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A Vicious Tenacity: The Efficiency Strategy Confronted With the Rebound Effect

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Studies of the phenomena known as the "rebound effect," "backfire," and the "Jevons Paradox" have cast doubt on the effectiveness, in terms of reduction of energy use, of measures based on efficiency gains. Some of them have shown that efficiency improvements are less effective than expected, others have lent strength to the hypothesis that efficiency improvements are counterproductive in the long run. The difference between the two groups is thus all but negligible. Moreover, it is of considerable pragmatic significance as it may undermine the foundations of solid expectations that had led to ongoing systems and repertoires of action. In this paper we provide a model about the hypothesis that the expectations related to the effects that efficiency gains have on energy and resource consumption may exacerbate the rebound effect and that they prevent alternative strategies, that may turn out to be more effective in reducing energy and resource use, to be enacted. In the concluding paragraph, we propose possibilities for further hypothesis and empirical research that could lead to the refinement of the model.

Keywords: rebound effect, energy efficiency, efficiency strategy, sufficiency, backfire, jevons paradox, consumption caps

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DEPICTING THE EFFECTS THAT EFFICIENCY GAINS HAVE ON ENERGY AND RESOURCE CONSUMPTION

Following centuries-long changes to the idea of efficiency (Alexander, 2008), activities took shape in the 1970s that—as suggested by ecological modernization theories—can be considered as stages in a more general process aimed at enabling industrial societies to cope with the problems—which had recently come to the fore—associated with a shortage of resources.

We may refer to these activities as "efficiency strategy" (Alcott, 2010). The efficiency strategy can be seen as being based on a problematization[1] having the following main characteristics: production systems should be oriented toward finding increasingly efficient goods and processes, i.e., which

[1]The vocabulary we use here is in part drawn from Actor-Network Theory, and specifically the terminology describing the stages of: (i) problematization, in which a focal actor defines a problem and its solution, frames a story, and identifies alliances between actants as well as the roles they must follow; (ii) enrolment, which takes place when the identified actants accept the roles assigned to them during problematization; (iii) mobilization of allies, which is when the network is capable of acting and pursuing the program of action defined at the outset; (iv) betrayal, when the actants leave the coalition, and the program of action is remodeled as a result (Callon, 1986).

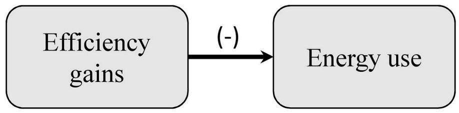

FIGURE 1 | Expected effect of efficiency gains on energy use (version 1).

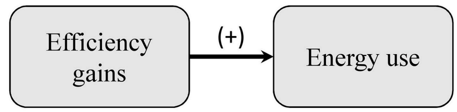

FIGURE 2 | Expected effect of efficiency gains on energy use (version 2).

require fewer and fewer resources for their production, and, subsequently, for their use; these goods and processes would then have emerged from the laboratories (public or private) and spread through the broader economic systems; it was thus necessary that research be redirected; that consumers ask for, and buy, more efficient products as they became available; and that the regulatory actors (national governments, for example) proceed as quickly and efficiently as possible to remove the barriers that could have impeded the creation and expansion of a market of this kind. Given these conditions, the consumption of resources would drop (Daly, 1973; Lovins, 1976, 1977; Von Weiszacker et al., 1997). Such a problematization offered a solution, and, what is more, a positive-sum solution, to industrial societies' presumed inability to continue along their development path and provided new life to a guiding concept—efficiency—for political and economic actors (Guice, 1999; Borup et al., 2006; Rosa and Scheuerman, 2009; Pollock and Williams, 2010).

Efficiency gains, though by no means the only solution at hand, are nevertheless described as being in themselves sufficient—or, better, capable of becoming sufficient, as everything could become more efficient than it actually is (Reijnders, 1998)—to solve the weighty problem of resource scarcity.

