable standards are not available (to be developed, provided as an annex to the implementing measure)
- Mandatory power management requirements (as outlined above)
- Mandatory declaration requirements (as outlined above)

Taking the machinery directive as a blueprint for an ecodesign implementing measure could result in an approach, which references the several standards to be applied.

Certain types of machine tools could be exempted, if a Voluntary Agreement is in place for this sector. Alternatively, the only manufacturers exempted from the Implementing Measure might be those which have previously signed a Voluntary Agreement endorsed by the European Commission.

A **Voluntary Agreement** or Self-Regulatory Initiative is under development for the metal working machine tools sector only (CECIMO SRI). For semiconductor equipment, a standard has been developed (SEMI 23), which could serve as the basis for a Voluntary Agreement, in addition. The Annex (Section 7.3) to this Task 7 report lists an abridged extract of criteria which a Voluntary Agreement should meet, in order to be acceptable as an alternative to an implementing measure.

The operational framework of the CECIMO SRI has not yet been developed in detail. A draft of ISO 14955-1, which will define the basic approach for a self-assessment of a machine tool, is available, but besides the initial position papers and later presentations by CECIMO no draft SRI document is available as yet. As it stands today, the SRI is characterised as follows:

- No quantifiable minimum environmental performance criteria are defined
- Good-design-practice Checklist as an informative Annex of ISO 14955-1 (draft)
- Power management requirements covered through the checklist approach
- Information/ declaration requirements are not yet defined, but mandatory publication of the checklists could be a way forward
- Benchmarking with a “standard” machine tool is intended, but the standard machine tool is to be defined by the manufacturer, which is extremely difficult to achieve, unambiguously.

**Table 7-4: Assessment of the CECIMO SRI for metal working machine tools**

Criteria	CECIMO SRI
Market coverage	<ul style="list-style-type: none"> <li>• High coverage to be expected, but no signatories confirmed yet; no proposal yet how to cover imported machine tools by non-CECIMO member countries</li> </ul>
Significant impact in terms of reduced environmental impacts	<ul style="list-style-type: none"> <li>• Checklist approach deemed appropriate to realise maximum impact, leaving the machinery developer with high flexibility regarding design decisions</li> <li>• Focus on energy consumption in use phase only</li> </ul>
Measurable criteria	<ul style="list-style-type: none"> <li>• Criteria partly quantifiable (power consumption in various modes), but most are generic criteria</li> </ul>
Availability of test protocols / standards	<ul style="list-style-type: none"> <li>• ISO 14955-1</li> </ul>

The "Blue Competence" initiative was recently extended to the European level for metal working machine tools, and is now operated by CECIMO at EU level. At the German level, as initiated by VDMA, this initiative covers many more sectors than purely metal working machine tools, namely also<sup>10</sup>:

- Power transmission
- Lifts and escalators

<sup>10</sup> [www.bluecompetence.net](http://www.bluecompetence.net)

- Foundry machines
- Metallurgical Plants and Rolling Mills
- Intralogistics
- Precision tools
- Robotics and automation
- Textile machinery
- Thermo process technology
- Fluid power
- Plastics and rubber machinery.

With this broad scope, several sectors are covered, which comprise also “related machinery”. Machine tools manufacturers joining the Blue Competence initiative “commit to promote sustainable product development and production process design by implementing actions in the following fields: energy, raw materials, emissions, waste and recycling managements, clean production and life cycle cost. The *Blue Competence Machine Tools* initiative is a voluntary initiative which is open to the participation of companies from across Europe. Companies which show convergence with the sustainability principles agreed upon in the Blue Competence charter can apply to become partners of the Blue Competence initiative.”<sup>11</sup> Further details are provided in the press release<sup>12</sup>:

Under the heading “manufacturing in Europe” the nature of companies invited to join the Blue Competence Initiative is explained: “*Only manufacturing companies producing machines or subsystems for working of metal and related materials who carry out at least two of the following three activities "design", "production and assembly" or "sale" in Europe can become a partner of Blue Competence Machine Tools.*” This restriction to European manufacturers might be in conflict with the fact that the ErP directive addresses all products brought on the market in the EU-27, regardless of whether they are manufactured in the European Union or are imported.

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<sup>11</sup> Invitation to the press conferences on February 17 and 29, 2012

<sup>12</sup> CECIMO: The European Machine Tool Industry drives sustainability into the heart of manufacturing under the Blue Competence Initiative, press release, 17 February 2012, Brussels

Requirements to be fulfilled address two levels: the company level, and the product level. Regarding the product level, a criteria catalogue is provided as follows:

*“2. Substantive technical preconditions*

*A Reduction in moving masses*

*B Use of energy-efficient components and subsystems*

*C Support for the operator in optimising energy consumption (e.g. monitoring)*

*D Provision for recovering/re-using energy and/or waste heat*

*E Avoidance/shortening of start-up and warm-up phases, or energy-saving stand-by concepts based on appropriate design measures or control system features*

*F Monitoring to detect leaks and losses of gas and fluids and consumables*

*G The product meets other criteria with an impact on sustainability (please indicate which criteria)*

*At least three of the technical preconditions shall be met, and none of the technical preconditions shall be infringed by products manufactured by any company that advertises using the Blue Competence trademark. Appropriate documentation shall be drawn up and kept safe in the company concerned, enabling it to be viewed as needed.”*

This criteria catalogue is an abridged version of a Best-practice-design-Checklist and is thus compatible with the checklist approach outlined above. *“The Blue Competence Machine Tools initiative is based on a self-declaration principle. Partner companies choose which preconditions are fulfilled according to the list of possibilities given in the contract.”* With respect to monitoring, the press release states: *“The Blue Competence Machine Tools trademark will not be developed into a product certification (even if a standard would exist). There are also no audits foreseen in this certification context. However, this decision could be reviewed over time.”*

The Blue Competence initiative clearly has an impact on the machinery sector, regarding the communication of environmental performance, and features some elements which are essential for a Voluntary Agreement. However, Blue Competence still lacks some components and defined targets to make it a valid alternative to an implementing measure, as explained below.

For example, **Energy efficiency labelling** of machine tools could be developed under the energy efficiency labelling directive, which, since its last revision, covers the same scope as the ErP directive.

Energy efficiency labelling requires the definition of energy efficiency classes and an energy efficiency indicator. Such an indicator has been proposed by the NC-Gesellschaft (see standard test cycle above), which by now is the most advanced approach so far.

As the draft energy efficiency indicator was published only in September 2011, no statistical market data for related indicator results is available, nor does this study provide a statistical survey of the power consumption of a larger number of individual machine tools. Such kind of data is not currently available.

Consequently, the development of an energy efficiency label for machine tools would require the following activities:

- (1) Defining an energy efficiency indicator and establishing a testing and calculation method (e.g., based on the indicator under development by the NC-Gesellschaft)
- (2) Obtaining statistical data on machine tools performance
- (3) Defining suitable classes for the energy efficiency label.

Once step 1 is completed, step 2 could be supported by a mandatory requirement to test every machine tool according to the test cycle defined in step 1, and to disclose related data. Hence, the possible introduction of an energy efficiency label could then be considered in a later stage.

Several stakeholders suggested or at least touched on the possibility of an energy efficiency label for various types of machinery in the past: NC-Gesellschaft e.V., Assembléon<sup>13</sup> (for pick-and-place machines), the project partners of MAXIME<sup>14</sup>. (However, the idea of an energy efficiency label was dismissed in the course of the project), by a

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<sup>13</sup> S. Van Gastel: The Environmental Impact of Pick-and-place Machines, SMT, PENN Well, March/April 2009

<sup>14</sup> Industry partners: Alfing Sondermaschinen, Bosch Rexroth, VW, BMW, Daimler, Heller, Siemens, MAG Powertrain, Audi, Studer, Grob

research team<sup>15</sup> at TU Braunschweig, Germany, and the Austrian project “Development of criteria to communicate the energy efficiency of plastics processing machines”, which defines an energy efficiency indicator based on the specific energy consumption per kg of polymer processed.

