Interpreting cost-effectiveness: target definitions versus policy objectives

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Abstract

The aim of this paper is to contribute to knowledge on SMART target setting and policy design. In doing so, the target setting of the EU Renewable Energy Directive is explored and an in-depth analysis of the Dutch renewable support instrument SDE is carried out. In addition, the paper discusses the extent to which the findings can be generalized to the field of energy efficiency.

Cost-effectiveness analysis provides a frame of reference for relating costs to the results of subsidy programmes. An important goal in ex-ante policy evaluation is to provide information for making decisions on the allocation of budget, for example: which energy efficiency or renewable energy technology shows the biggest pay-off per euro of support? This allows for a comparison and ranking of technologies.

The cost-effectiveness of a subsidy programme is often linked to its target definition. In cost-effectiveness analysis the efficiency is expressed in terms of the costs of achieving a given result, for example, the (additional) costs per kWh final or primary energy. The choice of the denominator (kWh) is often linked to the target definition of a subsidy programme. This choice has an impact on the ranking of the technologies. When for example euro per kWh of final energy is used for cost-effectiveness calculations, renewable electricity is penalized at the expense of renewable heat. However, one unit of renewable energy provides a bigger contribution to energy security and CO_2 reduction goals. This penalization becomes relevant and should be accounted for by evaluators when 1) technologies need to share a subsidy budget and 2) this budget is limited.

Introduction

Ideally, all policy targets are SMART, which means they are specific, measurable, achievable, realistic and time-bound (Herten & Gunning-Schepers, 2000; Rietbergen& Blok, 2010). For the evaluation of the effectiveness of a policy (target), its specificity and measurability are crucial. Without knowing what to achieve, and without having data about the progress towards target achievement, evaluation becomes an impossible mission. Specificity is about clarity: what is the purpose of the policy and what goal is to be achieved? The EU for example, has a 20% energy savings target for 2020 which in itself is not a very clear target.[1] (). However, the target becomes more specific when it is redefined as a 2020 energy consumption cap of 1,474 Mtoe for the EU27 (see Harmsen, Eichhammer & Wesselink, 2014). Monitoring progress towards such an energy consumption cap is relatively straightforward but leaves sufficient challenges for the evaluator, such as how much the *policy* contributed to the savings achieved and how much of these savings can be allocated to the *economic recession*.

[1] The 20% savings are relative to the 2020 projection of the 2007 EU baseline scenario.

In this paper the focus is on the interpretation of cost-effectiveness. Although the high level instrument choice is also governed by other considerations than *cost-effectiveness* (also referred to as "efficiency"), this criterion (together with *effectiveness*) is dominant in assessing the success of policy instruments (Bemelmans-Videc & Vedung, 1998). The European Commission, the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) define cost-effectiveness as the lowest cost of support which generally equates with the minimization of consumer costs (Del Rio & Cerda, 2014). The analysis of cost-effectiveness provides a frame of reference for relating costs to the result of a policy program or instrument. An important goal in ex-ante policy evaluation is to provide information for making decisions on the allocation of budget: Which energy efficiency or renewable energy technology shows the biggest pay-off per euro of support? This allows for a comparison and ranking of technologies.

In cost-effectiveness analysis, efficiency is expressed in terms of the costs of achieving a given result, i.e. the (additional) costs *per, e.g., kWh of energy saved* or *ton of CO_2 emission reduced*. The choice of the denominator (kWh of energy saved or ton of CO_2 emission reduced in these examples) is often linked to the target definition of the particular subsidy program in place. Such choice makes sense from the evaluation point of view and is backed by the principles of SMART target setting, unless the target is not as smart as thought. Literature shows that setting SMART targets is not clear-cut: In their study on policy interaction Oikonomou et al. (2012, p.177) already state that "given the complex policy environment, various objectives are pursued in terms of environmental and energy effectiveness, alongside with economic efficiency". A complementary insight is given by Meadows (2009, p.85) stating that "when a subsystem's goals dominate at the expense of the total system's goals, the resulting behavior is called suboptimization." McDonnell & Grub (1991, p.10) posit that "…policy design is often hampered by analysts' and policymakers' inability to diagnose a problem correctly."