Was that something substantially different from what had previously been the development of industrialized societies? In other words, were not efficiency gains already one of the distinctive features—as motors of competitivity—of industrialized societies? Not completely. On one side, innovation was (and still is) also related to finding new ways to use (more) resources. On the other side, it was only since that moment that efficiency was considered as an object of dedicated measures and policies. Moreover, despite all the most important categories of actors were given a role in this problematization, some others were not part of it: people, groups and scholars who thought that efficiency—via technicization—dehumanize man and deprive him of freedom; and—as what may be seen as a practical translation of this first aspect—those who advocated and/or concretely pursued a simpler life and simpler technical systems (Schumacher, 1973; Alexander and McLeod, 2014).

In its simplicity, the expected effect of efficiency gains on energy (and—more broadly—resource) use, can be represented by the scheme at **Figure 1**.

In the early 1980's, in the field of energy economics, it was argued that the foundations laid at the problematization stage were undermined by an error that could have prevented the expected enrolment of energy and resources (that is, not becoming scarcer) in the coalition of actors which was so enthusiastically—or confidently—being amassed. The critique was based on a phenomenon known as the Jevons Paradox, first formulated more than a century before by the economist (Jevons 1865). His intuition was later fleshed out in the "Khazzoom-Brookes Postulate" (Khazzoom, 1980, 1989; Brookes, 1990). As originally set out—with reference to energy efficiency, but it may also apply to other resources—the postulate stated that "with fixed real energy prices, energy efficiency gains will increase energy consumption above what it would be without those gains" (Saunders, 1992, p. 131)[2]. Given certain conditions, the effects of efficiency gains would be as those represented in **Figure 2**, which differs from **Figure 1** on a single, though very important, aspect.

It is possible to identify two main categories of meanings given to the rebound effect. On one side, it is used to refer to the extent to which the actual outcome of measures based on increasing efficiency falls short of the expected results. Thus, it could be measured, and it is possible to say that there has been a rebound effect of x% or y%. On the other side, rebound effect is also used to describe the causes, responses, and mechanisms leading to gaps between expected and actual results. Thus, it may happen to be read or heard (Arrobbio, 2014a) that the rebound effect (as measured difference) is due to the rebound effect (as array of mechanisms) or that there has been a rebound effect (one or more mechanisms have been activated) without rebound effect (with no difference between expected and actual results)[3]. An additional confusion may derive from the fact that rebound effect is also found to be used as a sort of synonym of negative side effect. In this case, confusion is not meant to derive from the fact that actual results may be better than the expected ones (the so-called positive rebound), but rather to the fact that a rebound effect lower than 100% (thus not a "backfire") means that improvements of some width with respect to the starting conditions have occurred.

Energy economists set out to scrutinize the Khazzoom-Brookes postulate from the theoretical standpoint and verify it empirically. Over the subsequent decades, ever more complex tools for measuring the rebound effect were developed, together with categorisations and definitions for investigating it (Turner, 2013). Though this process cannot be said to be over, it would appear to have arrived at a dead end, or in other words a deep rift has opened between scholars in the field. According to Herring and Roy (2007), there are two contrasting opinions among

[2]This is a situation in which the rebound effect exceeds 100%. The formula used to calculate the rebound effect is: (Expected reduction – Actual reduction)/Expected reduction. A rebound effect in excess of 100% is called a "backfire," meaning that the Jevons Paradox has manifested.

[3]Though not central in our argumentation, we should recall that the latter is a theoretically remote possibility, in the sense that whenever a result is expected, it is likely actual result to be different from it, at least slightly.

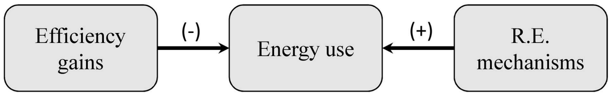

FIGURE 3 | Rebound effect (R.E.) as external to, and independent from, efficiency gains.

scholars about the rebound effect: there are those who maintain that the rebound effect is of slight to moderate magnitude and, more importantly, that without efficiency improvements resource consumption would have been higher than today's; and those who argue that efficiency gains can plausibly be seen as an important factor in explaining the growth of economic systems and their concurrent demand for resources. Unfortunately, none of this hypothesis can be verified (or falsified). The first one, because it is built on a counterfactual scenario; the second one, because measurements are less and less reliable, the more the boundaries of the system taken into consideration are wider. So, the following questions are still left unsolved: are increases in efficiency responsible (wholly or in part) for increased consumption? Is striving for efficiency enough? There are two possible ways to answer these questions. On one side it is possible to say that yes, efficiency gains are effective in reducing consumption, but there are external forces pushing in the opposite direction [European Commission (EC), 2017] (**Figure 3**).

