REVISED VERSION

The role of technology-forcing standards and innovation to dramatically accelerate product energy efficiency

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Abstract

There is mounting evidence that appliance energy efficiency programs have already delivered large carbon reductions, at very low or negative cost to society. As a result, most economies are continuing and expanding such programmes.

Future performance requirements for appliances programs typically span a two to six year time horizon; to cover technical analysis, negotiation, and time for industry to develop and market products which meet the new requirements. In addition, some governments publish more stringent 'reach' standards to describe likely performance requirements over a longer period.

These processes have successfully stimulated gradual energy efficiency improvements over short term horizons, with multiple iterations. However, some stakeholders wish to set longer term and stricter standards, though policy makers are constrained by what they know about current and likely future technologies and often rely on technology-cost information from industry, which may have an interest in not being forthcoming.

Implementing policies which push the energy performance boundaries to a level beyond what is currently considered cost-effective would be an approach to accelerate efficiency: Technology-Forcing Standards (TFS), if used appropriately, and coupled with earlier supporting policy measures on innovation may help identify the future trajectory of performance thresholds going from current products to new and as yet unidentified technology and services. This paper will consider such an approach, based on the lessons learned from a recently completed international project examining the suitability of TFS for product policy.

This paper reviews the approaches currently used in standards setting in the major economies, and compares-contrasts the various options of applying TFS and their appropriateness for different situations. This paper also includes a review of the benefits and risks of developing TFS and proposes some risk mitigating options.

The main findings are that for energy using products setting the stringency of minimum energy performance standards so high that it would be regarded as a TFS is high risk and would require a bold regulator to take this route with many possible risks of failure. Instead it is suggested that high performance levels are used in a number of ways to encourage ambition as part of a suite of policies that support innovation in energy efficiency. The overall vision is one where policy-driven innovation (PDI) delivers substantially greater energy savings than current programmes.

Introduction

There is mounting evidence that appliance energy efficiency programs have already delivered large carbon reductions, at very low or negative cost to society (Ellis 2007, CSES 2012 and Sachs 2012). As a result, most governments are continuing and expanding such programmes, using a range of policy instruments to help deliver and realise the potential savings. These policies consist mainly of mandatory energy labelling and mandatory energy efficiency performance standards (generally minimum energy performance standards, MEPS). The process of setting new regulations and them taking effect typically takes two to six years; to cover technical analysis, negotiation, and time for industry to develop and market products which meet the new requirements. In addition, some Governments publish more stringent 'reach' standards (i.e. ambitious standards that regulators hope to reach in future) to describe likely performance requirements over a longer period, such as the reach standards in some Chinese MEPS regulations.

MEPS have successfully stimulated gradual energy efficiency improvements over short term horizons, with multiple iterations (see for example Ellis 2007). However, some stakeholders wish to set longer term and stricter standards, though policy makers are constrained by what they know about current and likely future technologies. They must often rely on technology-cost information from industry, which may have an interest in not being forthcoming.

Implementing policies which push the energy performance boundaries to a level beyond what is currently considered cost-effective would be an approach to accelerate efficiency: Technology-Forcing Standards (TFS) which go beyond current stringency levels of current MEPS are examined further in this paper. There appears to be no universal definition for Technology-Forcing Standards. The concept of TFS appears from the field of environmental regulation, specifically on the banning of particular processes or material. In the context of product policy we propose a definition for TFS to be an energy performance standard which requires:

- technology beyond what is currently available on the market today; or,
- technology that may be too costly at present to be widespread;
- innovation or broad diffusion; and importantly,
- delivery via government regulation.

The International Energy Agency's Implementing Agreement on Efficient Electrical End-use Equipment IEA 4E recently funded a project to provide an initial examination of the usefulness of technology-forcing standards for appliances (Lane and Brocklehurst 2012). This paper draws on that knowledge, develops some standard terminology and suggests some pragmatic ways forward. Therefore, this paper reviews the approaches currently used in standards setting in the major economies, and compares the various options of applying TFS and their appropriateness for different situations. This includes a review of the benefits and risks of developing TFS and some risk mitigating options are proposed. The paper concludes with practical suggestions on how to improve the current standards and market transformation approach.

Technology and performance requirements for energy efficiency

POLICY CONTEXT

Before looking at energy efficiency performance levels it is worth clarifying what energy efficiency is in the context of energy-using products. In general, there are (at least three) dimensions to this:

- energy consumption of the appliance;
- functionality of the appliance;
- cost of improving the efficiency;

where energy and functionality combined represent energy efficiency. The main focus of an energy efficiency programme is bringing forth "technology" that reduces energy consumption of products at the same (or improved) functionality level within certain cost level constraints (e.g. minimum life cycle costs). An energy efficiency programme usually consists of a combination of measures.

When examining the role of energy efficiency policy measures for appliances, there are different types:

- information measures, such as labels or web sites;
- financial measures, such as subsidies, rebates or taxes;
- product conformity measures that mandate or require a minimum performance.

Together with the format of the measure (supportive, voluntary or mandatory – referring to the nature of the measure) it is possible to classify different types of policy measures, see Table 1.

Although it is possible for Governments to implement discrete policy measures, it is more common for Governments to implement a number of measures. These measures can be combined in a strategic way to move the market towards the sale of more efficient products in a more effective and timely manner. This package of measures is sometimes termed a market transformation approach (see e.g. DECADE 1997).

