Transforming product efficiency policy into system efficiency policy

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ABSTRACT: Minimum efficiency performance standards (MEPS) and energy labels are amongst the most widely used and effective policy instruments to increase energy efficiency for energy-using products. However, broader policies focused on the energy efficiency of *systems* could address a larger share of the energy consumption in an integral way and thus increase energy savings. Policy makers need to consider diverse strategic issues when pushing for this next frontier in energy efficiency policy because of a range of regulatory issues.

This paper explores a methodological approach that can be used to transform product efficiency policy into system efficiency policy. It provides a definition of a system, and presents a classification of systems to analyse options for regulating systems. The relevant elements of existing regulatory approaches are highlighted and applied to examples of different systems to illustrate and discuss the regulatory challenges. The paper provides suggestions for overcoming these challenges, and analyses the revision of water pump efficiency policy. The main conclusion is that verification procedures and test methods in particular need to be more flexible to fit to energy efficiency policies dealing with systems. This paper concludes with recommendations for further development of the system approach in efficiency policy.

1. INTRODUCTION

System efficiency policies seem to offer large(r) saving potentials than existing efficiency standards for products. This is highlighted by a number of studies, which estimate saving potentials up to 50% if system efficiency policies are applied (e. g. for lightning systems, van Tichelen et al, 2016). Minimum efficiency performance standards (MEPS) and labelling schemes to regulate the energy efficiency of many products exist in the EU and many other countries, whereas in the case of systems, no standard seem to exist. To support the development of an effective efficiency policy, system policies need to be further explored. This paper suggests a methodological approach, and discusses the challenges associated with the transformation of product efficiency policy into system efficiency policy.

2. DEFINITION AND CLASSIFICATION OF SYSTEMS

A system describes a whole or an entity made of several parts or individual items. The system as a unified whole refers to the functionality of the system, as well as the interaction between the different parts, and the interaction between the system and its environment. A system uses energy and/or other inputs, e.g. water and consumables, and it delivers a certain performance (functionality). **Error! Reference source not found.** summarizes the various aspects of systems:
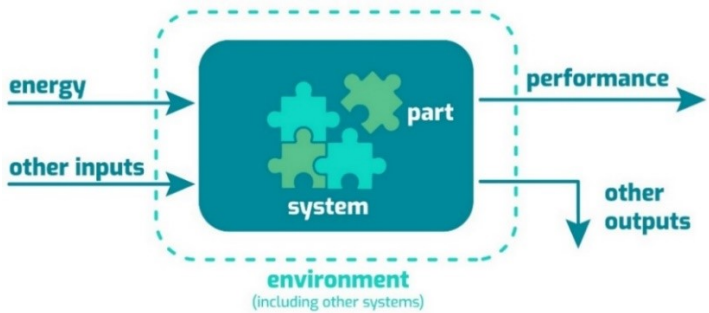

Figure 1: Systems aspects

A refrigerator can be considered a 'product', whose parts are assembled in an industrial process. In contrast, an 'system' has as essential and distinctive characteristic that (some of) the parts are assembled *on location* before the system can function; a system is produced not (only) in a factory but at a location where it will be used. The paper therefore suggests the following definition:

A system is a functional unit that consists of multiple parts that need to be assembled at the location where the system is used.

To function on site, energy using systems need to be assembled *and* installed, meaning connecting the system (or a product) to another system in the environment, e.g. to an energy grid.

The definition of a system provides two main avenues to explore regarding the challenges of regulating systems: the concepts of "parts" and "assembly". As such, systems can be classified using the attributes listed in **Error! Reference source not found.**:

Tab. 1: Attributes of a system relevant for classification

	Attribute	Range of values	Remarks
1	Number of parts	small; medium; large	Indicative values e.g.: small: <5, medium: 6-10, large >10

| 2 | Percentage of identical parts | small; medium; large | Indicative values e.g.: small: < 25%, medium: 25-75%, large: >75% |
| 3 | Impact of assembly on energy consumption or performance | small; medium; large | Note that this does not concern the "sizing" of the system. |

These attributes may influence the complexity regarding the establishment of a regulation, besides other existing attributes. The paper focusses on the attributes listed in **Error! Reference source not found.**. The number of parts (1) to be assembled influences many other attributes that exist and might be of relevance. Parts that are identical (2) will probably reduce regulatory burden for both regulators and market actors. The impact of the assembly on the energy consumption (7) of the system may also influence the verification and the type of requirements in a regulation.