Thus, an explanation for the worldwide increase in the consumption of material and energy resources can be sought by assigning responsibility and blame to an array of mechanisms and subjects: the growth of emerging economies, the spread of the Western lifestyle, the population increase, the obsession with GDP, the emergence of new consumers and insatiability of the old ones, planned obsolescence and the constant barrage of publicity, to mention but a few. On the other side, it is possible to say that efficiency gains are responsible for (at least part of) the pushing toward increasing consumption. In this case, those forces are considered as not completely external to/independent from efficiency increases.

Before going on we should focus our attention on the "enrolment" and "mobilization" phases. If results (i.e., decrease of energy consumption) are not as expected, this could depend on an as-yet incomplete, or less than optimal, mobilization of actors. It can thus be argued that bureaucratic barriers to obtaining incentives, economic difficulties, or problems in accessing credit slow down the implementation of the efficiency strategy. Of course, the level of mobilization could be higher than it currently is: governments measures could be more incisive and supportive; enterprises could give more funds to research activities; consumers could pay more attention to the mid-long term monetary and environmental savings. However, we can recognize the forms by which the enrolment—if not also the mobilization—actually manifests. The "efficiency strategy" is object of non-partisan support (Rudin, 2000) via the programs espoused by political parties and movements and even where support is not particularly conspicuous, this does not indicate open or significant dissent. It can be seen from the energy labeling system implemented across the European Union or elsewhere. Additionally, it can be seen from the fact that in many countries, expenditures for the purchase of high energy-efficiency domestic appliances and for energy upgrades on existing buildings are included in the exclusive list of tax-deductible expenses (which in some cases may also include outlays for health and education, and donations to charitable organizations). It can be derived from the EU funds allocated to research programmes related to energy-efficiency (e.g., 29.1 billion € for "Low-carbon energy" and 39.7 billion € for "Transport" through the EU Cohesion Fund for 2014–2020; 5.9 billion € for "Secure, clean and efficient energy" in the EU Horizon 2020 research funding programme). Lastly, it is evident from the efficiency gains registered in the EU in all sectors since 2000 (18.6% overall; 20.5% industry; 13.7% transport; 27.8% households)[4].

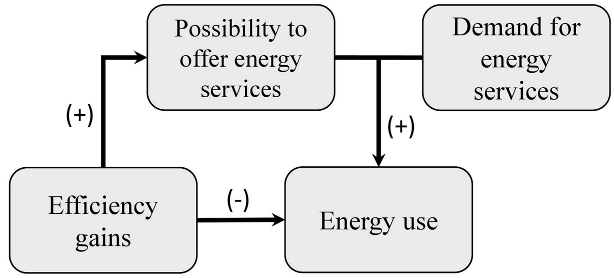

FIGURE 4 | Efficiency gains create room for more consumption.

Let us now take advantage of the following Sanne's definition to explain **(Figure 4)**.

> *"...rebound effect is taken to mean the overall effects of technical, organizational, and social progress, which increase the efficiency of the economy and give room for more consumption" (Sanne, 2000, p. 494).*

Speaking of "giving room" has the advantage of making it unnecessary to indicate the places, the practices and the subjects that will fill this room. In addition, this definition draws attention to another aspect of primary importance that clarifies the relationship of cause and effect between efficiency and increased consumption, viz., that increased efficiency does not lead inevitably and/or immediately to increased consumption, but it does inevitably make it more likely for consumption to rise. The room for consumption that is thus created will then (or can then) be filled as rapidly as the various mechanisms of the rebound effect (here intended as dependent from the efficiency increases) come into play, mechanisms that, simplifying the literature[5], we can classify as: (i) economic: greater efficiency brings down the cost, and this encourages demand (at the micro

[4]Data retrieved from http://www.odyssee-mure.eu/ (Accessed September 14, 2018).