Minimum Energy Performance Standards (MEPS) or minimum efficiency requirements (Table 1) are a regulatory approach to setting the lowest allowed energy performance in a given market. In principle they can be set at any performance level: from just above that currently available in the market to remove only the poorest performing products, to above that currently available on the market. The selection of the performance level depends on a number of variables including the rationale for the regulation, the nature of the market and the ambition of the policy maker.

MEPS have been provide to be very effective policy approach to improving efficiency, reducing energy consumption and reducing carbon emissions (e.g. Lane and Harrington 2010 show the long term savings from such measures in Australia), and continue to provide a significant scope for further savings (e.g. Desroches *et al* 2011).

In order to facilitate international discussion on the level of ambition of MEPS and other policy tools a 'standard set' of terms for these levels are essential. Such a set is developed Table 2, based partially on practice used in various jurisdictions. Possible information sources to gain an indication of the technology or performance level for a given product in a given market are also provided in this table.

These definitions are proposed by the authors. Some similar definitions are used in other jurisdictions; for example, the US DoE uses the term Max Tech to identify the best next available technology (DoE 1995, 2011). In this case each aspect of the technology is available as a prototype, but may not be as a single product combining all of these. As such this definition of Max Tech is very similar to BNAT.

Table 1. Classification and examples of policy measures.

		Format of measure		
		Supportive	*Voluntary*	*Mandatory*
Type of measure	*Information*	Making basic information available	Voluntary energy label	Mandatory labels
	Financial	Subsidies for pre-competitive research	Rebate programme by utility	Taxes
	Product conformity	Public research centres	Voluntary agreement by manufacturers	Minimum efficiency requirements

Table 2. Definition of technology level for products and information sources.

Technology level	Definition	Possible information source
MAT	Minimum Available Technology on the market.	• This can be determined by any existing MEPS regulation. • Checking existing market data (e.g. registration or commercial).
AAT	Average Available Technology: the average efficiency of the available technology on the market place. Usually the sales-weighted average is used.	• Checking existing market data (e.g. registration or commercial). Usually available for products with categorical labelling and good market data (e.g. products sold to consumers) and/or in countries for products where registration in a national database is required, e.g. products with MEPS in Australia and US.
BAT	Best Available Technology on the market.	• Registration databases, especially for endorsement labels (e.g. EnergyStar). • Similarly for tax and grant programmes (e.g. ECA in UK) • Other market information may focus on best available technology (e.g. TopTen). • Competitions.
MLCC	Minimum Life Cycle Cost to the consumer of the product, where the life cycle costs include purchase and running costs.	• Engineering and economical analysis
BNAT	Best Not (yet) Available Technology that which is known to be under development and may be available as a prototype but not currently available commercially.	• Competitions (e.g. SEAD). • R&D grants. • Innovation information fora (e.g. IEA 4E SSL annex).
Theoretical limit	The highest efficiency using theoretical considerations and the current understanding of how the required can be delivered.	• Theoretical academic research.

The relative stringency of these different technology (or efficiency) performance levels can be shown on an efficiency distribution curve (Figure 1). The x-axis describes increasing efficiency, with the different technology level names listed beneath the axis. An example of the proportion of the market is then shown by the curve. Above the curve, some typical policy measures are shown, with the likely mandatory measures in blue boxes.

ENERGY PERFORMANCE STANDARDS IN USE

Energy Performance Standards have been applied for several decades now in different parts of the world; while there are some key aspects in common there are differences in how they have been applied; in particular the process for how the performance level has been selected (in the context of the technology performance levels proposed above). This is illustrated by examples from US, EU, Australia and Japan, where this section will for each region:

- shortly describe the process;
- indicate the ambition/technology level the process/MEPS aim at;
- and indicate the challenges.

US Energy Conservation Standards

Energy conservation standards (ECS) or minimum energy performance standards (MEPS) have a long and successful history of use in the USA (especially since NAEEEC 1987), following their initial development and deployment in the State of California. As a MEPS, the efficiency standards apply to the sale of all new energy-using products on the market, are mandatory in nature, and all products must comply or manufacturers face sanctions.

The target levels for each product are developed in individual rule-makings, which are rigorously undertaken. The target levels themselves are based on economic optimums from the consumers' perspective (an example curve is shown in Figure 2), based on very detailed engineering analyses. The technology options are based on proven designs, even if they are not yet on the market, or the different combinations of options that have been used to that point.

Importantly, the targets can be beyond the current best on the current market, and this has occurred for several products, e.g. for the 2001 refrigerator standard (DoE 1995). Other observations and lessons include:

- cost calculations for determining ECS have not included the effects of learning (economies of scale) in the reduction of future purchase costs to date (e.g. DoE 2011). Though these have recently been added to the national impact assessment (NIA) models, with the intention to include this effect in the engineering life cycle costs (LCC) target models, so importantly they will also have an impact on the target levels themselves;
- recent ECS rule makings have included the societal cost of carbon in their NIA models;
- the MLCC ECS levels are unlikely to drive innovation (i.e. likely to satisfy the conditions of a true TFS as discussed in the next section);
- an important component of the DOE's ECS setting analytical framework is the concept (or identifying the technology level) of Max Tech, and this is pertinent to TFS. A recent Max Tech analysis by LBNL (Desroches and Garbesi, 2011), suggests 200 Quads (211,000 PJ) could be saved if Max Tech levels were implemented.