The aim of this paper is contribute to knowledge on SMART target setting and policy design. In doing so, the target setting of the EU Renewable Energy Directive is explored and an in-depth analysis of the Dutch renewable support instrument SDE[2] is carried out. Next, the paper discusses the extent to which the findings can be generalized to the field of energy efficiency / energy savings.

The EU Renewable Energy Target

The Climate and Energy Package (European Commission, 2008a) is the backbone of Europe's 2020 targets, which are often referred to as the 20/20/20 targets. The 2020 targets include a binding 20% reduction of GHG emissions compared to 1990, an indicative 20% energy savings and a binding share of 20% renewable energy in total final energy consumption in 2020. The latter target is the main objective of Directive 2009/28/EC on the promotion of the use of energy from renewable sources (hereafter: RES Directive).

Why Does Europe Have a Renewable Energy Target?

In the RES Directive renewable energy is framed as a means to mitigate climate change and to enhance security of supply. Recital 1 of the Directive (European Parliament & Council, 2009, L140/16) states that "The control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased efficiency, constitute important parts of the package of measures needed to reduce

[2] SDE is a Dutch abbreviation stands for "Subsidieregeling Duurzame Energie".

greenhouse gas emissions […..]. Those factors also have an important part to play in promoting the security of energy supply [….].”

It should be noted that at the time of designing the EU Climate and Energy Package it was projected that the 20% GHG reduction target could be achieved without a binding RES target (European Commission, 2008b). Still, a legally binding RES target was introduced. The European Commission felt the urgency of strengthening and expansion of the EU regulatory framework as the 12% RES target for 2010 (set in 1997) would not be met (European Commission, 2007). The growth of the RES sector (not so much needed for achieving the 2020 GHG target but crucial for mitigating climate change beyond 2020) was hampered by administrative problems, opaque and discriminating rules for grid access, and lack of information.

Why Does Europe Have A Renewable Energy Target Based On Final Energy?

In the 2007 renewable energy roadmap (European Commission, 2007), a 20% renewable energy target in gross inland consumption (i.e. primary energy) by 2020 was considered feasible and desirable. However, in the RES Directive a 20% renewable energy target in gross *final* energy consumption was set. The argument can be found in the impact assessment of the climate and energy package (European Commission, 2008b) and involves the expected penalization of non-thermal renewable energy sources such as wind and solar in case a RES target based on primary energy was chosen. As explained in the renewable energy roadmap (European Commission, 2007, p.6): “As biomass is a thermal process and wind is not, one unit of final energy produced from biomass counts 2.4 times more than one unit of final energy produced from wind and counted in primary energy.” In other words: the contribution of 1 unit of biomass electricity towards a renewable energy target based on primary energy is 2.4 times more than the contribution of 1 unit of wind electricity.

Although mathematically the argument can be understood, the choice for a final RES target is much harder to understand when considering the overarching objectives of the RES Directive, i.e. mitigate climate change and enhance security of supply. Using a final RES target, one unit of RES electricity provides the same amount of renewable energy as one unit of other RES such as heat, cooling or transport fuel, whereas using a primary RES target would mean that the contribution of one unit of *biomass* electricity would be 2.4 times more than the contribution of one unit of RES heat, cooling or transport fuel. This implies that the choice of a final RES target offers an incentive to RES heat, cooling and transport fuels compared to *biomass* RES electricity. Biomass is given in italics since the implication is not a general relation between RES electricity and other RES. Since the primary conversion factor of non-thermal RES electricity (wind, solar, hydro) used in statistics is 100%, there is almost[3] no difference between non-thermal RES electricity on the one hand, and RES heat, cooling and transport fuels on the other regarding the contribution to a final or primary RES target.

Was The Choice For A Final Renewable Energy Target Valid?

Based on the previous section the reader may expect big differences in the share of renewable energy sources depending on the definition of the renewable energy target (based on primary *or* final energy). In Table 1 the 2010 data (statistics) and the 2020 data (projection EU 2013 reference scenario) of total primary and final energy of the EU28 (including Croatia) are given. The table shows that the share of thermal-RES electricity (mainly

[3] This counts for individual renewable heating and cooling for which the supply of energy to the end user (natural gas, electricity) is considered final energy. In case of renewable district heating and cooling there would be a (small) difference since the supply of heat and cooling is considered final energy.

biomass) in the total RES share is about twice as big when expressing its share in primary energy instead of final energy. It is, indeed, mainly new wind (and new solar and hydro) that is "penalized". However, since the growth of non-thermal RES electricity is much higher than the growth of thermal RES electricity the penalization is limited (the share of non-thermal RES electricity in the total RES share drops from 38% in case of a final RES share to 31% in case of a primary RES share). For the other renewables (heat, cooling, transport) together, the share in total RES hardly changes between final and primary, suggesting only a small additional incentive for RES heat, cooling and transport fuels in case of a RES target based on final instead of primary energy.