[5]There is an extensive literature on the rebound effect. The summary we propose here is based chiefly on the following articles and reports: Berkhout et al. (2000); Greening et al. (2000); Hertwick (2005); Sorrell (2007, 2009); Polimeni et al. (2009);

as well as the macro level); (ii) psychological: where, for example, owning high-efficiency goods satisfies the ecological motivation for action, and this leads to a more "relaxed" attitude toward using and consuming these or other goods; (iii) technological: where efficiency gains for a good lead to the situation in which this good fulfills new and additional functions. In turn, the room that is created can be larger when certain not-infrequent conditions obtain: synergistic effects between production factors, "transformational" effects (creation of whole new economic sectors) and situations where the efficiency gain affects so-called pervasive resources, goods and technologies.

DIFFICULTIES IN ACTIVATING ALTERNATIVE MEASURES FOR THE REDUCTION OF ENERGY AND RESOURCE USE

What are the factors that, aside from the periods in which economic systems enter a crisis, could slow or prevent the rebound effect? Though no sharp dividing line can readily be drawn, we can distinguish between the factors that operate "downstream," when the room is filling up less quickly, and those operating "upstream," when the creation of more room for consumption is "artificially" limited or blocked. Such an outcome could be achieved by implementing systems based on quotas, such as consumption caps, cap-and-trade schemes, or on rationing the use of resources (**Figure 5**). These have been defined as "left-side" measures, from the left side of the I = f (P, A, T) formula (Alcott, 2010).

This, then, could be a stepping-stone toward counter-problematization: what would be necessary is the international (worldwide) introduction of consumption caps. Other solutions could in fact slow, or perhaps even accelerate, the mechanisms of the rebound effect, but they could not in any case prevent them from occurring.

Although the counter-problematization can be expressed in a few words, enrolling the actors who accept it would entail difficulties that must not be underestimated, as it calls for a radical overhaul of entrenched beliefs and repertoires of action. The notion of repertoire of ecological action derives from that of the repertoire of collective action (Tilly, 1976) propounded by the sociology of social movements. Echoing Neveu (1996), we can say that the ecologically oriented actors (social movements being one of them) are faced with a pre-existing sample of actions that are coded and accessible to varying extents. Actions based on efficiency are only a portion of a larger repertoire of possible ecologically-oriented actions and measures. These can be taken in many forms, individual or collective, direct or indirect, they can rely on sanctions or incentives, information or coercion, persuasion, or intimidation, etc. What we want to point out here is that these actions and the modes they employ may be in competition with each other (Buenstorf and Cordes, 2008; Bartiaux and Reátegui Salmón, 2012; Ozaki and Shaw, 2014). Actions based on efficiency are credited with an almost unparalleled effectiveness due not only to the alleged advantages in environmental terms, but also to a whole series of economic advantages (individual and collective) and strategic benefits [International Energy Agency (IEA), 2014]. Besides demonstrating one of the ways the efficiency strategy manifests, the already mentioned fact that in many countries, expenditures for the purchase of more efficient goods (equipment or installations) have been added to the very short list of tax-deductible expenses is in our opinion equivalent to a government subsidy for technological and individual solutions and may in practice make other solutions less viable.