The main feature of this ECS setting approach is that it is a 'no regrets' approach: the improvements in efficiency that are demanded by the regulation should not incur additional costs to consumers on average. The main disadvantage of this approach is the cost of undertaking such a detailed analysis for each product, and the review period and process of updating the standards (there is no automatic update or revision process). This approach to setting ECS standards is costly both in terms of timing and resources. The rigorous nature of the analysis means that, while the result is very robust (within the bounds of the analysis) this process is resource intensive for Government – it is the most expensive of the four MEPS reviewed here.

EU Minimum Energy Performance Standards (Ecodesign directive)

Similar to the US, the EU has developed minimum energy performance standards for a range of energy-using products. The current legal vehicle is a framework directive at the European level (Ecodesign directive 2009/125/EC), which allows for implementing measures, generally regulatory instruments.

The new standards resulting from the Ecodesign Directive are intended to be ambitious and deliver cost-effective technology change, and may be technology forcing in that it may propose levels that are not currently on the market. In practice this is very difficult given that there is a requirement that the MEPS levels are set at the least life cycle cost and no requirement to take account of reduced cost through learning in the EU methodology (Kemna 2011). However, the inclusion of learning is not forbidden in the regulations, and this is considered further in the conclusion section. A recent review of the processes is provided by Siderius (2013). Some other aspects of the Ecodesign Directive are:

- the regulations, including the performance levels, are decided by a Regulatory Committee taking views from a Consultation Forum into account. The underlying evidence and analysis is based on preparatory studies[1] which are contracted out by the European Commission;
- the analytical approach to target efficiency levels are similar to the US ECS, which are based on detailed engineering analyses (although with a smaller budget and consequently less detailed);
- non-energy aspects such as product performance (cleaning results for washing machines) are included in the ecodesign methodology (Kemna 2011);
- a best available technology (BAT) analysis is included, delivering indicative benchmarks which are useful to show the currently known best technology;
- a BNAT is included in the analysis.

The intention and ambition of the EU Ecodesign directive as laid out in its successive working plans[2] is laudable; however, a review of ecodesign implementation levels was undertaken by a campaign 'Cool products for a cool planet' (CoolProducts 2010) which suggested that the implementing measures under the Ecodesign Directive had not been sufficiently ambitious (e.g. had only a limited impact on the European market). This was echoed to some extent by the formal EC-funded methodology and evaluation review undertaken by CSES (2012). They found that they were restricted in their ability to assess the impact of measures implemented thus far, citing a lack of available data, but noted that while the initial (tier 1) requirements for some products seemed to have limited effect on the market yet there was scope for subsequent (tier 2) requirements (which had not taken effect at the time of the review) to have greater effect.

Australian MEPS

Australia has a long history of product policy, dating back to 1986 for mandatory labelling, though the first MEPS were not adopted until 1999 for refrigeration appliances. Its approach to MEPS regulation is similar to the US and EU in that it sets a specific minimum mandatory requirement for every product placed on the market.

With a relatively small market compared to US or EU, Australia has fewer resources to undertake detailed technology assessments; its regulators focus actively on developing effective

1. The Ecodesign and labelling page on the eceee website (http://www.eceee.org/Eco_design) provide signposting to the results of all these studies as well as the latest EC papers.

2. See http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/index_en.htm for details

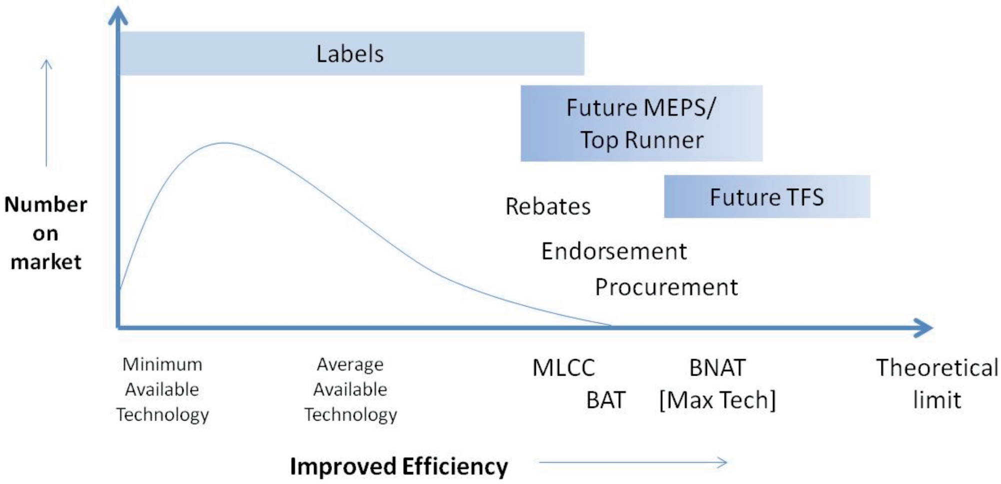

Figure 1. Schematic of efficiency distribution, technology levels and policy measure.