Looking at the 2020 PRIMES-2013 projection, the RES share in terms of final energy (20%) is higher than in terms of primary energy (17%). Given the characteristics of energy supply in the EU28, it is apparently easier to achieve the final target than the primary target (although in the case of less thermal electricity production, the numbers would converge). Based on this, it can be concluded that the choice for a final RES target does not align with the ambition formulated in the 2007 renewable energy roadmap. Based on the data provided in Table 1, the author also concludes that it turns out there is no strong justification for choosing a final renewable energy target.

Table 1. Share of renewable energy sources in the 2013 EU reference scenario (data from Capros et al. (2013) aggregated by the author)

	Primary energy [Mtoe]			**Final energy [Mtoe]**	
	2010	**2020**		**2010**	**2020**
Nuclear - electricity	237	193		79	64
Fossil - electricity	383	304		147	124
Thermal RES - electricity	34	49		13	20
Non-thermal RES - electricity	47	86		47	86
Fossil – heat, cooling, transport	963	889		790	723
RES – heat, cooling, transport	103	143		82	119
RES-share total	10%	17%		12%	20%
Of which:					
non-thermal RES – electricity	26%	31%		33%	38%
thermal RES – electricity	18%	18%		9%	9%
RES – heat, cooling, transport	56%	51%		58%	53%

The Dutch SDE Scheme

Like the other EU Member States, the Netherlands have to contribute to the EU 20% renewable energy target. The legally binding target for the Netherlands is to increase its share of renewable energy in final energy consumption from 2.4% in 2005 to 14% in 2020.

The main instrument in the Dutch policy package is the SDE, a feed-in tariff for renewable energy. Each year a maximum budget for new projects is set. This budget is allocated in six stages. For each stage a maximum amount of euros per kWh or GJ of final energy is set for each technology. The idea behind the stages is to prioritize the cheapest renewable energy options and to only allow more expensive options if budget remains. As such, the Dutch government aims for a cost-effective achievement of the target, focussing its support on the options needing the least financial support per kWh of *final* energy. In its wording, this does not contradict with the RES Directive itself stating in recital 9 that renewable energy is "… to be introduced in a cost-effective way" (European Parliament and Council, 2009, L140/17). However, when considering renewable energy as a means to combat climate change or to increase the security of energy supply, it can be argued that the most cost-effective options are the ones substituting the most *primary* energy or reducing the most CO_2 emissions, and not the ones being the cheapest in terms of euros per unit of final renewable energy. The choice of the denominator (kWh final vs kWh primary energy or ton of CO_2 reduced) has an impact on the ranking of the technologies and implies that renewable electricity is penalized at the expense of renewable heat and fuels when euro per kWh of final energy is used for cost-effectiveness calculations. This becomes an issue when new renewable electricity projects are supported from 1) the same budget as the support for renewable heating and cooling projects and 2) the annual budget is limited (and competition between the technologies can be expected). In the Netherlands both conditions are met.

A limited annual budget despite a big gap towards meeting the target is not a rare situation. In Spain the support scheme for solar PV was stopped in January 2012 as support costs exploded from 215 million in 2007 to 2,841 million in 2009 (Del Rio & Cerda, 2014). Such a large burden for consumers (who pay via a surcharge on their electricity bill) is considered economically unsustainable, socially unacceptable and politically unfeasible. These arguments are also used in the Netherlands.

Different Objectives, Different Outcomes

Table 2 provides insight in the priority ranking of the different renewable energy technologies using three different objectives: 1) cost-effective achievement of the final RES target, 2) cost-effective contribution of RES towards energy security improvement, and 3) cost-effective contribution of RES towards the GHG reduction target.