Figure 6 integrates a plurality of new aspects with respect to the previous figure, so let us explain them in detail. The higher the energy use, the higher the need to adopt measures to reduce it[6]. These can be "left-" or "right-side" measures (which besides the efficiency-based ones, also include sufficiency-based measures and actions, eco-taxes and bonus-malus schemes). The competition among measures we referred to above, is represented by the only one double-sided arrow, which is meant to mean that the more we follow one strategy, the less we follow the other (only one of them can be considered hierarchically—thus practically—superior at a given time). If efficiency gains increase together with energy (and resource) consumption, may means that the strength of "efficiency-as-solution" (by "efficiency strategy" we mean here its strength, attractiveness and rhetorical apparatus) may be immune, and—at least so far—positively correlated to its failures, thus representing a reinforcing loop. This may partially be seen as a consequence of concealing/emphasizing flows, which consists of cherry-picking indicators and data: about the use of specific resources; the emissions of a few specific substances; a single stage in the life cycle of goods; a given limited geographical area. It thus entails selecting a few aspects out of the overall picture, and ignoring the possible interrelations between phenomena: the reduction of emissions in areas undergoing deindustrialisation, as opposed to the increase in pollution in recently industrialized cities (Rice, 2009; Peng et al., 2016); the reduction in paper-based documents, as opposed to the increase in electronic waste, etc. (Berkhout and Hertin, 2004; Hilty, 2008; Røpke et al., 2010; Williams, 2011). Another relationship added in **Figure 6** is that the higher the expectations about the beneficial effects of efficiency increase, the higher the possibility for some of the rebound effect mechanisms (namely, the "psychological" ones) to enter in action.

On the consumption side, efficiency gains increase the possibility for consumers to enter in contact with ever more objects and to be engaged in ever more practices (Heikkurinen, 2016). The higher the number of objects consumers enter (directly or indirectly) in contact with, in a higher number of practices they are practitioners of, the less likely they will be prone to ask or accept to live without them. The presumed efficacy of efficiency gains thus allows consumers not to have to quit their careers as efficiency consumers, which may contribute to explain why the need for measures to reduce energy consumption

Jenkins et al. (2011); Maxwell et al. (2011); European Environment Agency (EEA) (2013); Santarius and Soland (2018).

[6]It may not have a universal validity, being a deliberate self-destruction accelerating process another possible outcome.

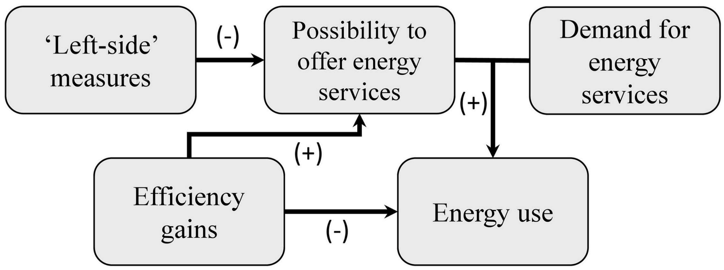

FIGURE 5 | The role of 'left-side' measures in preventing consumption increase.

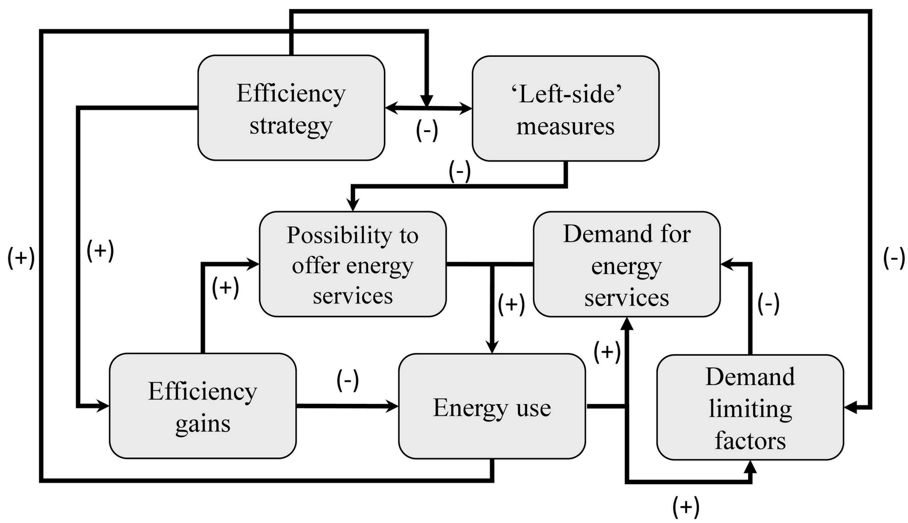

FIGURE 6 | Comprehensive view of the model: interrelations of beneficial and adverse effects of different strategies to reduce energy consumption.

is required to be satisfied by "right-side" measures. Moreover, being more and more practices carried out more efficiently, higher output levels are delivered by them. These higher output levels push normality upward (Shove, 2017) and are thus required even when the most efficient processes are not available. This last aspect may completely counterbalance the effects on demand that can be expected from its saturation, represented in **Figure 6** by the only one bifurcating arrow (bottom right side).