The findings of Task 3 indicate that there is a (moderate) interest in transparent, comparable data regarding energy consumption of machine tools, but there is no clear indication, that an energy efficiency label could provide the required information. Absolute power consumption figures, preferably adapted to individual production patterns, seem to be much more useful information for machinery purchasers, in particular if linked to cost calculations. In a stakeholder comment CECIMO points out the following additional shortcomings of an energy efficiency label for machine tools:

- it is not supported by an ISO standard for measures
- it makes comparisons between machines with different technical characteristics
- it does not take into account specific customization and requirements to satisfy the end users' needs
- it can create confusion and misuse for non-technical stakeholders
- taking into account the customization of the products which leads to meeting the specific requirements given by the end user, labelling is not a suitable tool and does not meet the need of the customer.

For light-stationary tools, an approach for Product Carbon Footprint (PCF) calculations for handheld power tools is under development by EPTA (the European Power Tool Association). Note that handheld power tools is a product segment explicitly excluded from the scope of this study; however, light-stationary tools (within this study) have a similar level of complexity, and the association working on the PCF methodology is common to both sectors.) In addition, a PCF class label might be feasible, particularly as long as the main energy consuming component (single-phase motors) are not subject to Energy Efficiency classifications. Motor efficiency labelling would be a possible alternative, and it would cover most of the environmental factors of relevancy identified in Tasks 4 and 6 for this type of equipment. If it could be feasibly established, such a mandatory PCF class label would be the first of its kind globally. Although Task 6 iden-

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<sup>15</sup> Herrmann, C. et al.: Energy Labels for Production Machines - An Approach to Facilitate Energy Efficiency in Production Systems, Proceedings of the 40th CIRP International Seminar on Manufacturing Systems, May 30 - June 1, 2007, Liverpool, UK

tified a significant improvement potential, the actual impact of such a label is difficult to forecast. An interest in such labelling among the users of light-stationary tools cannot be confirmed based on the findings of Task 3; this is because, basically, large enterprises were the focus of this investigation.

**Fiscal instruments** are of particular interest, as the analysis in Tasks 3-6 indicates, i.e., that in the machine tools sectors there are some technical measures which generate a return on investment (ROI). However, this ROI occurs over a timeframe that is too long to make the investment attractive for many industry clients. Furthermore, the long use lifetime of machine tools results in a high number of inefficient machine tools (particularly in the non-NC segment) being in operation also for the midterm future<sup>16</sup>. A rapid replacement of these non-state-of-the-art machine tools would result in significant energy savings. Such a scrapping bonus for automobiles, introduced in the economic crisis back in 2008 in several countries yielded significant environmental improvements<sup>17</sup> <sup>18</sup>. A scrapping bonus for industrial machinery was discussed in Germany already in 2010, but was not supported by VDMA at that time<sup>19</sup>. One of the arguments against such a bonus is the risk that manufacturers are incentivised to install over-capacities in times of a generally weak economy.

In order to stimulate the development and implementation of energy-efficient machinery in manufacturing industry sectors, financial measures could be initiated and installed. Financial incentives could focus on two different areas or industry sectors, and may work directly by monetary contribution or indirectly by fiscal bonus:

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<sup>16</sup> CECIMO comments that “if a machine can be in use for a long time and taking into account the upgrading tendencies, the environmental footprint of such machines should be considered more energy efficient than any other product which after a short use period of time needs to be replaced.” Although Fraunhofer acknowledges the fact, that long machinery lifetime as such is an important environmental feature, in particular as upgrading is common in industry, but it is rather not possible to achieve an efficiency level comparable to new state-of-the-art machinery solely through retrofitting measures. Given the low impact of machinery manufacturing compared to its use phase in most cases (see task 4), the use phase impacts are most relevant and measures to increase use phase efficiency should have preference, but a thorough analysis of this aspect has not been undertaken yet.

<sup>17</sup> Höpfner, U.: Abwrackprämie und Umwelt – eine erste Bilanz, ifeu Institut Heidelberg, 2009

<sup>18</sup> Hommel AG offered such a business model back in 2009, when they reduced sales prices of new machine tools by 5-10%, if used machine tools are given to Hommel for scrapping, see [http://www.industrieanzeiger.de/home/-/article/12503/26150836/Hommel-converts-%e2%80%9cscrap-iron%e2%80%9d-into-cash/art\\_co\\_INSTANCE\\_0000/maximized/industrieanzeigermarktaktuell](http://www.industrieanzeiger.de/home/-/article/12503/26150836/Hommel-converts-%e2%80%9cscrap-iron%e2%80%9d-into-cash/art_co_INSTANCE_0000/maximized/industrieanzeigermarktaktuell)

<sup>19</sup> See interview with H. Hesse (VDMA): <http://www.produktion.de/konjunktur/maschinenbau-will-keine-abwrackpraemie/>

- (1) The first mechanism is the **financial support of manufacturing industry actors to invest in new, energy-efficient machinery and equipment**. This can reduce the higher investment costs for energy-efficient equipment, or motivate the replacement of existing machinery with inherently higher energy consumption. This measure would have a short time effect in reduction of energy use in industry. Besides incentivising the investment in new, efficient machine tools, this measure could also address upgrading and retrofitting measures (such as installing sensor systems for monitoring fluid systems, energy consumption, and condition monitoring), which increase verifiably the energy efficiency of already existing machine tools. In addition, or alternatively, financial support could be provided for training courses to enhance the energy-efficient operation and maintenance of machine tools. This financial support could also include investment in equipment to improve non-energy related impacts, such as hydraulic oil purifiers.
- (2) The second financial support system is directed towards the machine tool industry and to producers of related machinery and equipment, and could **enhance the research and development for energy-efficient machines**. A stimulation instrument could be envisaged as an industry-directed funding of pre-competitive research, accompanying the development of energy-efficient solutions, new technical options, design guidelines or the implementation of best practice in designing products, or using products. This could accelerate ecological developments and generate sustainable concepts and solutions. In the sense of a European initiative, this might be a special action with mixed programme and funding schemes. It could consist on the one hand of European funding (e.g. under Horizon 2020, Intelligent Energy Europe etc.) in order to treat transnational questions, and on the other hand from national funding, which could address purposeful thematically-focused topics. The research measures and topics should be well co-ordinated in Europe in order to gain the active involvement of the main players, to utilise their expertise, and to ensure complementary activities. Such a tightly led and demarcated initiative could accelerate new or ongoing industrial developments, and could speed up industry-wide implementation of best practice, and up-to-date knowledge dissemination.

The BAT analysis undertaken in Task 6 is outlined in **Table 7-5**, including the calculated additional investment at the point of LCC break-even. (Note that an "LCC break-even point" in this context does not really mean a costs break-even from the usual company perspective. This is because the Table 7-5 results are instead calculated over



the *whole anticipated product lifetime*, i.e., it is different from typical commercial return-on-investment [ROI] considerations.). This gives an indication about the financial incentives which might be hypothetically considered, in order to make it attractive for purchasers to choose a more efficient machine tool instead of a less efficient one<sup>20</sup>. It is evident that rather small increases of up to 2% in machinery investment would pay for the additional machinery costs. On the other hand, such a bonus of 2% is much less than the difference between the typical resale value of a used machine tool and the price of a new model. This might hamper the effectiveness of a scrapping bonus in this range.