The table is developed using the SDE calculation model developed by ECN (the principle advisor of the Dutch government regarding the base SDE rates).[4] For the calculations ECN's input parameters were used (see Lensink, 2013). In addition to these, for electricity production a conversion efficiency of 42.8% was used to calculate the substituted fossil primary energy and for heat production a conversion efficiency of 90% was used (Buck et al., 2010). To calculate the avoided CO_2 emissions a CO_2 intensity of 581 kg/MWh electricity was used and a CO_2 emission factor for natural gas of 56.7 kg/GJ (Buck et al., 2010).

For illustration, a few table cells are coloured to show the changes in the priority ranking for the selected technologies based on the objective chosen. The grey (biomass boiler) and black (geothermal) marked table cells show technologies that lose their high ranking, whereas the wind and solar options significantly improve their position. These results suggest that the more stringent the annual limitation of the SDE budget the higher the chance that the budget allocation is suboptimal, at least from an energy security or GHG reduction point of view.

[4] The SDE calculation model is accessible via https://www.ecn.nl/projects/sde/sde-2014/.

Table 2. Ranking of technologies using different objectives

1.	**SDE priority ranking**	**Priority ranking by substituted fossil primary energy**	**Priority ranking by avoided CO_2 emissions**
Most cost effective	WWTP - green gas	Hydropower renovation	Hydropower renovation
	boiler fired by solid biomass ≥ 5 MWth	WWTP - green gas	WWTP - green gas
	Deep geothermal - low temperature	Onshore wind (stage 1)	Onshore wind (stage 1)
	boiler fired by solid biomass < 5 MWth	boiler fired by solid biomass < 5 MWth	boiler fired by solid biomass < 5 MWth
	Deep geothermal - high temperature	All feedstock digestion - heat	Onshore wind (stage 2)
	All feedstock digestion - heat	Onshore wind (stage 2)	Onshore wind >= 6 MW (stage 2)
	Hydropower renovation	Onshore wind >= 6 MW (stage 2)	WWTP thermal pressure hydrolysis
	All feedstock digestion - green gas	WWTP thermal pressure hydrolysis	All feedstock digestion - heat
	boiler fired by liquid biomass	boiler fired by solid biomass ≥ 5 MWth	onshore wind >= 6 MW (stage 3)
	Manure co-digestion - heat	Deep geothermal - low temperature	onshore wind (stage 3)
	thermal conversion (>10 MWe)	onshore wind >= 6 MW (stage 3)	boiler fired by solid biomass ≥ 5 MWth
	Manure co-digestion - green gas	onshore wind (stage 3)	Deep geothermal - low temperature
	All feedstock digestion (extended life) - CHP	onshore wind >= 6 MW (stage 4)	onshore wind >= 6 MW (stage 4)
	Onshore wind (stage 1)	Deep geothermal - high temperature	Deep geothermal - high temperature
	Deep geothermal energy - CHP	boiler fired by liquid biomass	boiler fired by liquid biomass
	All feedstock digestion - CHP	Manure co-digestion - heat	Solar PV >15 kWp
	WWTP thermal pressure hydrolysis	All feedstock digestion - green gas	Wind in lake
	Onshore wind (stage 2)	Solar PV >15 kWp	Manure co-digestion - heat
	Onshore wind >= 6 MW (stage 2)	Wind in lake	All feedstock digestion - green gas
	Agricultural digester - CHP	All feedstock digestion (extended life) - CHP	Hydro power new
	onshore wind >= 6 MW (stage 3)	Hydro power new	All feedstock digestion (extended life) - CHP
	onshore wind (stage 3)	All feedstock digestion - CHP	Offshore wind
	Manure co-digestion - CHP	thermal conversion (>10 MWe)	All feedstock digestion - CHP
	Manure mono-digestion - green gas	Agricultural digester - CHP	thermal conversion (>10 MWe)
	onshore wind >= 6 MW (stage 4)	Manure co-digestion - green gas	Agricultural digester - CHP
	Solar thermal >100m2	Offshore wind	Manure co-digestion - green gas
	Gasification - green gas	Deep geothermal energy - CHP	Deep geothermal energy - CHP
	Solar PV >15 kWp	Manure co-digestion - CHP	Manure co-digestion - CHP
	Thermal conversion (<10 MWe)	Solar thermal >100m2	Solar thermal >100m2
	Wind in lake	Manure mono-digestion - green gas	free tidal current energy
	Hydro power new	free tidal current energy	Manure mono-digestion - electricity
	Offshore wind	Thermal conversion (<10 MWe)	Manure mono-digestion - green gas
	free tidal current energy	Manure mono-digestion - electricity	Thermal conversion (<10 MWe)
	Manure mono-digestion - electricity	Gasification - green gas	Gasification - green gas
Least cost-effective	Osmosis	Osmosis	Osmosis