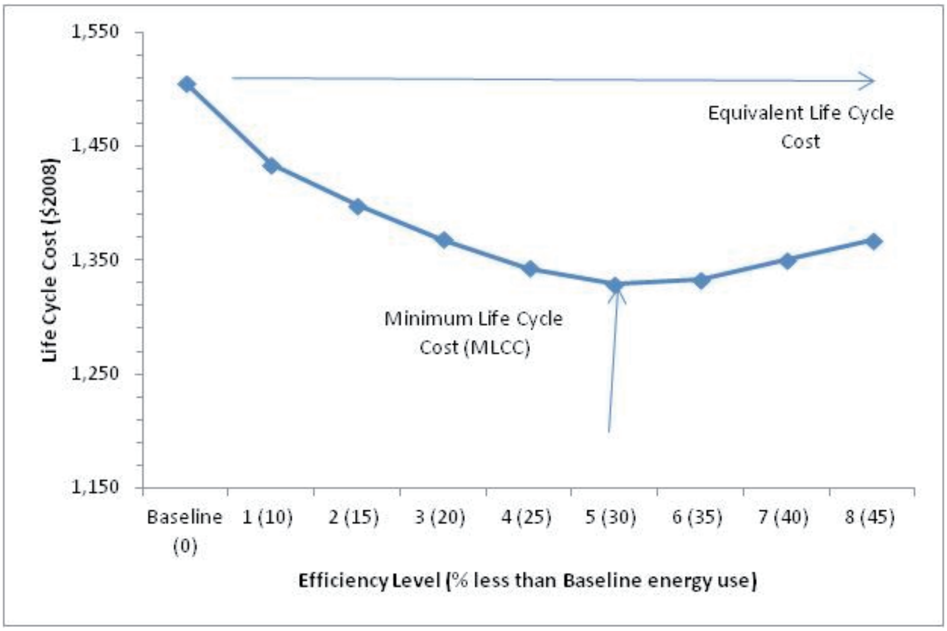

Figure 2. Example life cycle cost curve used in determining MEPS levels in regulations (US refrigeration example). Source: DoE (2009).

product policy. The mandate of the E3 committee (E3 2008), the body which proposes and implements the product regulations, has two parts of note:

- Australia should match the best regulatory practice, but with a suitable time-lag to allow local industry to adapt to the new policy; and
- to consider regulating products even in circumstances where a cost is imposed upon the community provided such action may offset even more expensive mitigation action sometime in the future.

The second point is interesting in developing more stringent performance standards. For example, this means the cost of (mitigating) carbon can also be included the analysis for setting the required performance levels. There are some other interesting characteristics of the Australian approach which are worth noting:

- As Australia is primarily an appliance importer (and has generally has no local industry) it feels it does not need to develop detailed manufacturer impact assessments, nor can it usually justify the resources to develop detailed cost-benefit curves for new technologies. Instead, in most cases it makes use of other regions who have already developed such technology assessments (primarily the EU and the USA), and augment the requirements and assessments as necessary. By choosing to harmonise with these international levels, it is easier to pass regulations; it also has other benefits for regulators and manufacturers. Primarily, it reduces the cost to the Government of developing the regulations, and delivers more efficient products to the Australian market.

- To aid this process of emulating best practice, Australia has recently decided to follow the International Electrotechnical Commission IEC standards (for measuring the performance of equipment) more closely, rather than developing their own standards. This should make it easier for its regulators to benchmark the performance of products being sold in their region against international best practice.
- A recent detailed evaluation show that MEPS have been very efficient at moving the market towards more efficient products; the subsequent impact of 'revalorisation' of labels is less obvious (Lane and Harrington, 2010).

Japan's Top Runner

The Top Runner approach is an alternative (to US and EU) approach to setting performance standards whereby the fleet average of each manufacturer or importer is required to meet a certain value rather than each product being required to meet a minimum standard. The average performance target is set based on the best available technology available at the time – hence the name 'Top Runner'; the discussion is about when in the future this target has to be met. Further differences are that manufacturers and importers are required to co-operate with standard setting process and compliance is by 'name and shame' rather than fines or legal penalties.

There are very few detailed evaluations in the public domain; however evaluations of Japan's Top Runner by Kimura (2010) and Nordqvist (2006) for AID-EE suggested that the Top-Runner approach:

- is useful as it avoids the issue of poor updating of MEPS (as was the case in Japan in 1980s), so could be quicker; though there is not an automatic update process;
- is flexible – standards can be set higher than the market leaders (during the setting phase) if technical analysis reveals this is possible (e.g. this was done for AC equipment). This is not unique to Top Runner and requires a technical analysis to show that the level can go beyond the current best available technology;
- is flexible – as it is not just a single policy measure, rather a policy programme. As such, it has been extended to include labelling aspect and retailer certification and supports other policies such as procurement;
- is not technology neutral, different standards for different technologies (e.g. CRT different level than LCD). So this would not drive innovation within a technology group classification (that is it would not encourage a switch between technologies e.g. from incandescent lamps to CFLs;
- has impact across the range and especially the low end (cheaper to remove very inefficient models than improve efficient ones) (shown for AC);
- contains a risk of non-cost-effective models being developed/required (though regulation has a light touch to avoid this (ECCJ 2008, p17));
- is difficult to project future developments for some products (e.g. fluorescent lighting and TVs where target easily met only two years after they were set, well ahead of target date). Though this issue is apparent for other MEPS such as the EU Ecodesign;
- has provided energy reductions in line or better than estimated, though detailed evaluation would have to be undertaken to extract impact of other measures/factors;
- is applied to the Japanese market, which is dominated by limited number of domestic producers (which all have high technology competency, so there is no risk of exclusion with higher targets). "A decisive success factor for the Top Runner programme in Japan is stakeholders' – in particular industry's – willingness and capability to co-operate extensively with the regulator and each other, devoting considerable time and resources in the process." (Nordqvist 2006)

One perceived disadvantage is that firms may not be so forthcoming with innovations if products they develop are to become the future standard level. This is a risk, but interestingly this does not seem to have happened in the Japanese case so far (from evidence available and reported).