**Table 7-5: Additional machinery investment at LCC break-even per Base Case**

	(1) CNC machining centres (and similar)	(2) CNC Laser cutting ...	(3) CNC Bending machine tools (and similar)	(4) Non-NC metal working ...	(5) Table saw (and similar)	(6) Horizontal panel saw (and similar)	(7) Througheed edge banding machine (and similar)	(8) CNC machining centre (and similar)	(9) Welding equipment
<b>Base Case machinery purchase price (kEuro)</b>	480		100			60	60	300	
<b>Additional investment at LCC break-even (kEuro)</b>	7,8		0,09			1	0,9	4,5	
<b>Total Energy at LCC break-even</b>	-4,8%		-2,2%			-5,0%	-5,5%	-5,0%	

The granting of fiscal incentives needs to be based on verifiable criteria, such as cross-checking against the previously-mentioned good-design-practice checklist, with a mandatory minimum number of the mentioned aspects to be implemented, in order to qualify.

#### 7.1.4 Product definition

Any measure might be applied on two levels:

- Machine tool
- (functional or physical) module/ component

<sup>20</sup> Given all other machinery parameters and productivity are exactly the same

Measures defined on the machine tools level would cover the whole unit as such. Given the analysis in this study the definition of “machine tools” as provided in task 1 applies. It is possible that measures could be defined for distinct sub-groups under the overarching “machine tools” definition, e.g. metalworking machine tools, or woodworking machine tools.

On the module/ component level, products beyond “machine tools” could be covered, namely “related machinery”, according to the definition in Task 1.

**Minimum environmental performance criteria** on the component/ module level could be defined if an environmental performance could be correlated with a distinct technical performance. Hence, sub-assemblies/ components could be regulated. However, “functional modules”, or complex physical modules, do not qualify for setting such minimum performance criteria. Suitable minimum environmental performance criteria are:

- Energy efficiency of arc welding power sources<sup>2122</sup> (at the rated output at 100 % duty cycle)
  - 70% for single phase power sources and AC welding power source.
  - 75% for three phase power sources

Such a requirement bans the less efficient and more bulky transformer type power supplies (stage 1).

As a mid-term target (within the following 4 years), higher efficiencies would be widely achievable (and are justified by the findings of Task 6, stage 2), which would allow the requirements to be tightened (still below the point of LLCC)<sup>23</sup>:

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<sup>21</sup> Such efficiency level is only achievable by arc welding power source. Resistance welding power sources are designed by thermal requirement and are not designed for a 100% duty cycle.

<sup>22</sup> The initial proposal in the draft final report was 75% for single phase and 80% for three-phase. This proposal was challenged by EWA with the following comment: “AC arc welding power sources will not achieve the three-phase requirement. The ban of the less efficient and more bulky transformer type power supplies at stage 1 will be achieved with a further allowance of 5% (6% of 2010 market). Change Stage 1 to: 70% for single-phase power sources and AC welding power source; 75% for three phase power sources”

- 75% for single phase power sources and AC welding power source.
- 80% for three phase power sources

As a long-term target (within the next 6 years, stage 3) requirements corresponding to the point of LLCC are feasible<sup>24</sup>:

- 80% for single phase power sources and AC welding power source.
- 85% for three phase power sources
- Idle state power consumption of welding power sources module at cold state
  - 50 W<sup>25</sup> (stage 1), 30 W (stage 2)
- All pump systems designed to operate at 2 working points or more shall be speed controlled

Other minimum environmental performance criteria for the component / module level have not been identified in the course of this study, given the broad system approach followed here.

For functional and physical modules, **sub-chapters of the good-design-practice checklists** are applicable in principle. For all machinery falling under the machinery directive and not being covered by any machine tools specific implementing measure

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<sup>23</sup> The initial proposal in the draft final report was 80% for single phase and 85% for three-phase. This proposal was challenged by EWA with the following comment: "AC arc welding power sources will not achieve the three-phase requirement. The ban of the all bulky transformer type power supplies at stage 2 will be achieved with a further allowance of 5% (29% of 2010 market). Change Stage 2 to: 75% for single-phase power sources and AC welding power source. 80% for three-phase power sources"

<sup>24</sup> The initial proposal in the draft final report was 85% for single-phase and 90% for three-phase. This proposal was challenged by EWA with the following comment: "AC arc welding power sources will not achieve the three-phase requirement. The ban of the less efficient inverter type power supplies at stage 3 will be achieved with a further allowance of 5% (80% of 2010 market). This still allows a savings potential larger than 10% as the mean average efficiency is 75% for three-phase power sources. Change Stage to: 80% for single-phase power sources and AC welding power source. 85% for three-phase power sources"

<sup>25</sup> Which takes account of the uncertainty stated in Task 6; 50 W is rather a threshold to ban the least efficient units

or voluntary agreement, the checklist approach can be applied for following components<sup>26</sup>:

- Drive units
- Lubrication system
- Cooling system
- Electric system
- Pneumatic system
- Hydraulic system
- Die cooling / lubrication
- Control unit

As the checklist approach is very generic and does not set quantified targets it is applicable for a rather broad scope.

**Table 7-6: Feasibility of measures on machine tools and module level**

Nature of measure	Machine tools level	Module / component level
Minimum environmental performance criteria	Not feasible due to <ul style="list-style-type: none"> <li>• broad spectrum of products,</li> <li>• missing statistical data on current performance</li> <li>• Application specific performance</li> </ul>	Feasible, if <ul style="list-style-type: none"> <li>• clearly defined as a performance indicator (e.g. energy efficiency of power transformation)</li> </ul>
Power management requirements	Feasible, if generic, possibly based on relative power consumption	Feasible, if generic
Good-design-practice Checklists	Feasible	Feasible (could be a sub-list of the overarching machine tools related list)
Information / declaration requirements	Feasible	Feasible, but module supplier is required then to provide the information / declaration

<sup>26</sup> List taken from ISO 14955-1 (draft), Annex A and B; component not listed here are “peripheral devices” as this is a “catch-all” category which hardly can be defined unambiguously

### 7.1.5 Sectoral scope

The discussion above leads to the conclusion, that different approaches are required for the various sub-segments. A distinction has to be made as follows:

- Metal working machine tools
- Wood working machine tools
- Welding equipment
- Other machine tools
- Related machinery.

Table 7-7 summarises a holistic concept, where an overarching implementing measure, similar to the machinery directive, for the scope of machine tools defined in Task 1 integrates segment-specific requirements, and for a broader scope (i.e. scope of the machinery directive) also some checklist components of the machine tools measure apply.

**Table 7-7: Policy options on a sectoral level**

Sector	Policy options
All machine tools	<ul style="list-style-type: none"> <li>• Overarching Implementing Measure               <ul style="list-style-type: none"> <li>○ Generic checklist approach</li> <li>○ Power management requirements</li> <li>○ Information / declaration requirements</li> </ul> </li> </ul>
Metal working machine tools	<ul style="list-style-type: none"> <li>• Exemption from the overarching implementing measure, if SRI is effective</li> </ul>
Wood working machine tools	<ul style="list-style-type: none"> <li>• Covered by overarching implementing measure</li> <li>• PCF declaration for light-stationary tools, as checklist and power management basically is not useful / applicable for these</li> </ul>
Welding equipment	<ul style="list-style-type: none"> <li>• Covered by overarching implementing measure</li> <li>• Specific power consumption requirements</li> </ul>
Other machine tools	<ul style="list-style-type: none"> <li>• Covered by overarching implementing measure, unless any Voluntary Agreement is implemented by any sub-sector (e.g. semiconductor equipment)</li> </ul>
Related machinery	<ul style="list-style-type: none"> <li>• For all machinery covered by the machinery directive: Implementing measure tackling selected components with the generic checklist approach</li> </ul>

Applying the checklist would be done in an internal process, just as with other requirements for CE-marking and under the machinery directive.