It already happened the benefits to be gained from efficiency increases to be doomed as optimistic, when not unfounded. The first wave of criticism with respect to the supposed beneficial effects of efficiency gains took place in the nineteenth century, launched by Jevons and other scholars (Polimeni et al., 2009), but it was neutralized by the subsequent increased ability to find and exploit the world natural resources. The second one was a reaction to the discourses on the dematerialisation of the economy that originated in the 1970s, but it got stuck by the controversies among scholars we mentioned above.

Although the debate has remained substantially confined within the bounds of expert spheres, something occasionally managed to penetrate the frontiers. Between late 2010 and early 2011, several non-specialist magazines and newspapers presented the "rebound effect" to a broader public. Noteworthy articles appeared in "Le Monde Diplomatique" during July 2010 (Gossart, 2010) and the "The New Yorker" in December 2010 (Owen, 2010), followed by articles in "The New York Times" (Tierney, 2011) and "The Guardian" (Rowley, 2011) during the year that followed. Even if they failed to do full justice to the theoretical debate, these articles helped expose a broader public to doubts concerning the benefits of efficiency gains. In the debates that followed and that took place in technical reports, papers in prestigious reviews as well as in the blogosphere, it happened the scientific inconsistency of the "backfire theories" to be stated, and its adherents to be discredited as—among other things—unshakable Luddites (Ackerman and Stanton, 2011; Gillingham et al., 2013; Arrobbio, 2014a,b).

In the same period, in 2011, the EU funded a project entitled "Addressing the rebound effect," which involved exchange of views between some 50 expert stakeholders. As what may be considered—at least for chronological reasons—as one the project's first results, the rebound effect was cited in the

European Commission's Communication 571 on the same year.

> *"However, it has been shown that in some cases, cost savings made from improving the efficiency of a technology can actually induce people to consume more. This phenomenon, known as a "rebound effect" must be anticipated, and accounted for, in developing policy and setting targets" [European Commission (EC), 2011].*

Nonetheless, the rebound effect and Jevons Paradox are absent from most energy and environmental policy guidelines and technical reports (Font Vivanco et al., 2016). If they are mentioned at all, it is often only as a timid call for caution in boasting of the benefits to be had from increases in efficiency, or to display that the existence of some "social factors" is recognized.

The EU has been temporizing with a compromise that retains the current regime (i.e., the efficiency strategy) but at the same time cannot be regarded as lasting, as it seems to be mainly listing the rebound effect under the umbrella of accountancy issues, where also lays the issue of the inaccuracy of expected savings: rebound effect level may look higher than in reality because engineering estimates of savings are inaccurate; estimated savings may have been exaggerated purposely by producers, in a sort of "Volkswagen-like" style applied to electric household appliances; but inaccuracy may also be due to overestimation of the level of consumption prior to the efficiency gains (e.g., Sunikka-Blank and Galvin, 2012).

How could the flux of environmental measures be rerouted from the "right-side" to the "left-side"? Let us extensively quote a passage from Smil (2010):

> *"There has been a widespread agreement that the new transition must be accompanied [. . .] by higher efficiency of energy use. [. . .] Fortunately, possibilities of such gains remain no less promising today than they appeared two generations ago: this energy transition toward more rational energy use can continue for decades to come. But better conversion efficiencies alone are not enough, they will just keep confirming a lasting truth of Jevons's venerable paradox that ≪it is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth≫ (Jevons, 1865, p. 140). The second precondition of a successful new transition in all affluent nations must be to avoid consuming more energy more efficiently, and this means that by far the most important step that those countries should take are gradual but significant overall reductions of energy use." (Smil, 2010, p. 150).*