When comparing the impact of the total energy savings achieved as a proportion of consumption, the Japanese approach and the EU approach seem to have realised similar amounts – there is not clear outcome based advantage of one over the other yet (Siderius 2013).

In terms of regulator cost, the Japanese Top Runner approach could be less than the US or EU case, since the costs of undertaking detailed technology assessments is somewhat avoided; however, this is generally not the case as it is still an extensive cooperative process (Nordqvist 2006). Furthermore, the explicit reporting of the US and EU analysis provides benefits beyond their own borders, such as to Australia, where they can make good use of the analysis to determine their own standards.

Technology-forcing standards

While it could be argued that MEPS have been applied in some cases as technology-forcing standards they have not been consciously developed within this framework. The IEA 4E (Efficient Electrical End-use Equipment) Implementing Agreement commissioned some research to look into policies that were explicitly labelled as TFS (either at the time of development or in subsequent review), what could be learnt from these and how the approach might be applied to energy using product policy (Lane and Brocklehurst 2012).

USE OF TECHNOLOGY-FORCING STANDARDS IN ENVIRONMENTAL POLICIES TO DATE

The term TFS first appears to be used in the development of catalytic converters in the early 1970s. Subsequent examples have been identified in the context of TFS, all outside the application of energy using appliances: they range from car carbon efficiency (e.g. zero emission vehicles in California), the ban on ozone depleting substances, SO_x, and perhaps building regulations and even renewable obligations. The policy mechanisms have ranged from outright bans through to trading mechanisms which put a price on a pollutant (and in some cases include a 'get out' clause to temper the case where targets are set too stringently). In all cases a TFS approach was used when it was perceived that there was a serious environmental or safety threat which needed to be addressed and a desire to act in an ambitious way – to incentivise a revolution in delivery without specifying the solution. Lane and Brocklehurst (2012) describe these policies in some detail. For brevity these are listed and summarised in Table 3. Though not all may be considered as strictly TFS regulations, they provide insight into different aspects of stringent regulation.

In all cases reviews of the policies were sought and lessons learnt from these reviews were collated. The learning points derived from this analysis can be grouped as follows:

- the importance of flexibility;
- that strong regulation, dependent on public support;
- the importance of industry cooperation.

Importance of flexibility

- need to be careful that industry does not concentrate on short term winners (RPS);
- regulations set the goal but do not specify the solutions, which develop in response (Montreal agreement);
- focus on energy service rather than specify technology or elements That is, let the industry decide on the way to achieve any target levels rather than being prescriptive on 'picking winners' (USA SOx trading, England zero carbon homes);
- frequent review of targets meant that they were kept ambitious and feasible – decisions can be based on current evidence (Montreal);
- need a get out clause (if nearly reached target) – some pragmatic flexibility (US Clean Air Act).

Strong regulation/public support necessary:

- strong public engagement and scientific evidence of need for action enabled widespread international agreement with strong targets (Montreal);
- strong regulatory (EPA) worked better than voluntary approach (NHTSA) (US Clean Air Act);
- political and regulatory factors of the implementation process can be decisive in effectiveness (US Clean Air Act);
- requires strong regulation and government to see through ambitious changes. (England zero carbon homes).

Degree/nature of industry co-operation is key:

- getting information on technology required can erase the problem of asymmetric information (that is industry has more information than Government on performance and the cost of changing this). Any asymmetry can mean a delay or reduction in performance levels. (US Clean Air Act);
- information asymmetry between government and industry is hard to address when many different processes and sec-

Table 3. TFS policies reviewed.

Name of policy	Region	Process/market affected	Date of introduction	References
Renewable energy (Portfolio) Standards (RPSs) In the UK – called the Renewables Obligation	UK (also elsewhere, e.g. China, USA)	Providing support to renewable energy generation	1990s	Wiser *et al* (2007)
Climate Change Agreements	UK	Incentivising energy efficiency in energy intensive industry	2000	Brocklehurst experience supporting UK regulator.
Montreal Protocol	Worldwide international agreement	The phase out of use of ozone depleting substances	1997	Miller (1990), Parson (2002), Sunstein (2007), Heaton et al (2006), DeCanio (2009)
Clean Air Act	USA	Reduction of tailpipe emissions (HC, CO and NO_x) from vehicles	1970	Gerard and Lave (2007)
Zero Emissions Vehicles (ZEVs)	California, USA	Vehicle manufacturers required to produce fraction of their sales as ZEVs	1990	Collants and Sperling (2008)
SO_x reduction via cap and trade	USA	Electricity generators	1990	Taylor *et al* (2005a) Taylor *et al* (2005b) SQW (2007), Burtraw *et al* (2009)
English Building regulations	England	Requirement for 'zero carbon' homes	2016	HM Treasury (2006)

Source: Lane and Brocklehurst (2012).

tors are involved (and even worse when there is no common metric within sectors, UK CCAs);

- information asymmetry leads to un-ambitious targets and low achievement of savings relative to the potential (UK CCAs);
- industry agreement makes strong action easier (inefficient lamp phase out);
- competition can drive manufacturers to develop technology early – either by reducing cost (competitive advantage) or technology suppliers providing information insights to regulators (US Clean Air Act).

BENEFITS, RISKS AND MITIGATION OPTIONS OF TFS

Benefits

From reviews of the TFS approach in general (see for example Porter *et al*, 1995) the main benefits of a TFS type approach in product policy can be described as being:

- effective (bring forward efficient technology);
- provide certainty;
- enable (require) investment in R&D and innovation of new technology.