It has to be noted, that several standards required to implement this measure are still under development or do not yet exist.

### **7.1.6 Related machinery**

The analysis did not address in detail “related machinery”, given the inevitable specifics of the analysed Base Cases. In the light of the identified suitable measures (rather generic design principles to be considered) it can be stated, that such a design-checklist approach can be applied to numerous other types of machinery, where similar design principle could yield significant savings. An extension of these requirements to “related machinery” requires a thorough definition of the modules addressed in this study. Such an unambiguous definition and in particular a definition of system boundaries (which components/ functionalities are considered to be part of a given module) could not be developed in the course of this study, given the multitude of possible applications. Such a definition is probably best developed via a standardisation process, which would progressively refine the definition of the related design checklists.

Applying the checklist approach only for certain modules of “related machinery”, but not in accordance with the approach for the whole installation, still runs the risk that optimisation would not holistically address the machinery system.

### **7.1.7 Summary**

Table 7-8 summarises the possible requirements for machine tools and related machinery. The scope is related to the definitions provided in Task 1 (1.1.2.2). In the end some exemptions might be needed, but as some major basics are still missing (relevant standards etc.) such exemptions cannot be formulated at this point. In theory the whole stated scope could be covered.

As outlined above, similar improvements could be achieved under Voluntary Agreements (non-existent as yet), which would define ambitious targets.

Besides the requirements listed below, fiscal instruments have been identified as a possible measure to achieve a timely replacement of inefficient machine tools by new ones. However, a detailed concept regarding how to set the right incentives for energy efficient investment goods is still required, but remains to be developed.

**Table 7-8: Summary of possible requirements**

Requirement	Scope	Evidence for relevance	Comments
<b>Energy Management</b>			
Provision of an interface to an external or internal energy monitoring and control system	CNC machine tools	Monitoring essential for influencing user behaviour (transparency regarding power consumption identified as a gap and as moderate potential for improvement in Task 6) Actual likely impact (behaviour change, and infrastructure adaptation) unknown	Includes also control commands for central systems (e.g. extraction systems in wood working)
Provision of manual stand-by option	All machine tools	Reducing power consumption in non-productive times is of high priority, with a negligible impact on productivity	For small units only off-mode
Transition time to a low-power mode (e.g. 10 min)	CNC machine tools	Reducing power consumption in non-productive times is of high priority, with a negligible impact on productivity (example provided on p. 13)	
Minimum power consumption in low-power compared to idle / ready for operation (maximum 20%)	CNC machine tools	Reducing power consumption in non-productive times is of high priority, negligible impact on productivity, if exemptions are possible	
<b>Good-design-practice checklists</b>			
Tools and methods for	All "machine	Task 5 and 6 findings demonstrate impor-	Only frameworks of

<ul style="list-style-type: none"> <li>(i) analyzing and decipher the current state</li> <li>(ii) Identifying energy intensive functions and modules</li> <li>(iii) Developing an overall concept,</li> <li>(iv) Assessing, selecting, and implementing</li> <li>(v) Monitoring and taking record of the process</li> </ul>	<p>tools” (metal working, wood working, welding, other machine tools), module specific checklists could apply also to “related machinery”</p>	<p>tance of implementing several improvement options, but to leave the decision to the machinery developer, which option is useful for a given application</p>	<p>such checklists are now available, design guidance on the module level are partly under consideration (fluids) Exemptions might apply as outlined on p. 18</p>
<p><b>Information / declaration requirements</b></p>			
<p>Power (and possibly media) consumption in the various modes</p>	<p>All “machine tools”</p>	<p>Important to allow for a direct comparison of machine tools for an informed purchase decision</p>	<p>Machinery settings (potentially workpiece) to be specified, use scenario will be generic and might not reflect properly the intended use; part of the documentation</p>
<p>Power consumption in absolute terms for a given use scenario</p>			
<p>Standardised life cycle costs calculation</p>	<p>All “machine tools”</p>	<p>Transparency regarding LCC and comparability of LCC (including energy and media) identified as a major barrier in task 3</p>	<p>Further specification of LCC methodology needed</p>
<p>How power management settings could be changed</p>	<p>CNC machine tools</p>	<p>Important to allow an adaptation to specific production conditions</p>	
<p>Any other instructions, which enable the</p>	<p>All “machine</p>	<p>Important for auxiliary consumption (e.g.</p>	<p>No further specifica-</p>



operator to operate the machine tool in a manner, which reduces environmental impacts	tools”		welding gas), and for operation of a machine tool in a larger production environment (e.g. adjustment of a central extraction system for wood working)	tion
Power (and media) consumption values in real time (for the machine tool as a whole)	CNC tools	machine	Monitoring essential for influencing user behaviour (transparency regarding power consumption identified as a gap and as moderate potential for improvement in Task 6) Actual likely impact (behaviour change) unknown	Part of the monitoring requirements
power (and media) consumption values in real time (on the component / sub-module level) and a historic energy consumption profile, (optional)	CNC tools	machine	Monitoring essential for influencing user behaviour (transparency regarding power consumption identified as a gap and as moderate potential for improvement in task 6) Actual likely impact (behaviour change) unknown	Part of the monitoring requirements
A warning before a low-power mode is entered automatically (optional)	CNC tools	machine	Important to avoid productivity constraints	
Power consumption savings compared to a standard machine tool	All tools”	“machine	Essential for “bottom-up” mechanism to quantify effectiveness of a measure	Part of the documentation, rather relevant for a VA, approach to define “standard machine tool” missing yet
Product carbon footprint declaration	All	“machine	Less frequently used units, material choice is	Coverage of those

	tools”, which operate with single-phase motors	relevant for total life cycle impacts, thus production should be included as well (also to account for trade-offs for material for motors of higher efficiency)	smaller units, which do not fall under the ecodesign regulation for motors (and for which no efficiency classes are defined yet)
<b>Minimum environmental performance criteria</b>			
Energy efficiency of welding power sources	Welding equipment	Corresponds with LLCC calculations in Task 6	To be implemented in 3 stages
Idle state power consumption of welding power sources module at cold state			

## 7.2 Impact Analysis

### 7.2.1 Scenarios

Scenarios are calculated based on the assumption that any measure takes effect from 2014, and that machine tools placed on the market during that year will be the first ones to deviate from “Business-as-usual”.

“Business-as-usual” is calculated with the Base Case results in Task 4 per unit, plotted with the annual stock figures according to the stock model developed in Task 2, for the years up to and including 2025.

For all of the policy scenarios, all stock installed before 2014 is calculated with the Base Case figures of Task 4. All stock implemented in 2014 and thereafter is calculated with the corresponding results of the related improvement option, as in Task 6.

This approach neglects that the stock still consists of numerous older, much less efficient machine tools. Replacing these machine tools by inherently more efficient ones is not considered in this simplified model (as it would not be an effect of policy measures, with the possible exception of a scrapping bonus).

The following policy scenarios are calculated:

- **LLCC:** Implementation of a good-design-practice-checklist, accompanied by power management requirements and declaration obligations, leading to machinery improvements corresponding to the point of Least Life Cycle Costs (LLCC).
- **LCC-BEP:** This can be considered a more “optimistic scenario”, where the analysis of individual machine tools shows in numerous cases a higher individual savings potential than what could have been addressed with the generic archetypal calculations from Task 6. Fiscal incentives furthermore are assumed to pay off for part of the additional machinery costs for implementing even more improvement options than in the LLCC scenario. Calculation basis for all machine tools sold in 2014 and thereafter is the Life-Cycle-Costs-Break-Even-Point identified in Task 6
- **10% VA:** A Voluntary Agreement is implemented, setting a target that all machine tools sold in 2014 and thereafter should, on average, consume 10% less energy than in 2010. Productivity increase is not accounted for in this model

calculation (but could and should be addressed in a VA). If productivity changes were taken into account, only the absolute values would change, not the general trends.