This competition for budget can be illustrated by the SDE 2012 and 2013 data for onshore wind, offshore wind and geothermal energy published by the Netherlands Enterprise Agency (RVO.nl, 2012 &2014). In Table 3 these data are compared with the renewable energy production from these technologies in 2012 (Statistics Netherlands, 2013) and the projected renewable energy production in the Dutch National Renewable Energy Action Plan (NREAP, 2010).

For offshore wind it becomes clear from Table 3 that the current system of budget allocation in the SDE scheme will not lead to new offshore wind farms in the short term. In the meantime, this has been recognized by the Dutch government and a separate tendering system for offshore wind (though having a lower goal than the original NREAP) has been announced (Hekkenberg, Londo & Lensink, 2013).

For onshore wind the cumulative annual production from projects that were granted subsidy in 2012 and 2013 is small. The amount of new onshore wind projects in the period 2014-2020 needs to be much higher in order to meet the onshore wind goal set for 2020.

Finally, geothermal energy would overachieve its 2020 goal if all projects that were granted SDE subsidy in 2012 and 2013 are actually realized (actual project realization depends on other variables such as access to capital which is not necessarily secured in all projects to which a subsidy is granted). Any additional geothermal project which is realized in the period 2014-2020 would mean more overachievement of the 2020 goal.

Based on Table 3 data, it can be concluded that geothermal energy is one of the winners regarding the competition for budget, at the expense of wind energy.

Table 3.SDE 2012 & 2013 outcomes versus 2020 goals

	Production eligible for subsidy from 2012 budget [PJ][a]	Production eligible for subsidy from 2013 budget [PJ][b]	Subsidy period [years][a,b]	Annual production 2012 RES projects [PJ]	Annual production 2013 RES projects [PJ]	Total production in 2012 [PJ][c]	Projected production in 2020 according to NREAP [PJ][d]
Onshore wind	0.2	46.5	15	>0	3.1	15.0	48.1
Offshore wind	0	0	15	0	0	2.8	68.5 (27[e])
Deep geothermal energy	121.9	51.9	15	8.1	3.2	0.5	10.8

[a] (RVO.nl, 2012)
[b] (RVO.nl, 2014)
[c] (Statistics Netherlands, 2013)
[d](Dutch Renewable Energy Action Plan, 2010)
[e] Adjustment in Hekkenberg, Londo & Lensink(2013)

The competition for budget has decreased in the past years. Whereas the total SDE budget in 2012 was €1.7 billion, it was increased to €3 billion in 2013 (of which 2.967 has been granted) and to €3.5 billion in 2014.

Relevance For Energy Efficiency / Energy Savings Policies

The tension between (overarching) policy objectives and target definitions is not specific to renewable energy. It is also (potentially) present in energy efficiency and energy savings policies.

In the Energy Efficiency Action Plan (European Commission, 2006) the goal was to save 20% primary energy in 2020. Among the main overarching objectives, as with renewable energy, were the improvement of energy security and the mitigation of climate change. The 20% goal was formalized in the Climate and Energy Package (European Commission, 2008) and repeated in the Europe 2020 Strategy as one of the headline targets

(European Commission, 2010). Article 3 of the Energy Efficiency Directive also refers to 20% primary energy savings as the main target for the directive, but it also extends the target definition: "..the Union's 2020 energy consumption has to be no more than 1,474 Mtoe primary energy *or no more than 1,078 Mtoe final energy*." (European Parliament & Council, 2012, L315/12).[5] This broadening of the energy savings target including a final energy option has a number of implications.

First, the 20% final energy savings target is more ambitious than the original 20% primary energy savings target under the assumption that primary conversion efficiencies will gradually improve (Yearwood, Harmsen & Toledo, 2013).