They thus appear to offer a way of increasing the speed of action on product energy efficiency. However they will not be suitable for all products and for all markets. Lane and Brocklehurst (2012) found from the review that the criteria for success are:

- appropriate testing protocols and experienced facilities are available;
- at least one known future technology pathway is known;
- the potential for increased cost risk is low.
- They then considered some product groups for suitability against these criteria.

Risk and risk mitigation options

In trying to determine some TFS standards for some specific end-uses (in Lane and Brocklehurst 2012), some risks have been identified; the major risks envisaged include:

1. Technical and policy: stringent targets are not ultimately achievable at acceptable cost. In this case the credibility of the TFS programme would be damaged, along with damage to the industry that tried to reach the levels, and damaged credibility of politicians who introduced the overly-stringent targets, etc.;
2. Technical: asymmetry of information (where industry tends to know more than regulators) means it is difficult to set stretching targets;
3. Technical: restricted access to capital for innovation and R&D means targets are not achieved;
4. Policy: leakage issues (that is the activity leaks to regions which are less tightly regulated or the industry in the regulated region becomes less competitive) – with associated risk of reduced competition due to spending on new processes/R&D;
5. Policy: no mandate to require TFS; need new legislation, which is time consuming and requires strong political support.

It is possible to take some mitigating action to reduce these risks: taking the first four risks in turn (the last relates to the "how" of TFS and is covered in the final section):

1) Targets are too stringent and not achievable at an acceptable cost

One of the main risks is that delivering products to a high efficiency level may mean significantly higher purchase costs which are passed on to consumers.

Mitigating actions include:

- getting accurate information on potential from innovation and costs of achieving it – covered in next risk (information asymmetry);
- regular reviews of progress – used in Montreal, CCAs and Top Runner. This is not in itself a panacea – industry may deliberately 'drag their feet' knowing that a review is due and if they make poor progress then the targets may be softened. There is also an inherent tension between the certainty which is needed to justify investment by companies in innovation and the need to review to check that targets are reasonable;
- innovation waivers – though in principal these are attractive, the reported experience to date is poor;
- collaboration amongst industry increases speed of change and reduces costs. This proved very effective in meeting the Montreal protocol targets;
- providing incentives for companies to share their IPR for effective diffusion of new technology – reducing costs (and the need to 'reinvent the wheel');
- supporting the TFS with other policies: procurement, subsidies, R&D grants or tax breaks, competitions etc.;
- where the targets are international and cover both developed and developing countries allowing developing countries more time to respond and providing financial support to help them meet them (as per the Montreal protocol, and the Kyoto Protocol under the UNFCC).

2) Information asymmetry makes it difficult to set stretching targets

Several of the examples examined in Table 3 illustrate this, for example CCAs. This also applies to the EU MEPS process.

Mitigating actions include:

- develop expertise directly or through (independent) contractors;
- obtain information from component suppliers who are looking to expand their market for an innovative technology;
- use competition (within region or foreign vs. domestic) to encourage firms to provide information;

- using a common metric (internationally) – this makes benchmarking straightforward making it harder for industry to 'muddy the water' and easier for good practice to stand out.

3) Technical – restricted access to capital for innovation and R&D

This may be a particular issue for small companies and may reduce competition. Alternatively in some areas the innovation may be driven by small companies and/or the need for innovation may open up the market and increase innovation.[3]

Mitigating actions include:

- encourage and support collaborative research (as per the first risk listed);
- offer grants or tax breaks in support of R&D;
- give confidence that the policy will be adhered to – companies are unlikely to be able to access investment if there is doubt that the targets will be held to and therefore that they are necessary/beneficial (but see comments on 1st risk regarding the need for review).

4) Leakage /reduced competiveness to non-regulated regions

If a stringent requirement is set in one country or region and not in another and requires considerable investment by manufacturers and/or results in a higher cost to consumers (who may themselves be manufacturers) then the manufacturing capability may move outside this region/country (i.e. leak), or the region/country may become less competitive. For energy using products, where the performance-in-use phase is mostly regulated, it is the latter risk which is significant. However, sometimes more efficient technologies turn out to be more cost effective in terms of manufacturing and more often, in terms of lifecycle; so this is not always a given negative. Also other regions/countries have the same environmental constraints and may adopt similar regulations in future so this may give 'first mover' advantage[4] to those who adopt early.

Mitigating actions include:

- making the coverage of the regulation as wide as possible – at least to cover those areas which are in direct competition (although clashes with 4 – i.e. increased time delay);
- reducing costs of innovation by supporting R&D investment and encouraging collaborative research.

Conclusions and recommendations: what role for TFS in product policy?

The previous section highlighted the technical and policy risks of using a TFS approach alone, which were mainly identified in the study by Lane and Brocklehurst (2012). The main risks identified are: failure to reach targets damaging credibility of regulator and the industry, asymmetry of information between regulator and industry, insufficient access to capital, insufficient mandate by regulators, and policy leakages. This may mean that a very rigorous and inflexible TFS may be considered too risky by some regulators and governments. These risks can be mitigated to varying degrees, as discussed above; however, alternative or complementary pragmatic measures to a TFS approach may yield similar or robust outcomes with reduced risk. This final section takes this next step and considers two main options:

- make existing MEPS (and similar mandatory) measures more stringent;
- consider using TFS performance levels as 'aspirational' targets within an integrated product policy approach.