For simplicity reasons, the range of values of the attributes is reduced, to suggest a structured classification tree (see

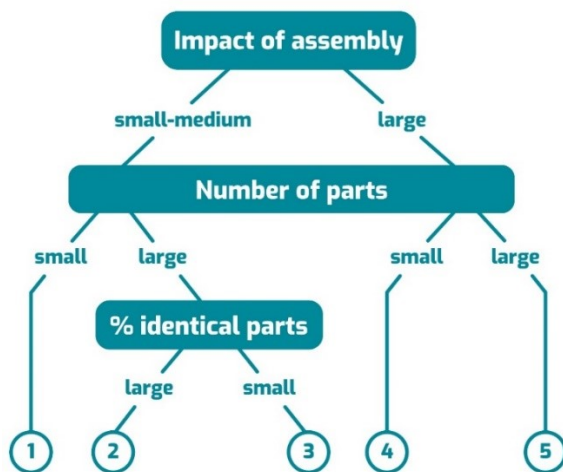Figure 2), where in general the complexity increases from left to right.

Figure 2: Classification tree

Some examples of systems in the various classes are:

① A multi split air conditioning system with one outdoor unit and several indoor units.

② A lighting control system (with standardized parts) for an office building.

③ A building and automation control system (BACS) with standardized parts (impact of assembly is small) providing a large number of functions (heating, lighting, security etc.); therefore the number of parts is large but the percentage of identical parts is probably small.

④ A walk-in cooler or freezer.

⑤ A compressed air system for a factory, including piping.

3.   ELEMENTS AND CHALLENGES OF REGULATING SYSTEMS

In the following, the main elements of energy efficiency measures and challenges of regulating systems are discussed.

3.1 SCOPE AND ADDRESSEES

The scope describes which products or systems are included or addressed in a regulation, and it is related to the (main) function(s) and/or the characteristics of the system. Focusing on the function(s) results in a "technology neutral" scope, i.e. all systems that fulfil the indicated function(s) are in scope regardless the technology used. For several applications, e.g. moving air or pumping liquid, both products and systems can provide the same function – hence, both need to be in the scope of the regulation and are subject to the same requirements. Defining the system boundaries is an important part of specifying the scope for a regulation. The setting of the scope is also related to the impact of the conditions of use. Tying the scope too close to certain conditions of use, runs the risk of easily evading the scope and thereby the regulated requirements. The scope has to be formulated in a general way which in turn could result in including even more usage conditions.

The system definition suggests different addressees: the manufacturer of the parts, the company that offers the system to a customer or the customer that specifies the system, or the company that assembles (and installs) the system.

3.2 EFFICIENCY METRIC AND REQUIREMENTS

Efficiency relates output (performance) to input (energy) – or vice versa. Whereas an efficiency metric can in principle always be formulated, the setting of requirements for a system can be more difficult, because its energy consumption and performance depend on the assembly, the design and the location where it is used. These conditions need to be reflected both when setting the requirements and in the test method; for example using a refrigerator in a warm room might lead to other requirements (and test methods) than when it is used

in a cold room. It might not be easy to establish a single requirement that all systems in scope must comply with.

Another aspect is the relation between requirements for parts of the system. First, efficient requirements for individual parts may not always lead to achieve a high efficiency for the system. An efficient electrical motor and an efficient variable speed drive (VSD) can work together in a way that is inefficient. Only an optimal reciprocal alignment turns the two parts into an efficient system. Second, an argument may be that setting a requirement for the system makes requirements for the individual parts superfluous. If both the requirements for the parts and the system requirements can be measured, the requirements for the parts could be considered superfluous. However, as indicated above, verification may depend on testing parts of the system and deriving the result for the system via a model. To ensure the correctness of the input data for the model, setting requirements for the parts can be useful. More importantly, parts used in regulated systems may also be used as standalone or be used in other non-regulated systems. Since in practice it is impossible to differentiate between a part used in a regulated system and elsewhere, the parts used elsewhere would not be regulated.

3.3 VERIFICATION AND TEST METHODS

The main purpose of a test method as an essential part of verification is to measure characteristics of a system, e.g. performance or energy consumption, in an objective and reproducible way. Test standards specify the test conditions, and define admissible deviations, the accuracy and handling of the test equipment. A test method should also be representative, i.e. the test conditions, including the prescribed operation of the system, should reflect the location where it is used. However, testing a system under real conditions might not be realizable; and testing the system only under laboratory conditions might be less useful if the impact of the assembly is large.

Verification should therefore focus on the (quality of the) assembly. There are three levels of verification (including any combination of them) which could be used in a systems regulation:

- System level: the system as assembled is tested. Modelling can be used to cover the full extent of the "operational" range of the system.

- Part level: all parts of the system are tested; results for the system can be derived via a model.

- Assembly: the quality of the assembly is checked.

3.4 REGULATORY POWERS

Another important aspect is the understanding if the relevant authorities (e.g. ministries, surveillance authorities) have the regulatory powers to adopt, execute and enforce these energy efficiency measures. This can relate to the scope, territorial jurisdiction or powers of market surveillance authorities. Systems may not be in the scope of the regulatory powers. Federal authorities may not have jurisdiction over systems that are assembled in a state or province. Market surveillance authorities may not have the power to enforce cooperation in case of testing or assessing a system on location. Changing regulatory powers is often a slow and difficult process due to the involvement of higher order legislation.