- **PCF label:** For light-stationary machine tools, this scenario is based on the assumption that transparency regarding life cycle impacts guides purchase decisions, and is an incentive for tool manufacturer to develop equipment with a lower carbon footprint, despite the slightly higher Life Cycle Costs. For the calculation of this Product Carbon Footprint label scenario, the implementation of both improvement options as outlined in Task 6 is assumed<sup>27</sup>.

### 7.2.2 Forecast 2025

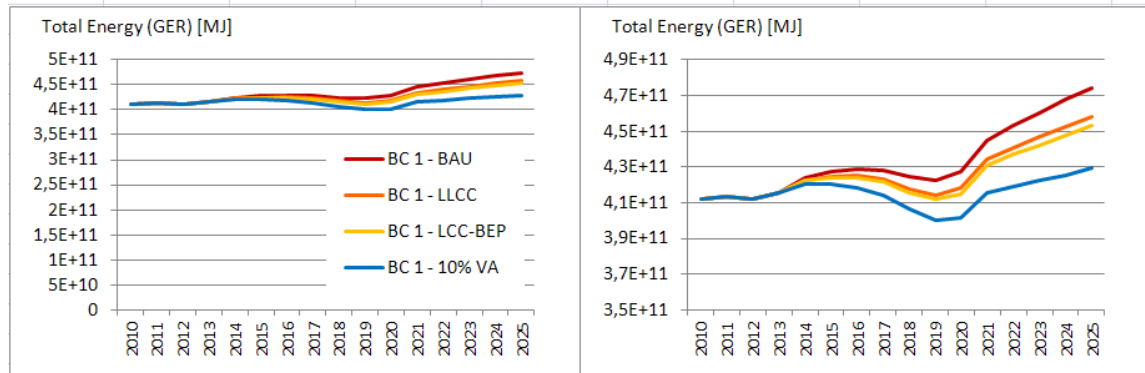
The forecast data depicted below refers only to Total Energy consumption. Similar trends can be anticipated for the other environmental impact categories. For each Base Case the results are shown in two graphs, one with the y-axis starting at zero to visualise the correlation of total changes (left), and a zoomed-in graph (right) to show the more minor differences among the scenarios.

Given the slight market growth of CNC machines the BAU scenario for Base Case 1 shows a slightly growing energy consumption trend (Figure 7-2). The LLCC and the LCC-BEP scenarios slightly lower the total energy consumption from 2014 onwards. In 2025, a significant number of CNC machining centres (and similar) installed before 2014 will still be in operation, which means that the gap between BAU and the other scenarios will continue to increase. The scenario with the highest improvement potential is “10% VA”, but still with only a moderate effect in 2025. More ambitious targets via a VA (or much stricter requirements and an implementing measure) could result in higher savings. A 20% target – if reached - would double the effect in 2025 for this and the following Base Cases.

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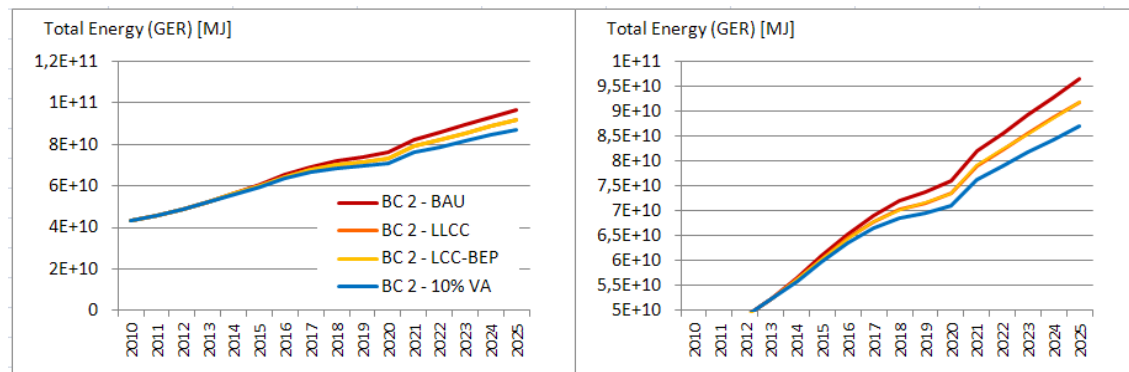
<sup>27</sup> whereas the replacement of aluminium by the more heavy-weight cast iron represents rather a “wildcard” for material changes and reductions as such

**Figure 7-2: Base Case 1 - Policy Scenarios - Total Energy 2025 Forecast**



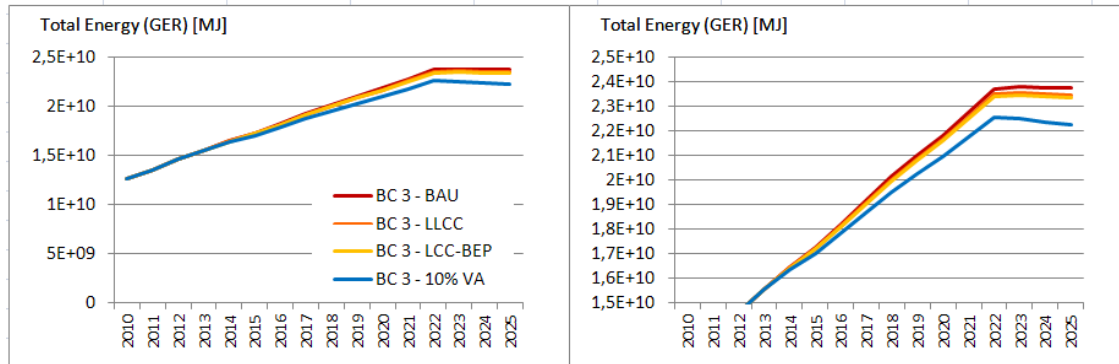
Given the significant market growth of laser cutting machines the BAU scenario for Base Case 2 shows a steadily growing energy consumption trend (Figure 7-3). The LLCC and the LCC-BEP scenario (in this case, both are the same) slightly lower the total energy consumption from 2014 onwards. In 2025 still some laser cutting machine tools (and similar) installed before 2014 will be in operation, which means the gap between BAU and the other scenarios will still increase. The scenario with the highest improvement potential is “10% VA”, but still with only a moderate effect in 2025.

**Figure 7-3: Base Case 2 - Policy Scenarios - Total Energy 2025 Forecast**



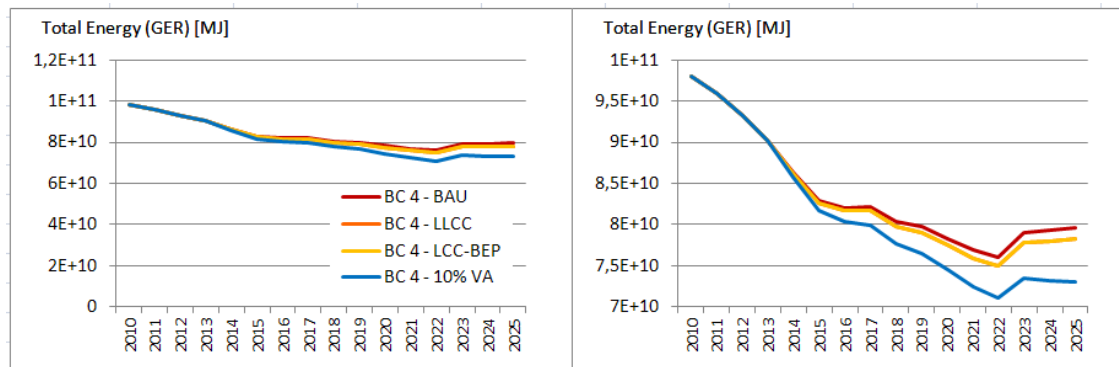
For hydraulic presses (and similar, Base Case 3) the same trend as for the other metal working machine tools is observed (Figure 7-4).