In terms of making existing MEPS more stringent, these could be done in a formalised way. The following could be considered where engineering analyses are currently used as the basis for the MEPS levels:

- target equivalent life cycle cost (rather than LLCC, as illustrated in Figure 2), which will:
  - deliver greater savings;
  - reduce the rebound concern (no net financial saving to consumer so no additional funds to spend on extra consumption);
  - mean when the MEPS are next revised the starting point for the life cycle analysis will likely be higher (than if the MLCC is chosen for the current iteration), so there may be scope for more cost-effective energy savings at the next MEPS iteration;
- include external costs/benefits in the LCC calculation:
  - such as carbon cost, air quality;
  - include marginal purchase costs reducing over time in the future due to learning. These are usually now included in the impact assessments (e.g. US, UK and Australia have done recently) though not yet in estimating the LCC, which is usually used in setting the level of the MEPS. This can be seen where the NPV of MEPS programmes is usually very large, which is an indication that the standards could be set at a higher level;
- reduce/remove technology classification – focus targets on service delivery:
  - e.g. remove different standards for side-by-side and top-bottom mounted fridge freezers.

However, these enhanced MEPS levels are still primarily based on existing technologies, even if these are not yet on the market. It may still be possible to consider developing TFS standards (or target levels) which are more stringent, though not made mandatory.

The second approach is to build TFS levels as aspirational targets within the standard Market Transformation strategy.

These policy components of market transformation, if done well, are used in a coordinated way, such that more expensive policies which encourage the best performing products to the market are used as the performance levels for future standards levels.

Setting 'reach' target levels which may be aspirational initially, which then become the rebate or endorsement levels,

3. For a discussion of the effect of product regulation on competition see Office of Fair Trading (2008).

4. Although the value of 'first mover advantage' is hotly debated, for example this is raised in the discussion on whether the EU should adopt more stringent climate mitigation measures than agreed to in international treaties.

then later the MEPS levels, may have some merit. The intention would be to set these target levels out in advance as best as possible as part of technology or efficiency road maps, or government target levels. These target levels (or performance standards) should be spelled out using metrics that are not technology specific and give the greatest scope for innovation.

There is a precedent to such a target-setting approach. The UK government in 2009 laid out in its 'Government Standards' (Defra 2009) what it expected future target efficiency levels to be for a range of products. These targets were set for multiple years into the future. Importantly, they did not tie the standard levels themselves to any specific policy measures. This was partly as it was too early to determine these and also that the policy-lead in setting these targets was not the lead department for all relevant policy measure tools (e.g. MEPS are necessarily set at the EU level, not the UK). This is a common issue, where different departments or jurisdictions have responsibility for different policy measures, meaning effective integration can be compromised.

Thus, the role of TFS, in this pragmatic market-transformation approach, would be to try to determine the future ambitious efficiency levels, and also what metrics would be appropriate. It could also be extended to develop appropriate policy roadmaps for reaching these levels.

FROM TECHNOLOGY-FORCING STANDARD TO POLICY-DRIVEN INNOVATION

Technology-Forcing Standards (TFS) if used appropriately, and coupled with earlier supporting policy measures on innovation may help identify the future trajectory of performance thresholds going from current products to new and as yet unidentified technology and services.

It is a bold regulator that would adopt stringent TFS for energy-using products directly, especially in some regions where regulations do not permit such an approach. For such regions, and even for the less bold regulator, emphasis on improving efficiency in the longer term will depend on supporting continued and enhanced innovation on energy efficiency. Concluding the recent IEA 4E project, it was expected that the thinking would be developed to tie Technology-Forcing Standards more with innovation, and such a project is underway, also funded by IEA 4E. This will look at how two traditional and important mechanisms for bringing high efficiency equipment to the global market could be applied, specifically:

- Technology Incentivising Programmes (TIPs) – which monitor equipment innovation and use a range of support mechanisms (e.g. grants, awards and endorsement labels) to encourage innovation;
- Product Improving Programmes (PIPs) – which allow governments to align future energy performance standards through examining the most cost effective levels for their country now, and into the future, from amongst the different options in the standards-setting spectrum.

The desire is to frame the development of policies in the context of driving innovation – the overall preferred term for this approach being Policy Driven Innovation. This will be a considered integration of policy programmes which should aid an updating of policy measure integration ideas, market transformation for a new generation.

References

Burtraw, D and Szambelan, SJ (2009) U.S. Emissions Trading Markets for SO_2 and NO_x, Resources for the Future Discussion Paper.

Collantes, G and Sperling, D (2008) The origin of California's zero emission vehicle mandate. Transportation Research Part A 42 (2008) 1302–1313.

CoolProducts (2010*) Energy savings in practice: potential and delivery of EU Ecodesign measures. Coolproducts for a cool planet campaign*. Available at http://www.coolproducts.eu/resources/documents/EnergySaving-in-Practice.pdf.

CSES (2012) *Evaluation of the Ecodesign Directive (2009/125/EC)*, final report.

DECADE (1997) Transforming the UK cold market, Environmental Change Unit, University of Oxford.

DeCanio, SJ (2009) Lessons from the Montreal Protocol for Climate Policy, Economics for Equity and Environment.

Defra (2009) *Saving Energy Through Better Products and Appliances*. Available at http://www.defra.gov.uk/publications/2011/06/16/pb13559-energy-products/.

Desroches, L-B and Garbesi, K (2011) Max Tech and Beyond: Maximizing Appliance and Equipment Efficiency by Design. Environmental Energy Technologies Division, LBNL, report LBNL-4998E. June 2011. Available at http://efficiency.lbl.gov/drupal.files/ees/MTAB%20Final%20LBNL%20Report.pdf.