3.5 METHODOLOGICAL APPROACHES FOR ASSESSING SYSTEMS

A number of methodological approaches for assessing systems do exist: black box approach, modular approach, procedural approach, statistical approach, and modelling approach. They can be applied in a single way or combined with each other. Each of these approaches has a different focus on a system: e. g. the black box approach assesses only the relevant inputs and outputs of the black box (system), without considering the system itself, whereas the procedural approach focusses on the assembly of the system. As such, the relevance for assessing systems classified according to the defined elements – impact of assembly, number of parts, % of identical parts – might vary.

If e. g. the impact of assembly is large, the procedural approach should be included, due to its focus on the assembly and installation of the system. Modular and modelling approaches can cover the different situations regarding number of parts, % of identical parts and variations in conditions (usage, operational), as they use calculating methods and mathematical formulas to assess the systems efficiency based on the parts and/or design parameters.

4. EXAMPLE OF REGULATING SYSTEMS: WATER PUMP UNIT

A water pump unit consists of several parts, and some are already regulated in the EU; such as the hydraulic part (Commission Regulation (EU) 547/2012) and the electric motors (Commission Regulation (EU) 2019/1781). Products placed on the market also have to meet a certain minimum efficiency, expressed as minimum efficiency index (MEI). In the revision of the water pump regulation, it is proposed to extend the scope to a 'water pump unit', i.e. the hydraulic part (pump), the electric motor and the VSD.

The efficiency requirements for the water pump unit are based on an energy efficiency index (EEI). Although the use of a VSD is not directly mandated, the

EEI requirement on the water pump will be set at such level that they can only be met with a VSD. The preparatory study for the review of the regulation estimates the savings for the EU at around 40 TWh/year in 2030 (Maya-Drysdale et al. 2018), which is an order of magnitude larger than for water pumps only (3,3 TWh/year). The reason is that applying a VSD ensures that load variations are matched by adjusting motor speed instead of using throttling values. In case of fixed load applications adjusting the water pump to the required load point can be done via motor speed control instead of pump trimming. Furthermore, the study indicates that testing methods for water pump units are available.

The main issue to be solved is the verification and enforcement. If a manufacturer is placing on the market a water pump unit, this unit has to comply with the requirements and verification by market surveillance authorities. However, the scope of the revised regulation also includes water pump units that consist of a water pump, an electric motor and a VSD – each individually placed on the market – that are assembled and installed on location. The challenges are to identify the actors that put water pump units into service, and the verification on location, as some market surveillance authorities in EU Member States do not have the legal powers to visit installation.

5. CONCLUSIONS

This paper investigates the challenges to regulate the energy efficiency of systems through policies. These challenges are firstly associated with the verification. Verification of systems in many cases will deal with the (quality) of the assembly. Secondly, setting requirements on systems can be challenging when they operate in a large variation of conditions. Finally, a lack of regulatory power is a further challenge. Methodological approaches to assess systems covering different aspects exist, but their applicability needs to be checked individually.

Regulating systems can be challenged due to verification and enforcement; in the case of the water pump unit, it will be difficult to check whether a VSD is included in the assembled and installed system because there is no register of installed systems. Based on these findings, this paper concludes with a number of recommendations, which are summarized in **Error! Reference source not found.**.

Tab. 2: Mapping systems and regulatory solutions

System class	Main elements of energy efficiency measures

	Scope and addressees	Efficiency metrics and requirements	Verification and test methods
①: impact of assembly: small-medium; small number of parts	Manufacturers of (parts of) the system.	Efficiency of the parts and of the system.	Measurements on the parts of the system; modelling to provide results for the system (in a variety of usage conditions).
②: impact of assembly: small-medium; large number of parts with a large % identical parts	Manufacturers of the parts.	Efficiency of the parts.	Measurements on the parts.
③: impact of assembly small-medium; large number of parts with a small % identical parts	Manufacturers of the identical and/or critical[a] parts of the system. Assemblers/installers of the system.	Efficiency of the (identical/critical) parts. Efficiency of the system as assembled and installed.	Measurements on the (identical/critical) parts. Modelling to calculate system efficiency as assembled and installed.
④: impact of assembly: large; small number of parts	Manufacturers of the parts. Assemblers/installers of the system.	Efficiency of the parts. Quality (control) of the assembly/installation.	Measurements on the parts. Check on the quality (control) of the assembly/installation.
⑤: impact of assembly: large; large number of parts	Assemblers/installers of the system.	Quality (control) of the assembly/installation.	Check on the quality (control) of the assembly/installation.

[a] critical with regard to energy consumption of the system.

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LITERATUR

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