**Figure 7-4: Base Case 3 - Policy Scenarios - Total Energy 2025 Forecast**



Conventional, non-numerical controlled machine tools see a decreasing number of installed units which results in a slowly decreasing energy consumption trend for the BAU scenario for Base Case 4 (Figure 7-5). The LLCC and the LCC-BEP scenarios slightly lower the total energy consumption from 2014 onwards. In 2025 still a significant number of non-NC machine tools installed before 2014 will be in operation, which means the gap between BAU and the other scenarios will still increase. The scenario with the highest improvement potential is “10% VA”, but still with only a moderate effect in 2025.

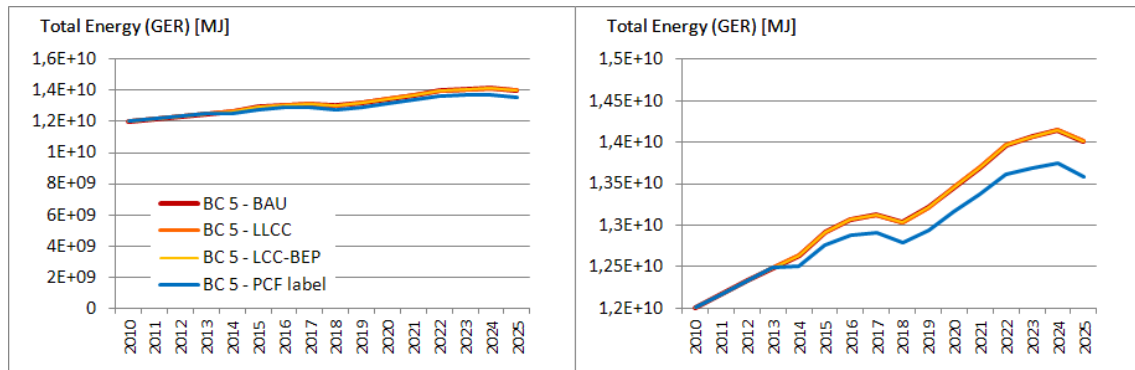
**Figure 7-5: Base Case 4 - Policy Scenarios - Total Energy 2025 Forecast**



For light-stationary machine tools, a near-stable total energy consumption is to be expected in the BAU scenario (Base Case 5, Figure 7-6). The LLCC and the LCC-BEP scenario actually do not apply for these, as neither LLCC nor a LCC-BEP were identified. Only the PCF label scenario results in savings, although on a very low level, which is basically due to the fact that the scenario in accordance with Task 2 is based on a lifetime of 20 years, which presumably overestimates real lifetime for some of the relevant market segments. In 2025 still numerous light-stationary machine tools installed

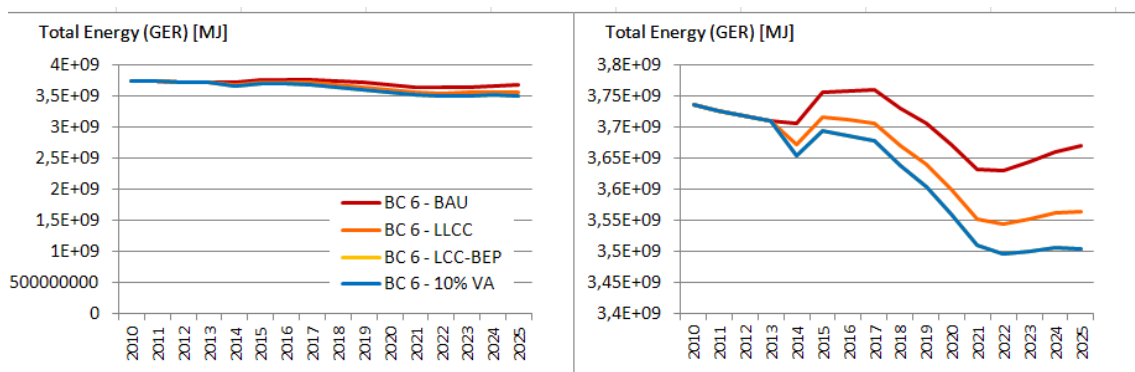
before 2014 will be in operation (actually nearly 50% of the stock), which means the gap between BAU and the PCF label scenarios will still increase.

**Figure 7-6: Base Case 5 - Policy Scenarios - Total Energy 2025 Forecast**



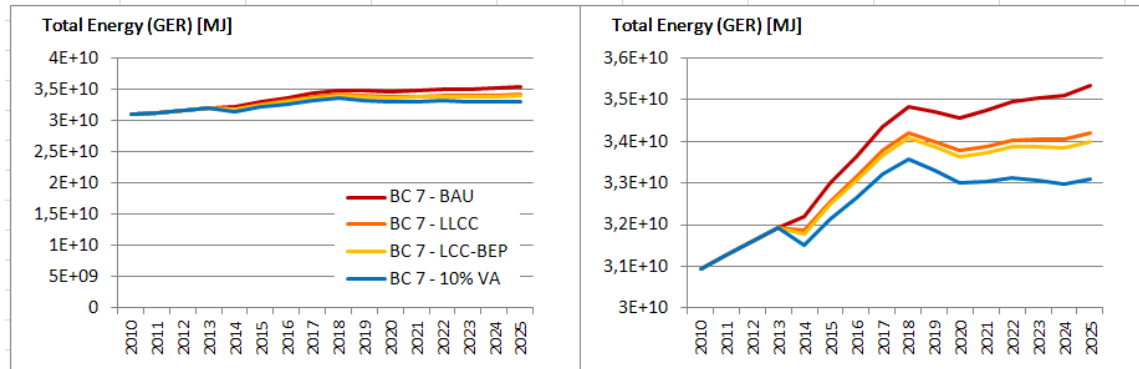
For larger industrial wood working machine tools the anticipated long lifetime results in similarly small short- and mid-term effects of policy options: For panel saws (and similar, Base Case 6) total energy consumption remains on a stable level in the BAU scenario (Figure 7-7). The LLCC scenario results in a small energy consumption reduction. The LCC-BEP scenario is the same as the 10% VA scenario, and although meaning a significant saving per unit, the effect on the stock is very moderate. In 2025 still numerous panel saws installed before 2014 will be in operation, which means the gap between BAU and 10% VA scenarios will increase beyond 2025.

**Figure 7-7: Base Case 6 - Policy Scenarios - Total Energy 2025 Forecast**



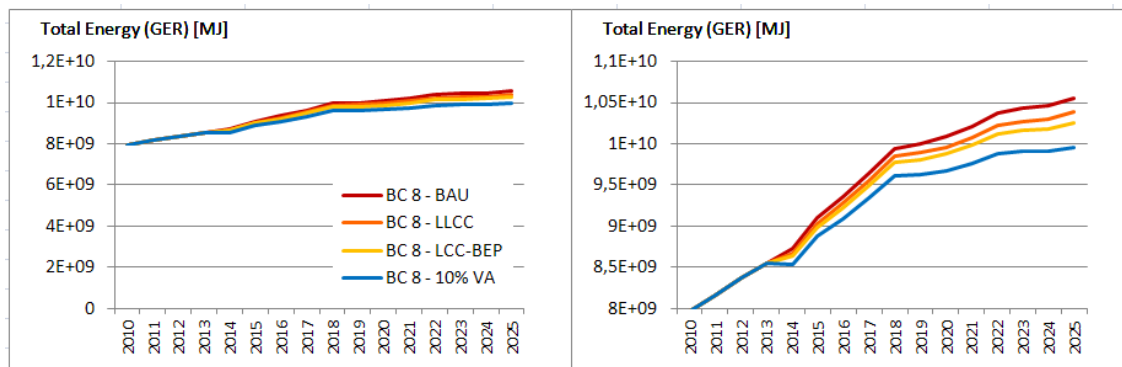
For throughfeed edge banding machine tools (and similar, Base Case 7, Figure 7-8) same statements as for the panel saws above apply.