Desroches, L-B; Garbesi, K; Kantner, C; Van Buskirk, R and Yang, H-C (2013) Incorporating experience curves in appliances standards analysis. *Energy Policy* 52 (2013) 402–416.

DoE (1995) *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-freezers, and Freezers (Final Rule)*, Washington, DC.

DoE (2009) *Preliminary Technical Support Document: Energy Efficiency Program for Consumer Products: Refrigerators, Refrigerator-freezers, and Freezers*. November 2009, Washington, DC.

DoE (2011) Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heap Pumps, and Furnaces (Direct Final Rule), Washing, DC.

E3 (2008) Equipment Energy Efficiency Program: Achievements 2007/08. Report number 2008/03. September 2008. Available at: www.energyrating.gov.au.

Ellis, M (2007) *Experience with Energy efficiency regulations for electrical equipment*. International Energy Agency, Paris.

Gerard, D and Lave, L (2007) 'Experiments in technology forcing: comparing the regulatory processes of US automobile safety and emissions regulations', *Int. J. Technology, Policy and Management*, Vol. 7, No. 1, pp. 1–14.

Hahn, R (1989) *A primer on environmental policy design*. New York: Harwood Academic Publishers.

HM Treasury (2006) *The 2006 Pre-Budget Report, Cm 6984 'Investing in Britain's potential: Building our long-term future'*. Accessed February 2013. Available at: http://www.hm-treasury.gov.uk/pre_budget_report/prebud_pbr06/prebud_pbr06_index.cfm.

Kemna, R (2011) *Methodology for Ecodesign of Energy-related Products (MEErP): Methodology report, Part 1: methods*. Prepared for the EC, DG-ENTR. 28 November 2011. Available at: http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/index_en.htm, accessed January 2013.

Kimura, O (2010) Japanese *Top Runner Approach for energy efficiency standards*. SERC discussion paper: SERC09035. Available at http://www.climatepolicy.jp/thesis/pdf/09035dp.pdf.

Laitner, John A. "Skip" (2004) How Far Energy Efficiency? Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings.

Lane, K and Brocklehurst, F (2012) *Technology-Forcing Standard for Energy Efficiency*. A report for the IEA's 4E Annex. Available at: http://www.iea-4e.org Accessed January 2013.

Lane, K and Harrington, L (2010) *Evaluation of energy efficiency policy measures for household refrigeration in Australia: an assessment of energy savings since 1986*. E3 report no 2010/10. December 2010. Available at http://www.energyrating.gov.au/resources/program-publications/?viewPublicationID=2150.

Miller, AS (1990) The development of substitute for Chlorofluorocarbons: Public-private co-operation and environmental policy, Ambio vol 19: no 6–7.

Nordqvist, J (2006) *Evaluation of Japan's Top Runner Programme*. Within the framework of the AID-EE Project. 3rd July 2006. Energy Intelligence for Europe programme, Contract number EIE-2003-114. Accessed 27 November and available at http://www.aid-ee.org/documents/018TopRunner-Japan.PDF.

Office of Fair Trading (2008) *The competition impact of environmental product standards*. A report prepared by Frontier Economics for the Office of Fair Trading. Available from http://www.oft.gov.uk/shared_oft/economic_research/oft1030.pdf.

Parson, EA (2002) The Technology Assessment Approach to Climate Change, Issues in Science & Technology, Summer 2002.

Porter, ME and van der Linde, C (1995) Toward a New Conception of the Environment-Competitiveness Relationship, The Journal of Economic Perspectives, Vol 9 no 4, pp. 97–118.

Sachs, N (2012) Can we regulate our way to energy efficiency? Products standards as climate policy. 65 *Vanderbilt Law Review* 1631, 19 May 2012.

Siderius, P.J.S (2013) Speeding up adopting ecodesign and energy labelling measures – analysis, challenges and solutions. Proceedings of the ECEEE Summer Study. June 2013, France.

Siderius, P.J.S., H. Nakagami. (2013) A MEPS is a MEPS is a MEPS: comparing Ecodesign and Top Runner schemes for setting product efficiency standards. Energy Efficiency 6: 1–19.

SQW Ltd (2007) Exploring the relationship between environmental regulation and competitiveness (phase 2), Annex : SO_2 and NO_x case study, for Defra.

Sunstein, CR (2007) Of Montreal and Kyoto: a Tale of two Protocols, Harvard Environmental Law Review, Vol 31.

Taylor, M; Rubin, E and Hounsehell, D (2005a) Regulation as the Mother of Innovation: The Case of SO_2 Control. Law & Policy, Vol. 27, No. 2, pp. 348-378, April 2005.

Taylor, M; Rubin, E and Hounsehell, D (2005b) Technological Forecasting & Social Change 72 (2005) 697–718.

Wiser, R; Namovicz, C; Gielecki, M and Smith, R (2007) Renewable Portfolio Standards: a factual introduction to experience from the United States. Environmental Energy Technologies Division, LBNL. April 2007.

Glossary

IEA 4E	International Energy Agency Implementing Agreement for a Co-operating programme on Efficient Electrical End-Use Equipment
MEPS	Minimum energy performance standard
MLCC	Minimum life cycle cost
NIA	National impact assessment
NPV	Net present value
PDI	Policy-driven innovation
SEAD	Super-efficient Equipment and Appliance Deployment Initiative
TFS	Technology-forcing standard

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