Second, it potentially disturbs the level playing field of electricity savings measures. Assume that one country adopts a final energy savings target and another country adopts a primary energy savings target. Saving 1 kWh of electricity in country_1 yields 1 kWh of final energy savings, whereas in country_2 the 1 kWh of electricity savings results in 2.4 kWh of primary energy savings. Assuming that the share of electricity in total final energy demand is about 21% (this is the case for EU28 in 2010, derived from Capros et al., (2013)), then 20% electricity savings in country_1 results in 21% x 20% = 4.2% energy savings. Assuming that the share of fuels for electricity production in total primary energy demand is about 42% (2010 situation in EU28, derived from Capros et al., (2013)), then 20% electricity savings in country_2 results in 42% x 20% = 8.4% energy savings. Since the difference between final and primary energy for district heating[6] and transport fuels is much smaller, the conclusion is that electricity savings are penalized by choosing a final energy savings target, not only in terms of contribution to the target but also in term of cost-effectiveness. Electricity saving measures that need financial support become less attractive compared to heat or transport fuel saving measures when cost-effectiveness is expressed in euro/kWh of final energy. This becomes relevant when electricity savings need to share a limited subsidy budget with heat and transport fuel savings. It is also relevant in the case of separate budgets for each of the savings categories in case the budgets are allocated using a cost-effectiveness criterion based on euro/kWh of final energy.

Interestingly, electricity saving measures that are cost-effective (i.e. have negative costs) compared to their reference technology become even more cost-effective when the cost-effectiveness is expressed in euro/kWh of final energy. This counterintuitive result is explained by the fact that negative values of cost-effectiveness are invalid (see Taylor, 2012).[7] It should be noted that the negative cost issue does not play a role in the cost-effectiveness assessment of subsidy programmes, the primary focus of this paper, as the rationale of subsidy programmes is that the energy saving measures are not cost-effective.

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[5] Note that both 1,474 Mtoe primary energy an 1,078 Mtoe final energy reflect 20% energy savings relative to the 2020 projection in the 2007 EU baseline projection (Capros et al., 2008).

[6] Note that for individual heating primary and final energy are equal since the primary energy (e.g. natural gas) delivered to the end user is considered final energy and not the heat produced in the boiler, i.e. final energy is not the same as secondary energy.

[7] Assume that an electricity saving measure saves €100 per kWh final energy. Then the cost-effectiveness in terms of final energy is -€100/kWh. Assuming a primary conversion factor of 2.4, the cost-effectiveness in terms of primary energy is -€100/kWh / 2.4 = -€42/kWh, a less favourable cost-effectiveness which is not backed by the facts.

Implications For Target Setting And Evaluation

Implications For Renewable Energy

With climate change mitigation and enhancing security of supply as the main drivers for stimulating renewable energy it would have been preferable to express the RES target in primary energy, since primary energy offers a much stronger link to CO_2 emissions and energy security than final energy does. This is especially true for electricity for which conversion efficiencies are relatively low. The analysis is this paper shows that the argument used by the European Commission to choose a final energy RES target is insufficiently backed by data. The numbers do show however (see Table 1) that, given the current and projected European energy supply, a 20% final energy RES target is easier to achieve than a 20% primary energy RES target. This means that the choice for a final energy RES target has resulted in a less ambitious target than aimed for in the 2007 renewable energy roadmap.

The analysis of the Dutch SDE scheme shows that a policy focusing on cost-effective achievement of the RES target alone (minimizing support in € per kWh or GJ final energy) in the situation of a *shared and limited* budget leads to the stimulation of technologies that actually would require more support when climate (€/ton CO_2) or energy security (€/kWh or GJ primary energy) are used as cost-effectiveness criteria.

General Implications

The cost-effectiveness of a subsidy program is often linked to its target definition. The analysis in this paper suggests that SMART targets should be linked to the overarching policy objectives, since otherwise wrong incentives could be sent when policy makers focus on cost-effective target achievement. The final renewable energy target leading to penalizing renewable electricity at the expense of renewable heat when euro per kWh of final energy is used for cost-effectiveness calculations rather than primary energy or CO_2 (which both better connect to the energy security and CO_2 reduction goals linked to renewable energy) provides a clear example of this. Such penalization, which might also happen in the field of energy efficiency between electricity and fuel savings, becomes relevant and should be accounted for by evaluators when 1) technologies need to share a subsidy budget and 2) this budget is limited.

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