In an incredibly diplomatic way, Smil suggests a complete reversal of the efficiency strategy. Of course, not in the sense that we should aim at increasing inefficiency (whatever it might mean). Rather in the sense that given that, at their best, efficiency gains have minor effects, they should be given a secondary and ancillary role. Why was such a resort to tact necessary? How could the actors of the efficiency strategy's coalition accept such a disruptive translation of their visions? The sectors of production and technological research would no longer be able to seek justification, or reward, from operating "ecologically," at least until such time as the counter-program has been fulfilled. Similarly, the public, who is with difficulty beginning to obtain gratification and rewards from its efforts at ecological consumerism and a few ecological micro-practices, should once again, or chiefly, turn toward the political sphere, toward broader geographical and decision-making levels, toward predominately collective action (Dalton, 1996; Norris, 1999; Micheletti, 2003; Blühdorn, 2017; Theocharis and Van Deth, 2018). For its part, the environmental movement may believe that with the strategy (or the ideal) of sufficiency and by helping to identify inefficiency, waste and the responsibilities for them, it has already made a vital contribution (and, above all, a contribution which is believed to be alternative—or at least complementary—to the efficiency strategy) to achieving sustainability (Princen, 2005; McDonald et al., 2006; Alcott, 2008).

CONCLUSION

In this paper we aimed at delivering a model about the fact that the efficiency strategy, which consists of both an array of concrete actions and measures, and the rationale attributed to it, exacerbates the rebound effect. More importantly, we suggest that the efficiency strategy prevents alternative strategies, that may turn out to be more effective in reducing energy and resource use, to be (more decisively) enacted. We claim that the higher the expectations on energy efficiency, the lower the results, not in terms of efficiency gains, but rather in terms of reduction of energy and resource use. We hypothesize that we are dealing with a reinforcing loop on which the higher the severity of environmental problems and resource and energy scarcity, the more the efficiency strategy is given strength. Such a reinforcing loop emerges because of the need of the coalition of actors (supposedly) playing the efficiency strategy to preserve its integrity. At the same time, it comes from the difficulties—which on their turn are due to the strength of the rhetorical apparatus sustaining the efficiency strategy—to create and enact a counter-programme of action.

It is out of our possibilities to say whether the reinforcing loop will go on indefinitely or not. However, it is possible to see the reactions that the efficiency strategy's proponents have been putting in place. The first one consists in considering the causes of the rebound effect and the backfire as external to, and independent from, the efficiency increases. The second one may consist in rearrangements to the narratives, to the rhetorical apparatus of the efficiency strategy, which has recently been reinforced by concepts such as circular economy and energy transition to renewables (which is not yet clear whether they represent any substantial change or not), and by the "energy efficiency first" principle (which we doubt is something new).

Moreover, we suggest that the efficiency strategy—together with the definition of the functioning of the rebound effect which is linked to it—currently represents the only acceptable or viable programme of action for the current coalition (as it is the most acceptable and viable for the actors mobilized in it) regardless of whether it is (really) effective or not. Contrary to what would happen in case of practical acceptance of the "left-side" arguments, the efficiency strategy allows its members to play. It should be difficult to act ecologically in a system which is inherently taking into account of planet's and ecological boundaries. In a system where this does not happen, playing ecologically, or playing at being less ecologically-harmfully, is possible. Could not—as we suggested—the "left-side" and "right-side" measures coexist at the same hierarchical level, this would bring the need to dismantle the efficiency strategy, or at least the discourses about its beneficial effect, until the effectiveness of efficiency gains in reducing consumption is proven.

Finally, the model we delivered is built on arguments and hypothesis that we tried to make evident, hoping that in this way they can be subject to further debate and refinement and may offer suggestions for further research. Our argumentations may mainly derive from having concentrated our efforts on the EU context and on having interpreted efficiency unspecifically. Further lines of enquiry may thus relate to the validity of the model in different economic, social and political contexts and in specific applications of efficiency improvements.

AUTHOR CONTRIBUTIONS

OA contributed to the conception and design of the study and wrote the first draft of the manuscript. OA wrote all sections of the manuscript. DP wrote section Depicting the Effects That Efficiency Gains Have on Energy and Resource Consumption and section Conclusion. All authors contributed to manuscript revision, read and approved the submitted version.

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