**Figure 7-8: Base Case 7 - Policy Scenarios - Total Energy 2025 Forecast**



For CNC wood working machining centres there is a slight energy consumption growth trend (Base Case 8, Figure 7-9), given a market growth in this segment, but otherwise the same statements apply as for the other industrial wood working machine tools, above.

**Figure 7-9: Base Case 8 - Policy Scenarios - Total Energy 2025 Forecast**

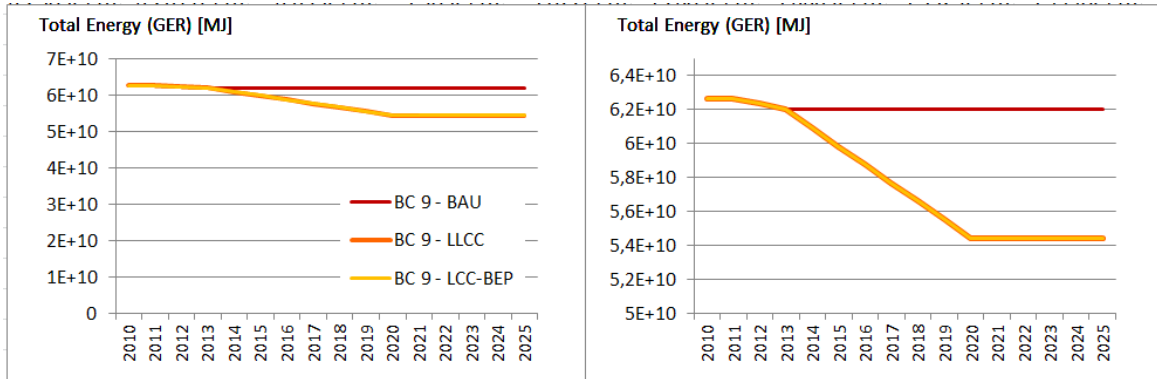


For welding equipment (Base Case 9, Figure 7-10) a stable stock is anticipated in terms of units. Consequently the BAU scenario results in a constant level of energy consumption over time. The LLCC and LCC-BEP scenarios lead to a significant drop in total energy consumption from 2014 onwards. Note that LLCC and LCC-BEP are based on improvement options which result in lower power consumption than proposed in 7.1 with staged implementation. This means that where longer transition times occur (as proposed in Task 7.1), this savings potential will only be realized later. As LLCC and LCC-BEP already constitute a savings potential larger than 10%, no 10% VA scenario is calculated here.

It should be noted that the calculations presented do not include further savings of welding/ shielding gas.

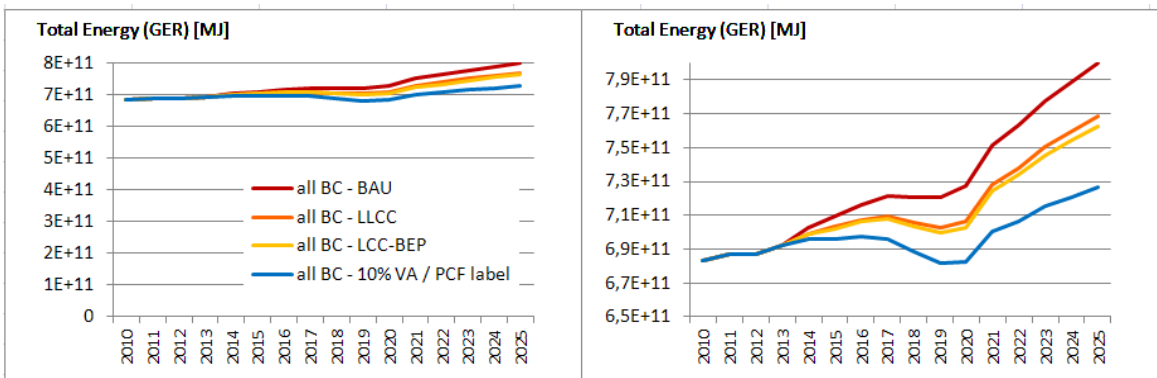


**Figure 7-10: Base Case 9 - Policy Scenarios - Total Energy 2025 Forecast**



An aggregated graph for all Base Cases and related scenarios is depicted in Figure 7-11: The short- to mid-term effect of any policy measure is hampered by the long lifetime, i.e. low exchange rate of investment goods, such as machine tools. Moderate savings can be achieved with the LLCC and LCC-BEP scenarios, and the difference between both is minor. A target-setting of 10% improvement could result in significant total savings. However, even then the absolute total energy consumption level of today is exceeded, and only the power consumption increase is slowed down.

**Figure 7-11: All Base Cases - Policy Scenarios - Total Energy 2025 Forecast**



Total savings range from 31 PJ in 2025 (LLCC scenario) to 74 PJ (10% VA / PCF label). More ambitious targets under a Voluntary Agreement at high market coverage could yield higher savings.

**Table 7-9: All Base Cases - Policy Scenarios - Total Energy 2025 Forecast**

Total Energy (GER) [PJ]	2013	2014	2020	2025	Savings
all BC - BAU	692	702	727	800	-
all BC - LLCC	692	699	706	769	31
all BC - LCC-BEP	692	699	703	762	38
all BC - 10% VA / PCF label	692	696	682	726	74

When interpreting these results it is important to remember the shortcomings of this analysis:

- Although the Base Cases cover the most important market segments of machine tools, a gap has to be stated for numerous other types of machine tools, which cannot be represented properly by the chosen Base Cases (see annex of Task 4). Consequently, the total impact and the total savings potential will be higher than stated here; at a best estimate, these figures might be between 10 and 50% higher, but a reliable extrapolation is not feasible.
- The calculations do not reflect the increasing complexity (and productivity) of almost all machine tools types, which will actually lead to an even faster increase of total energy consumption – but presumably also lower energy consumption per product output.
- There is a high level of uncertainty regarding individual stock figures, which means also an uncertainty for the absolute figures, but this does not affect the overall trends observed.

### 7.2.3 Plausibility

For metal working machine tools the results are confirmed by a top-down calculation provided by VDW. Based on the assumption that a savings potential of 20% for new machine tools vs. old machine tools is feasible<sup>28</sup>, Hagemann and Würz calculate a an electricity savings potential of 7,54 TWh for 2020. This calculation is based on the assumption that the more efficient technologies are implemented already from 2010 onwards. The baseline consumption scenario is provided in Task 4, 4.5.10.1. VDW calculations regarding stock effects are documented in Table 7-10.

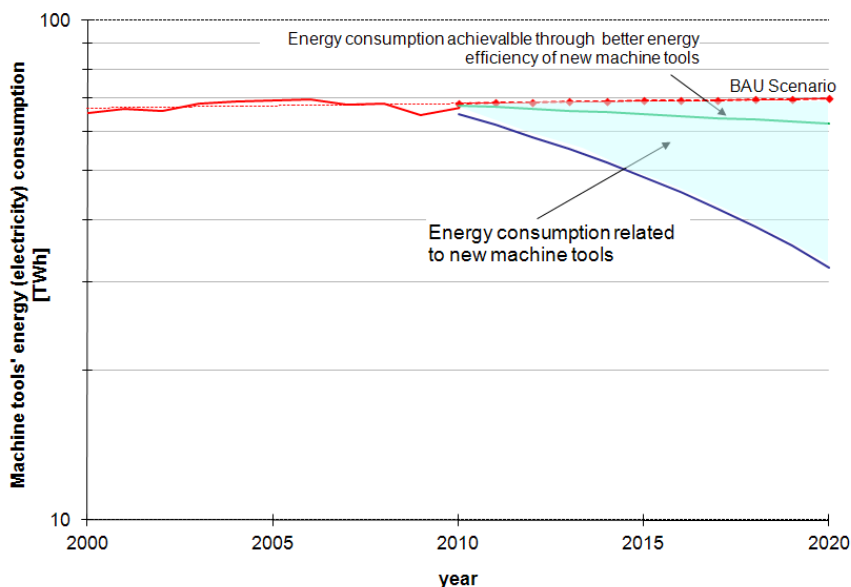
<sup>28</sup> Comparing machine tools in operation currently with those which will be optimized and newly brought on the market, our analysis compares “new, not realizing the optimal savings potential” vs. “new, economically ecodesigned”. Hence, our calculation is based on lower savings potentials.

**Table 7-10: Top-down estimate electricity savings potential of metal working machine tools in EU-27 (estimate by VDW, translation Fraunhofer)**

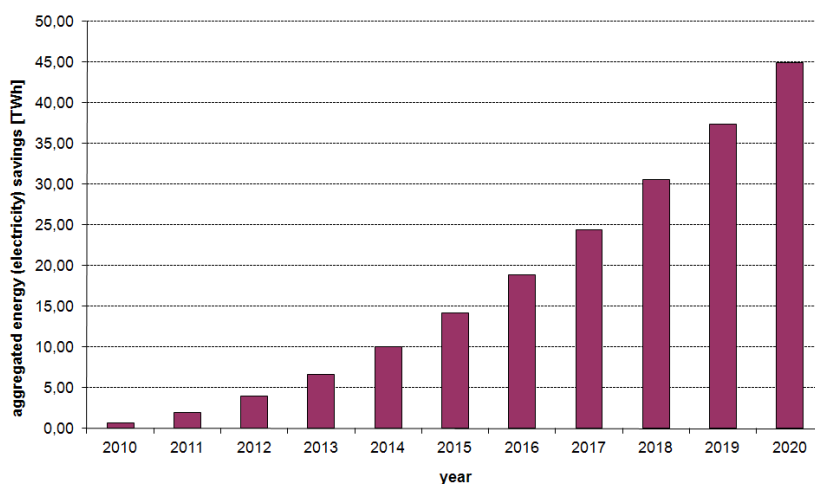
	2010	2012	2014	2016	2018	2020
<b>Energy consumption of machine tools replaced in a given year [TWh, electricity]</b>	3,24	3,42	3,44	3,45	3,47	3,48
<b>Aggregated energy consumption of machine tools replaced in a given year (= subject to potential efficiency gains) [TWh, electricity]</b>	3,24	10,08	16,94	23,84	30,76	37,72
<b>Energy consumption "old stock" [TWh, electricity]</b>	65,08	58,52	51,94	45,33	38,69	32,02
<b>Energy efficiency related savings [TWh, electricity]</b>	0,65	2,02	3,39	4,77	6,15	7,54
<b>Aggregated savings [TWh, electricity]</b>	0,65	3,99	10,08	18,93	30,54	44,93
<b>Total energy consumption [TWh, electricity]</b>	67,67	66,58	65,49	64,40	63,30	62,19
<b>CO2 savings [t/a] (0,616kgCO2/kWh)</b>	398.921	2.460.084	6.211.521	11.660.250	18.813.289	27.677.654
<b>Aggregated CO2 savings [kt]</b>	399	4.078	14.413	34.797	68.633	119.342

The power consumption (end-energy) forecasts, based on VDW's estimates are depicted in Figure 7-12 and as aggregated savings from 2010 to any given year until 2020 in Figure 7-13.

**Figure 7-12: Top-down estimate electricity savings potential of metal working machine tools in EU-27 (estimate by VDW, translation Fraunhofer)**



**Figure 7-13: Aggregated electricity savings of metal working machine tools in EU-27 according to VDW calculations**



### 7.2.4 Other impact criteria

Besides environmental criteria, there are some more, which are relevant in an impact assessment. Reflecting the findings of all tasks, Table 7-11 provides a qualitative assessment of some of the key indicators for the three policy scenarios.

**Table 7-11: Impact Matrix**

Impact Indicator	LLCC	LCC-BEP	10% VA / PCF label
Change in comparison to "Business-as-usual"			
<b>Economic impact indicators:</b>			
- functionality of the product	0	0	-
- affordability of the product	0	-	-
- Implementation costs / administrative costs	-	--	-
- life cycle costs of the product	+	0	0
- competitiveness	0	0	+
<b>Social impact indicators:</b>			
- health	+	+	+
- safety	0	0	0
- number of jobs	0	+	0
<b>Environmental impact indicators:</b>			
- energy use	+	+	++
- greenhouse gas emissions	+	+	++
- end of life	0	0	0
<b>Other criteria:</b>			
- durability of the product	0	0	0
- technical feasibility	++	+	++
- interaction with other Community interventions	++	+	+
- efficiency & effectiveness (value for money)	0	0	0

### 7.3 ANNEX - Criteria for Voluntary Agreements

Voluntary agreements proposed by industry have to be assessed against the 9 criteria indicated in Annex VIII of the Directive (source: Working Document - Voluntary agreements under the Ecodesign Directive 2009/125/EC, March 12, 2010):

#### Criterion 1: openness of participation

The self-regulatory initiative shall be open to any new signatory.

#### Criterion 2: added value

The self-regulatory initiative must deliver added value, i.e. more than 'business as usual', in terms of environmental performance of products in its scope

#### Criterion 3: representativeness

The self-regulatory initiative must cover a large majority of the relevant market. As an order of magnitude it means that in principle more than 70% of the products placed on the market should be covered by the agreement.

#### **Criterion 4: quantified and staged objectives**

The self-regulatory initiative must set quantified and staged objectives, starting from a well-defined baseline and measured through clear and reliable indicators, based on extensive scientific and technological background. These indicators must allow monitoring the compliance with the objectives.

#### **Criterion 5: involvement of civil society**

The self-regulatory initiative must be publicised, including through the use of Internet and other electronic means of disseminating information. The same must apply to interim and final monitoring reports. Interested stakeholders, including NGOs and consumer organisations, must be invited to comment on a self-regulatory initiative and have access to the relevant information (e.g. annual reports, meetings of the monitoring/steering body).

#### **Criterion 6: monitoring and reporting**

Signatories are responsible for including a well-designed, credible and reliable monitoring and reporting system in the self-regulatory initiative, based on verifiable, objective and detailed data. It is notably expected that the signatories will report annually to the Commission on their progress in meeting the objectives of the self-regulatory initiative. These reports will have the form of aggregated data gathered and submitted to the Commission. Member States wishing to verify the reported values will be granted access to the background data upon request. To enable independent inspection to occur the signatories will have to declare which products are covered by the VA and which are not. (...)

#### **Criterion 7: cost-effectiveness of administering a self-regulatory initiative**

The self-regulatory initiative, notably as regards monitoring, must not lead to a disproportionate administrative burden.

#### **Criterion 8: sustainability**

The self-regulatory initiative shall be in line with the objectives of the Ecodesign Directive and in particular: free circulation, enhanced environmental performance of products in a lifecycle perspective.

#### **Criterion 9: incentive compatibility**

The self-regulatory initiative shall be consistent with existing framework conditions, especially incentives.